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WASH-1538

Vol. 1

ENVIRONMENTAL STATEMENT
WASTE
MANAGEMENT OPERATIONS

Hanford Reservation
Richland, Washington

VOLUME 1

SEPTEMBER 1974

UNITED STATES ATOMIC ENERGY COMMISSION

MASTER

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ENVIRONMENTAL STATEMENT

WASTE MANAGEMENT OPERATIONS

HANFORD RESERVATION
RICHLAND, WASHINGTON

VOLUME 1

(1 of 3 Volumes)

- I. Summary
- II. Detailed Description of Hanford Site
- III. Environmental Impact
- IV. Unavoidable Adverse Effects
- V. Alternatives
- VI. Relationship Between Local Short-Term Uses of Man's Environment and the Maintenance and Enhancement of Long-Term Productivity
- VII. Relationship of Proposed Action to Land Use Plans, Policies, and Controls
- VIII. Irreversible and Irretrievable Commitments of Resources
- IX. Comparison of Costs and Benefits

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SEPTEMBER 1974

UNITED STATES ATOMIC ENERGY COMMISSION

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Authorizing Official
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FOREWORD

General

Since 1944, when the first Hanford facilities were operated to produce plutonium for the Manhattan Project, radioactive waste has been generated as a result of the operation of the Hanford facilities. Consequently, there has been a continuous and evolving program for waste management and environmental assessment for over 30 years. The Atomic Energy Commission (AEC) actions and concern with respect to waste management and its environmental impact over the 30-year period are partially reflected in over 2,000 studies and documents which have been collected in "Radioactive Waste Management," a bibliography of available literature pertaining to the AEC's Hanford, Washington Production Site (TID-3340, August 1973).

Scope of Statement - Nature of "Proposed Action"

The purpose of this statement is to reassess the environmental impact of the Hanford Waste Management Operations program in order to assure that further major actions minimize adverse environmental consequences and to account for those environmental consequences that may not have been fully evaluated at the outset or at each stage of the waste management program. The statement will serve as a base for evaluating the environmental impact of future actions in relation to the existing environment at Hanford.

This statement is the evaluation of a long-existing program; consequently, the results are presented as of a particular date. The cut-off date selected for the inclusion of fully evaluated data and experience was December 31, 1972, because preparation of the report began in September 1973. Preliminary data for 1973 are included where available. Specific details that would reveal classified weapons material production rates are, of course, not included.

The quantities of radioactive and nonradioactive materials released to the environment from future Hanford operations is anticipated to decline from the 1972 values as a result of modifications and construction of new facilities for effluent control and curtailment of production activities.

Since the purpose of this statement is to reassess an existing program, the following sections of this Foreword are intended to provide an introductory summary of: 1) the current policies, plans and standards applicable to the Hanford Waste Management Operations Program², 2) the current waste management program, and 3) the programs and activities at Hanford that are not covered in this environmental impact statement.

Policies, Criteria, and Standards for Management of Radioactive Waste

The current basic policies, criteria, and standards for management of AEC-generated radioactive waste at Hanford and at other sites are contained in the AEC Manual Chapter 0511 (September 19, 1973), which provides in part:

- "(1) Field offices and their contractors shall conduct their operations and dispose of and store radioactive waste in such a manner as to assure that present and future radiation exposures to individuals and population groups will be at the lowest levels technically and economically practical not exceeding limits established in AECM 0524 Appendix parts I and II.
- (2) Continuing efforts shall be made to develop and use improved technology for reducing the radioactivity releases to the lowest technically and economically practical level.
- (3) High-level liquid radioactive waste shall not be transported offsite.
- (4) The extent and degree of radioactive contamination of land by AEC waste management activities shall be minimized."

The basic standards for protection of the health and safety of the public are those contained in AECM 0524, which provide, in part:

"AEC and AEC Contractor operations shall be conducted in such a manner as to assure that radiation exposures to individuals and population groups are limited to the lowest levels technically and economically practical."

The policies in AECM 0524, including the specific protection standards for external and internal exposures have as their basis the guides and recommendations of the International Commission on Radiological Protection, the National Council on Radiation Protection and Measurements, and the Federal Radiation Council. In 1959, the Federal Radiation Council was formed to provide a policy for Federal agencies on human radiation exposure. A major function of the Federal Radiation Council was to "Advise the President with respect to radiation matters, directly or indirectly affecting health, including guidance for all Federal agencies in the formulation of radiation standards and in the establishment and execution of programs in cooperation with the States ...". [Public Law 86-373 (1959)].

In February of 1970, the Federal Radiation Council requested the National Academy of Sciences-National Research Council to review and reevaluate the existing scientific knowledge concerning radiation exposure to human populations. On October 2, 1970, the Environmental Protection Agency was established by the President's Reorganization Plan No. 3 of 1970. On December 2, 1970, the activities and functions of the Federal Radiation Council were transferred to the Office of Radiation Programs of the Environmental Protection Agency. In November of 1972, the National Academy of Sciences-National Research Council published a report which included their view on the existing scientific knowledge concerning radiation exposure to human populations. The publication of that report was preceded by the following statement:

"This report was prepared under contract No. PH-43-64-44 between the Department of Health, Education, and Welfare (on behalf of the Federal Radiation Council) and the National Academy of Sciences. Publication is made jointly by the Department of Health, Education and Welfare and the Environmental Protection Agency, which succeeded to the authorities of the Federal Radiation Council under Reorganization Plan No. 3 of 1970. The report is solely the product of the contractor. The data and analysis contained in the report represent a major review of the effects of low levels of ionizing radiation and the role of such information in measures to protect the public. They will be reviewed extensively and with the utmost deliberation and care by the Department of Health, Education, and Welfare and the Environmental Protection Agency, with particular regard to their usefulness and applicability in the regulatory and other program activities of the Department and the Agency.

Publication of the report does not constitute acceptance or approval of its contents; neither does it indicate their rejection or disagreement. Publication is made at this time so that the report will be available as a resource to the scientific community and the public generally."

The report of the National Academy of Sciences-National Research Council is currently undergoing review by the Department of Health, Education, and Welfare, the Environmental Protection Agency, the Atomic Energy Commission and other interested organizations. The analysis in this environmental impact statement uses the existing standards and guides recommended by the Federal Radiation Council and others. These guides are contained in AECM 0524.

Current Program

1) High-Level Waste

Approximately 47 gallons of liquid waste and 25 million gallons of solidified waste are currently stored in underground tanks at Hanford. This waste was generated during the period 1944 to 1974 as a result of processing fuel from up to nine production reactors. The processing of the fuel was required to extract plutonium primarily for use in atomic weapons. This quantity of high-level waste represents about 90% of the total high-level waste expected to be generated through the operation period of the Hanford plutonium production facilities. At

the present time, only one production reactor (N Reactor) is operating which requires fuel processing, which in turn results in the generation of additional high-level waste. Based on current production plans, the operation of N Reactor^(a) and the Purex processing plant results in the generation of approximately 1 million gallons of high-level waste each year. The current plans call for the shutdown of N Reactor in late 1977 or early 1978.

The thrust of the current waste management program for high-level waste has been to convert stored and currently generated high-level waste from a liquid to a salt cake form. The existing evaporators, along with one evaporator currently under construction, will solidify most of the stored and currently generated liquid waste to salt cake. Shown in Figure 1 is a graphical summary of the Hanford high level waste solidification program progress. The large increase in the rate of reduction of liquid waste starting in late 1973 and continuing through 1976 is due to the high capacity of the larger new vacuum evaporator crystallizer installation. A residuum of highly caustic liquid will remain which cannot be further evaporated with these evaporators. The evaporators are scheduled to be in equilibrium with residuum and currently generated waste in CY-1976. The residuum will be treated to produce a solid either by chemical addition or a special type evaporator. These alternatives are now under development. The spread in predicted waste volumes after 1978 shown in Figure 1 depends on whether the development work aimed at solidification of the residuum is completed on schedule.

The solidification of the liquid waste along with the use of high integrity tanks to contain the liquids in interim periods is considered to be the current program for the high-level waste. The objective of this program is to continue to maximize the isolation of the high-level waste from man's environment.

The current waste management program also includes research and development to determine the best ultimate disposal method for the salt cake

- (a) Pursuant to special statutory authority (Public Law 87-701, AEC Authorization Act for Fiscal Year 1963) and special contract arrangements, the byproduct steam from the N Reactor is used to generate approximately 860 megawatts of electrical power from the Washington Public Power Supply System generating facilities located on the Hanford site.

by focusing on alternative solid forms and storage methods which would have minimum dispersability characteristics over very long periods of time. In addition, research and development efforts directed toward final disposal of high-level waste from the commercial power industry will be followed for applicability to Hanford waste.

2) Other Radioactive Waste

• Liquid

In addition to the high-level liquid waste from fuel processing plants, large volumes of water containing low concentrations of radioactive materials or no radioactivity are produced during operations and are released onsite (controlled areas). For some of this waste, it is practical to reduce the radioactivity to levels within established standards for release offsite (uncontrolled areas) by treatment methods, such as ion exchange, decontamination by evaporation or retention to allow for the decay of radionuclides. Other waste, containing levels of radioactivity which would be unacceptable for release to uncontrolled areas, is at a level that it may be safely released to controlled areas with suitable natural characteristics. Present practice has been to use soil columns, seepage basins, evaporative ponds, or retention ponds to retain radioisotopes. Wherever such practices are followed, a continuing program exists for extensive monitoring for the movement of these materials.

The practice of using the favorable ion exchange properties of some soils to remove radioactivity from liquid waste and confine it in soil columns is a well established procedure. However, because of the long-term burden of control and surveillance inherent in the use of a technique that results in local accumulations of radioactivity in soil, the AEC program at Hanford has been based on the goal of major reductions in the concentration of radionuclides in effluent streams. Alternate waste treatment techniques are being considered to decontaminate the bulk of the waste to levels within established standards for release to uncontrolled areas.

Solid Waste

Solid waste of widely diverse nature and contaminated to varying degrees with many different forms of radioactive materials is generated at Hanford. The sources of radioactivity in this waste are fission products, induced radionuclides, and alpha-active transuranium elements, principally plutonium.

Solid waste containing U-233 or transuranic elements (plutonium, etc.) is being segregated, packaged and buried under soil in such a manner that retrieval in 20 years with the exterior surface of the container free of radioactive contamination could be accomplished. Other radioactively contaminated solids are packaged in boxed, drums, etc., and buried underground in trenches. Some large equipment from the Chemical Processing Plant (Purex) is stored in adjacent railroad tunnels awaiting final disposition. Planning and development is proceeding to reduce the volume of solid waste by incineration of combustible solids and compaction of other solids.

Gaseous Effluents

Building ventilation systems are filtered with high efficiency filters to remove particulate matter. Process gas streams are treated by various means such as scrubbers, chemicals reactors, etc., and finally filtered before discharge. Radioactivity in the air at plant boundaries is well below AECM 0524, Table 2 concentrations.

Plans to provide further reductions which may be practical are proceeding.

Scope

This is an environmental impact statement on the Waste Management Operations program at Hanford. It presents a complete analysis of the environmental impact of existing waste management operations at Hanford. This analysis is primarily based upon extensive environmental monitoring which has been conducted and reported on for the past 30 years. The statement covers waste generated by production, research and development and other programs and activities at Hanford. This statement does not

cover the alternatives and/or costs and benefits with respect to the production of special nuclear materials or the operation of research and development programs, since it is not a statement on the operation of those programs. The primary role of N Reactor and the Purex Chemical Processing Plant is the production and recovery of plutonium and other materials for national defense and research and development activities. However, in order to compare and evaluate waste management alternatives in terms of their environmental impact, the section on alternatives includes an analysis of impact if production or research and development activities and facilities ceased to operate. This should provide a clear basis for comparing the impact of managing the waste to be generated in the future with managing the waste that was generated over the last 30 years.

Since the waste management program at Hanford is an on-going program as distinguished from a proposed action or a proposed program, many of the long-term, as well as the short-term, options for the control, handling and disposal of radioactive waste are in various stages of research and development. Although the status of these research and development efforts will be discussed in the statement, some of these research and development programs may require their own environmental statements at a later point in time. In accordance with the Atomic Energy Commission's regulations,³ these statements will be written late enough in the development process to contain meaningful information, but early enough that whatever information is contained may be factored into the decision-making processes. These statements will be prepared before the development process has reached a stage of investment or commitment to implementation likely to foreclose or restrict later alternatives.

Comments

The notification of the preparation of this statement, published in the Federal Register on August 14, 1973, (38 Fed. Reg. 156) invited suggestions from all interested persons. Comments were also requested on the draft outline of the statement from the Environmental Protection

Agency, the Washington State Department of Ecology, and the Natural Resources Defense Council. The AEC and the EPA held a public meeting in February 1974 in Richland, Washington, to discuss the environmental impact statement and the waste management activities at the Hanford Reservation (27 Fed. Reg. 4800, Feb. 4, 1974). Copies of all the written suggestions and comments received, together with a guide indicating where substantive comments relating to the scope of the statement are presented in **the Appendixes**. These comments, as well as documents referenced by this statement, are also available for review at AEC Public Document Rooms in San Francisco, California; Washington, D. C., and at the Federal Building in Richland, Washington.

Waste management operations at Hanford, as well as for all Atomic Energy Commission sites, are continually reviewed, analyzed, and updated to reflect improved technology or administrative procedures for waste treatment and storage. As a result of this environmental statement, possible additional improvements may be identified. The Commission welcomes responsible comments from individuals and from Federal, state, local, and private organizations regarding the operations described in this statement. Comments should be addressed to Dr. J. L. Liverman, Assistant General Manager for Biomedical and Environmental Research and Safety Programs, USAEC, Washington, D. C. 20545.

FIGURE 1 HIGH-LEVEL WASTE SOLIDIFICATION PROGRAM

REFERENCES

1. Guidelines, Council on Environmental Quality, 40 CFR, Part 1500.13, 38 Federal Register No. 147, August 1, 1973.
2. Plans of the Management of AEC-Generated Radioactive Waste, WASH 1202, July 1973.
3. 10 CFR 11.5(a) (4), 39 Federal Register No. 32, February 14, 1974.

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I SUMMARY

I.1 INTRODUCTION

In early 1943, the United States Army Corps of Engineers selected the Hanford site as the location for reactor and chemical separation facilities for the production and purification of plutonium for possible use in nuclear weapons. A total of eight graphite-moderated reactors using the Columbia River water for once-through cooling, and a new type of dual purpose reactor (N Reactor) using a recirculating water coolant and producing both plutonium and electricity, were built along the Columbia River. Today, only the N Reactor remains in operation.

I.2 BACKGROUND

I.2.1 Description of Site

The Hanford site measures 570 square miles or 365,000 acres. The reactor facilities are located along the Columbia River in what is known as the 100 Areas. The reactor fuel processing and waste management facilities are in the 200 Areas which are on a plateau about 7 miles from the river. The 300 Area, just north of Richland, contains the reactor fuel manufacturing facilities and the research and development laboratories.

Liquid waste containing high-level concentrations of radionuclides from the chemical processing plants is stored on an interim basis in large underground tanks in the 200 Areas. The waste storage complex includes:

- 149 single-wall tanks ranging in capacity from 50,000 to 1,000,000 gallons each which are constructed of reinforced concrete with a steel liner
- three new double-wall 1,000,000-gallon tanks
- four additional double-wall 1,000,000-gallon tanks now under construction

- four water evaporators to convert the radioactive waste from the storage tanks to a less mobile solid sludge; a fifth evaporator is currently under construction.

Some radioactive liquid effluents waste is released to ground via structures called cribs. Since most of the radionuclides discharged to cribs are absorbed on or filtered by the 150 to 300-foot soil column, they do not reach the water table. Continuing efforts are being made to develop and to use improved technology to reduce the amount of radionuclides discharged to cribs to the lowest technically and economically practical level. A total of 177 cribs are provided for disposal of intermediate-level liquid waste. Of these, 144 are now deactivated, eight were not used, ten are in standby, and 15 are in current use.

Since the beginning of the Hanford Project, about 130 billion gallons of cooling water have been discharged to 30 surface ponds or ditches. About 360 acres of land have been used for these disposal operations, with about 180 acres currently in use. Any radionuclides discharged to these facilities 1) result from accidental equipment failures, 2) are of low-activity level, and 3) are also absorbed on or filtered by the soil column which prevents significant quantities from reaching the water table. The depth to the water table and the good absorptive properties of the Hanford soils have made crib, trench, and pond disposal possible with a limited radionuclide inventory reaching the water table below the disposal sites.

More than 5 million cubic feet of contaminated dry solids are buried. Initially, transuranic waste received special packaging for containment, but was not buried for 20 year recovery. Since May 1970, transuranic waste is packaged in sealed metal containers, segregated from other waste, and placed in special burial trenches to permit recovery in the original packaged condition.

Sanitary waste is disposed to septic tanks draining to tile fields, leaching trenches and sanitary sewers. Most chemical waste is contained with the high-level liquid waste in tanks. Gaseous effluents are treated

by multiple high-efficiency filtration and/or by chemical treatment where practical to assure that gaseous emissions are as low as practicable. Gaseous and liquid effluents are monitored to measure the quantities of radioactive materials that may be released.

Environmental measurements and comprehensive evaluation programs in radiation, ecology, hydrology and meteorology are maintained to measure the direct impact of the Hanford facilities on the environment and to help assure adequate process controls. Environmental impacts that might occur in the future will be observed by these programs and corrective action promptly initiated.

I.2.2 Anticipated Benefits

The primary anticipated benefit of the Hanford Waste Management Operations Program is to continue isolation of significant quantities of radioactive and other waste materials from man's environment.

Conduct of the Hanford Waste Management Operations Program makes possible 1) production of plutonium for the U.S. defense needs and byproduct steam for the generation of electricity and 2) research and development in most areas of nuclear energy. Many ecological and biological studies on the movement of behavior of radionuclides in the environment are performed as part of the overall waste management effort.

I.2.3 Characterization of the Existing Environment

The population living within a 50-mile radius of the Hanford site varies from about 250,000 for a radius center midway between the two chemical processing and waste storage areas to about 160,000 for a radius center at the 300 Area. Land uses in the surrounding area include urban, industrial, and irrigated and dry land farming. Of the irrigated crops, alfalfa hay uses 30% of the total area, wheat 15%, and sugar beets about 8%. Water removal rights, other than Hanford's, amount to about 200,000 acre ft/year within 50 miles of the N Reactor.

The National Register of Historic Places does not list any sites on the Hanford Reservation; however, applications for three sites are currently being processed. Three listed sites are within 50 miles: 1) Marmes Rockshelter, 2) Olmstead Place State Park, and 3) Whitman Mission National Historic Site. The remains of many Indian campsites and fishing grounds are found along the Columbia River within the Hanford Reservation boundary.

Eastern Washington is dominated by the Columbia Basin geologic province encompassing about 50,000 square miles. It is underlain by the vast field of flood lavas of the Columbia River Basalt Group. Late in the Pleistocene epoch, large floods scoured and carved the Ringold formation surface beneath the Hanford Reservation. These floods, of about 18,000 to 12,000 years ago, deposited the sediments now found on the site.

The Hanford Reservation is in a region of low to moderate seismicity. On the basis of the damage that has been experienced since 1840, the U.S. Coast and Geodetic Survey designated the area a Zone 2 seismic probability, implying the potential for moderate damage from earthquakes. The underlying sands and gravels in the Hanford Reservation provide excellent protection against damage. Earthquake intensities greater than four on the Modified Mercalli Scale (MM-IV) have not occurred in the immediate Hanford area.

Over 1,500 wells were drilled at Hanford to provide data for evaluating the chemical and physical properties of the underlying materials. These wells provide the data to characterize the absorptive properties of the soils as well as the direction and flow rate in the groundwater.

The climate has been recorded since 1912 and is characterized as mild and dry with occasional periods of high wind. The average maximum temperatures in July and January are 91.8°F and 36.7°F. The average annual precipitation is 6.25 inches. Tornadoes are rare in this region and tend to be small, with little damage when they do occur. In

29 years of observation, a single small tornado was observed on the Reservation and resulted in no damage.

The vegetation mosaic of the Hanford Reservation consists of eight major kinds of shrub-steppe communities.

The anadromous salmon and the steelhead trout are the fish of greatest economic importance in the Columbia River. About 9,500 fall Chinook salmon spawn in the Hanford reach of the river.

The mule deer is the only big game mammal, while the cottontail rabbit is the most abundant small game mammal on the Reservation. Small mammals are abundant, particularly the Great Basin pocket mouse. The chukar partridge is the most important gamebird. Hunting is not permitted on the south or west sides of the Columbia River, the major portion of the Reservation.

The Hanford Reservation provides refuge for several rare, threatened, or indeterminate species: 1) Prairie falcon, 2) American peregrine falcon, 3) ferruginous hawk, 4) American osprey, 5) Northern long-billed curlew, and 6) Western burrowing owl.

I.3 ENVIRONMENTAL IMPACT

I.3.1 Environmental Effects of Routine Operation of Plant Facilities

The principle pathways of radiation exposure to the public involve only the releases of waste to the atmosphere and to the Columbia River. The maximum dose to an individual from effluents released at Hanford in 1972 was 0.6 mrem/yr, while the dose to the average individual was 0.01 mrem/yr. The total-body dose to the population within 50 miles of Hanford was 2.4 man-rem/yr for 1972 which is only 0.01% of the naturally-occurring radiation background of 27,400 man-rem/yr. This is imperceptible when compared to the normal 10 to 15% fluctuations which occur annually in the natural background radiation levels. A conversion of the population dose to health effects using the data from the National Academy of Sciences BEIR Report indicates that the maximum potential

number of cancer death ascribable to 1972 Hanford operations is 0.0007 for the population living within 50 miles of the site. Since the total number of health effects is far less than one, it may be concluded that there are no health effects due to Hanford operations for 1972. Well over 1000 years of operation at the 1972 population dose levels would not be expected to result in more than a single cancer death.

No deleterious effects to the numbers or species of terrestrial or aquatic life have been observed during 30 years of Hanford operations.

Water intake structures may lead to some loss of lower level trophic life in the Columbia River, but most intake structure velocities are not sufficient to entrap fish. No significant effects on the river ecosystems due to entrainment are noted even when all nine reactors were in operation and removing a substantially greater water volume. Chemical contamination and heat waste do not produce a significant impact on the Hanford reach of the river. Studies show that the effluents from up to nine plutonium-production reactors have had no harmful effects on the migration or spawning of salmon or produced any biotic downgrading of the aquatic ecosystem in almost 30 years of plant operation and concurrent scientific observation. An annual survey in the Hanford reach of the river shows a fairly constant increase in Chinook salmon nesting from the late 1940's up through the fall of 1973.

Onsite, about 3% of the 365,000-acre Hanford Reservation is used for structures and waste disposal sites. The areas directly associated with the major waste disposal sites are committed to long-term control (thousands of years). Groundwater within the Hanford control perimeter contains small amounts of radioactivity. The small total area committed for such control and use does not constitute a significant adverse effect to the Hanford ecological community.

Chemical releases to the atmosphere and to the Columbia River produce only limited, local disturbances, if any at all.

I.3.2 Postulated Waste Management Accidents

A range of accidents that might be expected to occur based on present facility design and operation were analyzed. The postulated accidents included tank leaks, tank gaseous releases, tank dome failures, transfer line failures, major facility filter failure, onsite shipment accidents of both solid and liquid waste, range fires, solid waste burial site fires, and accidents due to natural forces. In the selection of postulated accidents and in assumptions made for the analysis, a consistent attempt was made to be conservative in the analysis, that is--to analyze the worst conditions credible.

The analysis indicated that the maximum individual total-body dose (50-year dose commitment) of 0.4 rem resulted from the postulated solid-waste-carrying vehicle accident followed by fire occurring near the southern boundary of the site. The maximum population dose of 37 man-rem (50-year dose commitment) resulted from the postulated major waste transfer line break and resultant surface spill during the most severe weather conditions. The postulated accidents that provided a mechanism for atmospheric dispersion of radioactive materials produced the greatest offsite dose impact.

I.4 UNAVOIDABLE ADVERSE EFFECTS

Unavoidable adverse effects from the Hanford Waste Management Operations Program may arise from radioactive, chemical, or thermal components in waste effluents being released to the atmosphere, Columbia River, or the ground. The effects may be both onsite, such as limiting use of actual waste disposal areas for other purposes, and offsite, such as contributing less than 0.01% of the total population radiation dose.

The unavoidable radiation dose to the maximum individual for 1972 was 0.6 mrem. The population dose was 2.4 man-rem. The individual dose

resulting from naturally-occurring radiation was about 110 mrem and the population dose was about 27,400 man-rem. The health effects were up to a maximum of 0.0007 cancer deaths of all types for the population living within 50 miles of the Hanford site. Since the total number of health effects is far less than one, it may be concluded that there are no health effects due to Hanford operations for 1972.

About 3% of the 365,000 acre Hanford Reservation is used for structures and for waste disposal sites that require long-term commitment to such use. Releases of heat and chemicals to the air and Columbia River produce only small local effects, if any.

I.5 ALTERNATIVES

Reasonable alternatives to the current Waste Management Operations program are presented for treatment of high-level liquid radioactive waste, other radioactive liquid waste, radioactive gaseous waste, radioactive solid waste, nonradioactive waste, and other potential environmental pollutants. Waste management facilities and activities to reduce the quantities of radioactive materials released to the environment or to improve control of such materials in the event of abnormal operation conditions are included in the FY-1973 through FY-1975 budget in the amount of nearly 42 million dollars.

Major alternatives to present programs for the treatment of high-level liquid waste, liquid effluents, and gaseous effluents are also presented. For the high-level liquid waste, the alternatives are:

- continue the present program with replacement of some or all of the single-wall tanks with new double-wall tanks
- shutdown of N Reactor
- shutdown of the Purex fuel processing plant
- discontinue the solidification to salt cake and
 - a) hold the waste as liquid in new double-wall tanks till a different form is found,

- b) calcine the waste, or
- c) prepare a special insoluble waste formation

- several options for ultimate disposal of salt cake

Liquid effluent cleanup alternatives to reduce discharges to the Columbia River and/or the ground involved the construction of new high capacity liquid evaporator and/or ion-exchange system and relocation of the N crib. Additional gaseous cleanup for the N Reactor stack was also examined.

Adoption of these alternatives has essentially no effect on the overall population dose since the current dose from the facilities to be altered is near zero. The advantages are basically better containment of all radioactive materials.

I.6 RELATIONSHIP BETWEEN LOCAL SHORT-TERM USES OF MAN'S ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

Future plans for the Reservation call for the continuation of its present use as an area dedicated primarily to nuclear energy activities. Certain small areas will essentially require perpetual surveillance. Thus, the use of man's environment will be long-term. Therefore, the relationship to be considered is that of long-term use and the maintenance and enhancement of long-term productivity of the environment.

Current use of the land has probably barred major irrigation projects from the Reservation because of their potential impact on the water table levels. Also, an inventory of mostly tritium and ruthenium-rhodium-106 will remain in the groundwater under the Reservation for 10's of years. Fission products and Pu will be in the soil columns under cribs, trenches, and ponds for many centuries. The radionuclide concentrations in the groundwater are below the current drinking water standards except near a few disposal sites.

Large portions of the land on the Hanford site are being put to other productive uses:

- Arid Land Ecology Reserve
- Washington State Game Reserve
- Commercial Nuclear Power Plants
- Research and Development Facilities for Energy.

I.7 RELATIONSHIP OF PROPOSED ACTION TO LAND USE PLANS, POLICIES, AND CONTROLS

The continued operation of the Hanford waste management facilities will not conflict with national, state, or local plans and programs. Implementation of the action proposed herein, i.e., a continuation of effluent and waste management practices at Hanford, calls for land use as described in Sections II and III. All land is and will be managed consistently with federal regulations to assure the safety and well-being of the public.

Continued land use in addition to effluent and waste management on the Hanford Reservation includes 1) research and development associated with the Arid Land Ecology (ALE) Program, and various laboratory facilities in the 100, 200, and 300 Areas, 2) N Reactor and plutonium production facilities in the 200 Areas, and 3) the Fast Flux Test Facility in the 400 Area. Some of the land just north of the Columbia River will continue to be administered by the U.S. Bureau of Sport Fisheries and Wildlife, the U.S. Bureau of Reclamation, and the Washington State Department of Game. The State of Washington leases land on the 200 Area plateau for radioactive waste burial. Private leases of land include the Washington Public Power Supply System (WPPSS) steam plant operating at 100-N Area and the WPPSS Power Reactor now under construction.

The potential environmental consequences and **relationships** of all specific proposed projects to the Hanford Effluent and Waste Management

Operations program are studied and considered. Environmental impact statements for individual projects will be prepared, as appropriate. The impact and feasibility of each individually proposed program will be evaluated, including any potential impact on the Hanford Waste Management Operations.

I.8 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

The resources that are considered to be committed in an irretrievable and irreversible manner by the Hanford Waste Management Operations are 1) land and materials containing or used for storing radionuclides with a half-life longer than 10 years, 2) labor expended by construction and operating personnel, and 3) materials, such as fuel and chemicals, that are burned, diluted, or consumed during use.

About half a million tons of fossil fuels and 50,000 tons of chemicals are expected to be irreversibly consumed by the Hanford Waste Management Operation. Some components of the concrete structures and equipment as well as about 6,000 acres of desert land are in essence irretrievable due to the practical aspects of reclamation and/or radioactive decontamination.

I.9 COST-BENEFIT ANALYSIS

The Waste Management Operations program objective is to maintain control over all waste materials in a manner resulting in the best balance of costs and benefit for the United States citizens. Currently planned waste management program improvements (FY-1973 through FY-1975) are budgeted at a cost of nearly 42 million dollars. These programs will provide improved control over radionuclides during abnormal operations. In addition, these programs will also reduce the current population dose of 2.4 man-rem/yr. by about 0.1 man-rem/yr.

The high-level waste alternatives are designed to improve engineered barrier control over high-level waste and to convert the waste to a form

less likely to interact with the environment--that is, the formation of solid, low leakable, high stability form. Liquid effluent cleanup systems to reduce the quantities released to the ground are considered at 5 million dollars and 50 million dollars. The 50-million dollar alternative would provide liquid effluent streams containing radio-nuclide concentrations below current public drinking water standards. Neither of these alternatives would change the already essentially zero population dose from such sources.

A 15-million dollar alternative for the N crib would reduce the population dose by about 0.5 man-rem/yr, while a few tens of millions would be required to substantially cleanup radioactive gas emission from the N Reactor, resulting in a dose reduction of about 1.3 man-rem/yr. Shutdown of N Reactor would reduce the population dose by 2.3 man-rem/year. Since the population doses are low and other environmental impacts are equally low or nonexistent, it is difficult to determine the level of federal funding that may be justified for additional improvements.

II BACKGROUND

II.1 DETAILED DESCRIPTION OF HANFORD SITE

II.1.1 Plant and Waste Management Facilities

II.1.1.1 External Appearances

II.1.1.1.1 Introduction

The semiarid Hanford site occupies about 570 square miles of the southeastern part of the State of Washington just north of where the Yakima and Snake Rivers flow into the Columbia River. The first known occupants of this area were the Indians tens-of-thousands of years ago. Settlers, who in the latter 1800's and early 1900's began farming near the river, developed local irrigation districts to utilize the Columbia River as a source of irrigation water.

In early 1943, approximately a month after the successful Fermi experiment in Chicago showed that nuclear fission could be controlled in a small reactor, the United States Army Corps of Engineers selected Hanford as the location for a facility to build larger versions of the Fermi reactor to produce plutonium for possible use in military weapons. Actual construction started on three reactor facilities and three chemical processing facilities in March 1943. The first of the reactors went into operation about 18 months after the start of construction and the first plutonium was available some 4 months later. During the course of the construction effort, approximately 94,000 men and women were involved at various times in the project with a peak onsite population of 51,000.

Over the years following the war, a total of five reactors similar to those built during the war were constructed, making a total of eight graphite-moderated reactors using the Columbia River water for once-through cooling, i.e., water circulated through the reactor only once

before being held for radioactivity monitoring and some heat dissipation prior to release back to the river.

In the early 1950's the construction of the research and development facilities known as the Hanford Laboratories began. This marked the first diversification of Hanford from a purely defense materials production facility to one heavily involved in the peacetime uses of the atom. In 1963, a new type of reactor, the N Reactor, was built. N Reactor is different in that it produces in addition to plutonium, the by-product steam which, since 1966, has been used by the Washington Public Power Supply System to generate electricity. Thus, the N Reactor was the first--and so far, the only--dual purpose reactor constructed in the United States.

In early 1964, a Presidential decision to begin closing down the older Hanford reactors resulted in the shutting down of all eight of the older reactors by the end of 1971, leaving N as the only production reactor in operation. Another major change occurred in 1964 with the departure of General Electric who had, in 1946, succeeded DuPont as the prime operating contractor. In a unique "segmentation and diversification" program, 1) General Electric was replaced by a number of contractors, 2) the communities' economic base was diversified, and 3) Hanford became involved in many AEC programs relating to the peaceful use of nuclear materials and radiations.

The current principal operating contractors at Hanford are:

- Atlantic Richfield Hanford Company (ARHCO)--responsible for fuel processing, waste management, and all site general support services such as plant security, fire protection, central stores, electrical power distribution, etc.
- Battelle Memorial Institute (BMI)--responsible for the operation of the Pacific Northwest Laboratory which includes research in general areas of life sciences, environmental science, environmental surveillance, advanced methods of nuclear waste management and a wide variety of other physical and biological sciences.

- United Nuclear Industries (UNI)--responsible for operations of the one remaining production reactor--N Reactor--and the N Reactor fuel fabrication.
- Westinghouse Hanford Company (WHC)--responsible for the operation of the Hanford Engineering Development Laboratory (HEDL) which includes advanced reactor developments--principally the Liquid Metal Fast Breeder Program and the Fast Flux Test Reactor.

The Hanford site operating areas are identified by area numbers. Each area which is identified as a controlled or limited access area is totally enclosed in a high antipersonnel fence. The six 100 Areas, bordering directly on the Columbia River in the northernmost portion of the Reservation, are where the plutonium production reactors were built. At one time in the early 1960's, nine production reactors were operating. Currently, only the dual-purpose N Reactor is operating to provide plutonium for military purposes and byproduct steam for electrical power production in the Washington Public Power Supply System (WPPSS) Plant.

In the middle of the site on a plateau about 7 miles from the Columbia River are the two 200 Areas where the fuel and waste processing and waste storage activities are located. The location of the 200 Areas was chosen because it provides the most isolation from the site boundaries and is the most removed from both surface and subsurface water. Under this area, the groundwater table is some 150 to 300 feet below the surface.

The 300 Area is nearest to Richland. The research and development laboratories and the fuel fabrication facility for the N Reactor are located in this area.

The 400 Area is about 7 miles north of the 300 Area and is the site of the Fast Flux Test Reactor now under construction.

The area of the Reservation not included as one of the 100, 200, 300, or 400 Areas is designated as the 600 Area. Figure II.1-1 is a map of the

Hanford Reservation showing the locations of these various operational areas and other features (refer to detailed map in Appendix II.1-A).

Currently, 86,000 acres of the site north of the Columbia River are being developed as a wildlife refuge and recreation area by the U.S. Bureau of Sport Fisheries and Wildlife and the Washington State Department of Recreation. In 1964, the Commission leased 1,000 acres of land near the 200 Areas to the State of Washington for commercial nuclear use. The Nuclear Engineering Company provides commercial solid waste burial service on 100 acres of this tract under a license from the State. A 120-square-mile ecology reserve is established between a public road, State Highway 240 which traverses the southwestern portion of the site, and the top of Rattlesnake Mountain.

A flowchart depicting waste management operations at Hanford is presented as Figure II.1-2.

FIGURE II.1-2 RADIOACTIVE WASTE MANAGEMENT OPERATIONS AT HANFORD

II.1.1.1.2 100 Areas

Only one of the nine reactors constructed along the Columbia River is operational; the remainder were retired or placed on standby. The size, construction schedule and current status of each reactor is shown in Table II.1-1.

TABLE II.1-1

SUMMARY - REACTOR STATUS

<u>Area</u>	<u>Size-Acres</u>	<u>Reactors</u>	<u>Construction Start</u>	<u>Operation</u>	
				<u>Start</u>	<u>Shutdown</u>
100-B	650	105-B	Aug-1943	Sept-1944	Feb-1968
		105-C	June-1951	Nov-1952	April-1969
100-K	135	105-KW	Nov-1952	Jan-1955	Feb-1970
		105-KE	Jan-1953	April-1955	Jan-1971
100-N	90	105-N	May-1959	Dec-1963	Operating
100-D	960	105-D	Nov-1943	Dec-1944	June-1967
		105-DR	Dec-1947	Oct-1950	Dec-1964
100-H	320	105-H	Mar-1948	Oct-1949	April-1965
100-F	540	105-F	Dec-1943	Feb-1945	June-1965

II.1.1.1.2.1 B and C Reactor Areas (100-B/C)

B/C Reactor Area is shown in its present condition in Figure II.1-3. The area of about 650 acres, which is the furthest upriver of the six 100 Areas, contains two reactors, 105-B and 105-C. In Appendix II.1-B are a map identifying major facilities and a table which lists the waste management facilities in the B/C Area. Very few personnel are currently assigned to the area.

Essentially all facilities in the area are on standby with the exception of the B/C water system which provides all the water supply for the

FIGURE II.1-3 B/C REACTOR AREA

200 Areas. Fire protection for all of the area and service utility water for some facilities are maintained. An electrical substation in the area taps power for the pumps providing the 200 Area water.

II.1.1.1.2.2 K Reactor Area (100-K)

The 100-K Area, about 135 acres, is almost 2.5 miles immediately downriver from the B/C complex and contains two reactors, K East and K West. Although about 10 years newer than the original Hanford reactors, both were recently put on standby. K Reactor Area is shown in its present standby condition in the aerial photograph of Figure II.1-4. In Appendix II.1-B are an area map identifying major facilities and a table listing the waste management facilities in the K Area.

Considerable use is made of the shutdown 100-K Area, and all services and utilities except the power house are in operation. The Reactor Plant Services Section of United Nuclear Industries (UNI) operates from offices and laboratories in this area. UNI also operates a research and development laboratory in 1706-KE. This effort, which is in support of N Reactor activities, includes bench-scale studies of water quality, filtering and corrosion. Some small scale decontamination studies are also carried out under this program.

Battelle-Northwest (BNW) is presently using the K East river pumps to analyze the accuracy of a venturi flowmeter for flows up to 450 cubic feet per second (cfs). The raw river water is pumped to the K East sedimentation basins and then returned to the river.

II.1.1.1.2.3 N Reactor Area (100-N)

The 100-N Area, about 90 acres at river mile 380 and 2.3 miles immediately downriver of the 100-K Area, contains 43 buildings including the N Reactor and the WPPSS steam generating plant. About 330 people work in the Area during the 5-day, 8 to 5 work week and about 53 during off shifts and weekends.

FIGURE II.1-4 K REACTOR AREA

N Reactor is the only Hanford Reactor still in operation which was designed for the production of plutonium. The reactor is a dual-purpose unit and provides low pressure steam for the 860,000 kW WPPSS generating plant nearby.

The 100-N Area is shown in its present operating condition in the aerial photograph in Figure II.1-5. In Appendix II.1-B, each facility is identified in a map while a table lists the waste management facilities at 100-N Area.

II.1.1.1.2.4 D and DR Reactor Area (100-D/DR)

The D/DR Area of about 960 acres is located 1.7 miles immediately down-river of 100-N Area. The area as it currently exists is shown in the aerial photograph of Figure II.1-6. In Appendix II.1-B, an area map identifies major facilities and a table lists the waste management facilities in D Area.

Although both 100-D Area reactors are retired, this area is extensively used, and its utilities and services are in operation. The electrical substation serves as backup supply for N Area. The water system in 100-D is a backup for systems from B Area supplying the 200 Areas.

UNI operates an engineering laboratory (185-D) in support of N Reactor operations. This includes the NPR loop facility which was the original test facility for N Reactor.

Various contractors use facilities such as the 183-D settling basin, 190-D and others for special studies; for example, thermal hydraulics, emergency core cooling, and treatment of oil spills. Hanford Engineering Development Laboratory (HEDL) is conducting experiments studying total control of high temperature sodium fires in the 105-DR fan room. Ventilation flows including gaseous oxides of sodium pass through a water scrubber and filter before exiting through the reactor stack.

FIGURE II.1-5 N REACTOR AREA WITH WPPSS GENERATING PLANT TO LEFT

FIGURE II.1-6 D/DR REACTOR AREA

II.1.1.1.2.5 H Reactor Area (100-H)

The 100-H Area is located about 3.2 miles downriver of D/DR Area and contains about 320 acres. Very little activity continues in this area, which is shown in its present retired condition in the aerial photograph of Figure II.1-7. Several major buildings including the power house and stacks and some of the water treatment buildings have been removed. In Appendix II.1-B is an area map identifying major facilities as well as a table listing the waste management facilities in this area.

II.1.1.1.2.6 F Reactor Area (100-F)

The 100-F Area, shown in its present retired condition in Figure II.1-8, is located 3.2 miles downriver of 100-H, and is the reactor area closest to Richland, Kennewick and Pasco. In Appendix II.1-B are an area map identifying major facilities and a table listing the waste management facilities remaining in the area of about 540 acres.

Although the reactor facilities in 100-F Area are shut down, BNW operates biology laboratory facilities located just outside the perimeter fence. Here, studies are conducted on animals of the effects of inhaled and ingested radioactive and toxic materials. Present plans call for these activities to be transferred to research laboratories in the 300 Area and south of the 300 Area starting October, 1974 and to be all transferred by October 1975.

FIGURE II.1-7 H REACTOR AREA

FIGURE II.1-8 100-F REACTOR AREA

II.1.1.1.3 200 Areas

The fuels processing and plutonium separation portion of operations at Hanford are located 18 miles northwest of Richland and near the center of the Hanford Reservation. The 200 East and West Areas are shown in the aerial photographs of Figures II.1-9 and II.1-10, and are located on the site map of Figure II.1-1. Additional area activities include plutonium fabrication and processing, waste fractionization, laboratory work and management of the high-level radioactive liquid waste resulting from the separations process. Radioactive waste from the 100 and 300 Areas also is sent to the 200 Areas for disposal. (Details of 200 Area waste management facilities and operations are presented in Appendix II.1-C).

II.1.1.1.3.1 200 East Area Plants

Purex Plant

The Purex Plant is the most recently constructed of the irradiated fuel processing plants. Constructed between April 1953 and October 1955, Purex took over fuel processing operations from the Redox Plant. The Purex Plant, currently being maintained in standby condition, is operated intermittently as required by N Reactor plutonium production.

Irradiated fuels processing is accomplished in the Purex Plant where plutonium (Pu), neptunium (Np), and uranium (U) are recovered from irradiated uranium fuels. The processing steps include metal dissolution, solvent extraction and ion exchange. Irradiated uranium fuel elements are charged to dissolvers, chemically de-clad, then dissolved with nitric acid. Chemical additions to the dissolver solution are made to produce suitable feed for the solvent extraction operation, where the major separation of the plutonium, neptunium and uranium from fission products is accomplished. The partition cycle separates plutonium from neptunium and uranium. The plutonium stream is routed through two additional solvent extraction cycles for further purification. After final concentration, the plutonium nitrate solution is loaded into containers for transfer to the plutonium finishing operations. The stream from the partition cycle,

FIGURE II.1-9 200-E AREA WITH 200-W AREA AND 100 B/C REACTOR AREA IN BACKGROUND

FIGURE II.1-10 200-W AREA WITH 100 B/C AREA IN BACKGROUND

bearing the neptunium and uranium, is routed to the final uranium cycle where neptunium is separated and returned to the backcycle waste stream, and final purification and concentration of the uranium is accomplished. The product, uranyl nitrate hexahydrate solution (UNH), is stored in large tanks and ultimately transferred to the UO_3 Plant by truck-trailer for conversion to uranium trioxide (UO_3). A portion of the backcycle waste stream is routed to the neptunium recovery and purification process which consists of a solvent extraction cycle, a concentrator and an ion exchange column. The neptunium nitrate product solution is loaded into plastic containers for storage and shipment offsite. Supporting process systems include organic decontamination and recovery, nitric acid recovery, and waste concentration and treatment.

Figure II.1-11 is a flowchart of the Purex Process. The Purex Plant is shown in the aerial photograph of Figure II.1-12. Major facilities may be identified on the map in Appendix II.1-C, Part 1.

B Plant

B Plant was one of the original fuels separations facilities. B Plant, constructed from August 1943 to February 1945, was operated using the bismuth phosphate process. It was last used for this purpose in 1952. B Plant is shown in the aerial photograph of Figure II.1-13. Major facilities may be identified on a map in Appendix II.1-C, Part 1.

Waste from the bismuth phosphate process contained the uranium from the irradiated fuel, was very dilute, and required large volumes for storage. The subsequently developed Redox and later the Purex processes successively reduced the waste volume per unit of plutonium production, resulting in increased concentrations of fission products and heat generation in the waste, to the point where it was self-boiling. Only 20% of the Purex waste is self-boiling waste.

FIGURE II.1-11 PUREX PROCESS SCHEMATIC

FIGURE II.1-12 200-E AREA PUREX PLANT

FIGURE II.1-13 200-E AREA B PLANT. RIGHT FRONT EXTENSION OF BUILDING IS ENCAPSULATION FACILITY.

As a result of a program to develop methods for the solidification of high-level waste, B Plant was converted in 1968 to a waste fractionization plant. It now functions to remove ^{137}Cs and ^{90}Sr from Purex current acid waste and from high-level supernatant liquids, and sludges from self-boiling liquid waste. In addition, an encapsulation and storage facility was constructed on the west end of the B Plant building. Here the strontium and cesium will be converted to solid strontium fluoride and cesium chloride, doubly encapsulated, and placed in retrievable water-cooled storage.

Semiworks and Critical Mass Laboratory

The Semiworks, built as a pilot plant for the Redox process in 1949, was later converted to pilot the Purex process. In 1960, the Semiworks was reactivated and equipped for the processing and loadout of fission products. Separating megacurie amounts of ^{90}Sr , ^{147}Pm and ^{144}Ce , it operated in the dual capacity of production and process demonstration to pilot the B Plant conversion to a waste partitioning facility. The Semiworks is presently shut down.

The Critical Mass Laboratory (CML) research on the criticality safety of plutonium in various forms and combinations with other elements develops data for verification of analytical methods used to predict criticality safety for plutonium in various fuel cycles.

The Semiworks and Critical Mass Laboratory are shown in the aerial photograph of Figure II.1-14.

Support Facilities

General area facilities not specifically related to the various plant processes are located near the main area gate. They may be identified on a map in Appendix II.1-C and are shown in the aerial photographs of Figures II.1-9, II.1-12 and II.1-13.

FIGURE II.1-14 200-E AREA CRITICAL MASS LABORATORY AND SEMIWORKS

II.1.1.1.3.2 200 West Area Plants

U Plant

Although U Plant, shown in the aerial photograph of Figure II.1-15, was one of the three original fuels separations facilities (T Plant, B Plant, U Plant) designed to use the bismuth phosphate process, it was never used for that purpose.

Uranium was not recovered in the bismuth phosphate extraction of plutonium from irradiated fuel. However, the later Redox and Purex processes recovered the uranium which still retained economic value. Following startup of the Redox Plant, U Plant was converted to recover the uranium from stored radioactive waste. From 1952 to 1958 waste was mined from the storage tanks and U Plant was used for uranium recovery. Although this processing is now finished and the building is unused, the adjacent uranium oxide plant is still used to produce powdered UO_3 by calcining (UNH) solutions from Purex Plant. The UO_3 is sealed in steel drums for offsite shipment. A by-product of the calcination process is nitric acid, which is returned to the Purex Plant for reuse.

Figure II.1-16 depicts a simplified process schematic of the UO_3 Plant operation. The UO_3 Plant is currently being maintained in standby condition and will not operate until the Purex Plant resumes reactor fuels processing.

Redox Plant (200 West Area)

The reduction-oxidation process for fuel separation succeeded the bismuth phosphate process, and preceded the Purex process. The Redox Plant is shown in the aerial photograph of Figure II.1-17.

Redox Plant was constructed from May 1950 to August 1951. It operated until July 1967 when it was shut down. Although the building is shut down, the 222-S analytical laboratory is in operation. It supports the operation of B Plant, performs research, and helps develop waste management and environmental control processes.

II.1-27

FIGURE II.1-15 200-W AREA U PLANT

FIGURE II.1-16 UO₃ PLANT PROCESS SCHEMATIC

FIGURE II.1-17 200-W AREA REDOX (S) PLANT

T Plant

T Plant was one of the original fuel separation facilities and is shown on the aerial photograph of Figure II.1-18. T Plant was constructed from June 1943 to October 1944, and operated for the bismuth phosphate process. It was last used for this purpose in 1956. Floor space and facilities in T Plant are presently used on an irregular basis for decontamination projects and equipment repair. The 224-T building is used for plutonium storage.

Z Plant

Constructed in 1949, Z Plant, shown in the aerial photograph of Figure II.1-19, is the site of plutonium laboratory and finishing operations, including the processing of plutonium scrap materials and the preparation of plutonium products. The Plutonium Reclamation Facility processes plutonium scrap in a variety of forms and plutonium content to produce a pure plutonium nitrate solution. Americium is subsequently recovered from the solvent extraction high salt aqueous waste stream generated during the plutonium processing. Generally, the scrap is appropriately incinerated, then leached or dissolved with nitric acid in the feed preparation facilities. The solution generated is then adjusted chemically for feed to the extraction battery. Solvent extraction removes the impurities and produces a pure plutonium nitrate solution. The salt waste stream is further treated for trace plutonium and americium recovery. Contaminated waste streams consist of high and low salt aqueous solutions and degraded organic solutions. The high and low salt waste solutions are routed to underground storage tanks for conversion to salt cake. The degraded organic solutions are stored and/or processed in the in-tank solidification facilities.

The Plutonium Processing Facility converts plutonium nitrate feed to either plutonium oxide or metal, depending upon customer requirements. The plutonium is precipitated with oxalic acid, filtered and calcined (for plutonium oxide product) and then fluorinated and reduced to metal (for

II.1-31

FIGURE II.1-18 200-W AREA T PLANT

FIGURE II.1-19 200-W AREA Z PLANT

the metal product). The facility is currently being operated as required to convert plutonium nitrate from the scrap process to metal. Waste streams consist of solids and the oxalate precipitation filtrate, which are recycled for plutonium recovery in the Reclamation Facility. Aspirator jet water, steam condensates and miscellaneous waste streams with very low concentrations of plutonium are routed to underground storage tanks for conversion to salt cake. Figure II.1-20 is a flowchart for this process.

Support Facilities

General area facilities not specifically related to the various plant processes are located near the main area gate. They may be identified in Appendix II.1-C on a map and are shown in the aerial photographs of Figures II.1-10 and II.1-19.

II.1.1.1.3.3 Tank Farms and Solidification Facilities

Liquid waste containing high concentrations of radionuclides from the chemical processing plants was stored on an interim basis in underground tanks at Hanford since startup. The complex of waste storage tanks, including 149 tanks with capacities ranging from 50,000 to 1,000,000 gallons, are constructed of reinforced concrete with a carbon steel liner on the bottom and side walls. The two new AY tanks, 1,000,000 gallons each, are of a tank-in-tank design with a primary containment steel liner and a surrounding liner to the fill line. Five additional tanks of this latter design are under construction, one of which was completed in October 1973.

Associated with the various tank farms are the evaporators used to convert nonboiling liquid waste to salt cake. There are presently four units in operation, and a fifth under construction. The first two constructed, for in-tank solidification (ITS), were ITS-1 and -2. Both are permanently installed in specific tanks in EY tank farm in 200 East Area and operate by heating the waste in the tank. The 242-S and 242-T evaporators in the 200 West Area, and the under construction 242-A evaporator

FIGURE II.1-20 PLUTONIUM RECOVERY AND FINISHING OPERATIONS

in the 200 East Area, are separate facilities adjacent to the S and SX, and T, TX and TY, and the A, AX, AY and AZ tank farms respectively.

200 East Area

In Appendix II.1-C, Part 2, numbers and sizes of tanks, and a listing of tank farm facilities, are given for 200 East Area. These tank farms are shown in the aerial photographs of Figures II.1-21 and II.1-22 and in Figure II.1-23.

200 West Area

Numbers and sizes of tanks, and a listing of tank farm facilities in 200 West Area, are given in Appendix II.1-C. These tank farms are shown in the aerial photographs of Figures II.1-15 and II.1-24 and in Figure II.1-25.

II.1.1.1.3.4 Cribs, Ponds, and Ditches

Intermediate-level liquid waste is released to the ground via structures called cribs. Essentially all of the radionuclides discharged to these sites are retained in the soil column above the water table due to filtration and ion exchange sorption.

A total of 177 cribs have been provided for disposal of intermediate-level liquid waste since startup of the 200 Area facilities. Of these, 144 have been deactivated, 8 were not used, 10 are in standby, and 15 are currently being used.

The chemical processing operations use very large quantities of water, most of which never come in contact with radioactive materials. This aqueous waste, which is primarily cooling water with some steam condensates, is discharged to ponds for evaporation and/or percolation through the ground eventually to the groundwater.

FIGURE II.1-21 200-E AREA TANK FARMS AY, AX, A AND C

FIGURE II.1-22 200-E AREA TANK FARMS BY, BX AND B

FIGURE II.1-23 200 EAST AREA TANK FARM FACILITIES

FIGURE II.1-24 200-W AREA TANK FARMS SX AND S

FIGURE II.1-25 200 WEST AREA TANK FARM FACILITIES

Approximately 1.3×10^{11} gallons of cooling water and steam condensates have been discharged to 30 surface ponds and ditches in the 200 Areas since the start of chemical processing operations. Approximately 360 acres of land were used for these waste disposal operations, with about 180 acres of this total in current use. Radionuclides discharged to these sites, primarily from accidental releases due to equipment failures, are largely filtered or sorbed and held in the soil beneath the pond or ditch area.

200 East Area

In Appendix II.1-C, Part 2, cribs and ponds for 200-E are listed in a table along with size and use information and may be located on area maps. Aerial views of these cribs and ponds are found in the photographs of Figures II.1-12, II.1-14, II.1-21, II.1-22, II.1-26, II.1-27, II.1-28 and II.1-29.

200 West Area

In Appendix II.1-C, cribs and ponds for 200-W are listed in a table along with size and use information and may be located on area maps. Aerial views of these cribs are found in the photographs of Figures II.1-15, II.1-17, II.1-18, II.1-19, II.1-22, II.1-30 and II.1-31.

II.1.1.1.3.5 Solid Radioactive Waste Burial Grounds

More than 5 million ft^3 of contaminated solids have been buried on the 200 Area plateau since the start of chemical processing operations. These wastes consist of so-called "dry waste" (soiled clothing, laboratory supplies, tools, etc., packed in cardboard, wood or metal containers) and industrial waste (primarily items of failed process equipment packaged in heavy metal or concrete boxes). Transuranic bearing waste has been packaged in sealed metal containers and segregated in the burial trenches since May 1, 1970. Contaminated solid waste is buried in 19 sites on the 200 Area plateau using 155 acres.

FIGURE II.1-26 216-B-3 POND

II.1-43

FIGURE II.1-27 GABLE MOUNTAIN POND

FIGURE II.1-28 WEST LAKE

FIGURE II.1-29 200-E AREA BURIAL GROUNDS 218-E-10, 5A, 5, 2, 9 AND 4

FIGURE II.1-30 216-S-16 POND

FIGURE II.1-31 200-W AREA BURIAL GROUNDS 218-W-2A, 3 AND 3A

Prior to 1968, essentially all of the waste buried was generated by the 200 Areas operating facilities. Since 1968, waste generated by 300 Area operations also has been buried in the 200 Areas sites. Beginning in December 1973, waste from reactor operations in the 100 Areas is being sent to the 200 Areas for burial. Small volumes of solid waste, generated by offsite AEC operations, have been and will continue to be buried here. During 1973, approximately 2000 ft³ containing less than 4 Ci of mixed radioactive materials were received from offsite.

200 East Area

In Appendix II.1-C, Part 2, burial grounds are listed in a table and shown on a map. These burial grounds appear in the aerial photographs of Figures II.1-12, II.1-14, II.1-29 and II.1-32.

200 West Area

In Appendix II.1-C, burial grounds are listed in a table and shown on a map. They appear in the aerial photographs of Figures II.1-17, II.1-20, and II.1-31.

FIGURE II.1-32 218-E-12-B BURIAL GROUND

II.1.1.1.4 300 Area

The 300 Area is located about 1 mile north of the Richland city limits on the bank of the Columbia River. Roughly rectangular in shape, it includes about 375 acres and will shortly expand northward to include approximately another 200 acres for added waste management facilities. The aerial photo, Figure II.1-33, shows that the area is bounded by the Columbia River on the east and the highway on the west. The recently built Life Sciences Facility in the very lower left marks the south boundary while the second process water discharge pond marks the northern boundary. This pond, separated by the V-shaped sanitary waste leach trench from a similar pond, is a distinctive landmark. Waste burial sites now covered are seen at the top (west) of this photo taken in 1973 and at the right side of the figure.

Most facilities in the 300 Area, completed in 1943 and the years immediately following, were related to the fabrication of reactor fuel. These included many technical and service support facilities as well as fuel manufacturing. As the Hanford Production Reactors were shut down, fuel manufacturing activities decreased. Thus, for over 15 years, research and development programs have constituted a major part of the activities in the 300 Area. The newer facilities house mostly laboratories and large test facilities in support of peaceful utilization of plutonium, reactor fuels development, liquid metal technology, fast flux test reactor support, gas cooled reactor programs and life sciences programs.

FIGURE II.1-33 300 AREA

II.1.1.1.5 400 Area

The 400 Area is the Fast Flux Test Facility (FFTF) Construction Area. An environmental impact statement has been prepared.¹

II.1.1.1.6 600 Areas

Included in the 600 Area (all area of the reservation which is not included as 100, 200 300 or 400 Areas) are:

- the Arid Lands Ecology Reserve,^(a) a 120-square-mile tract set aside exclusively for the study of ecology
- 1000 acres leased to the State of Washington
- 1,089 acres for WPPSS nuclear plant Hanford No. 2, of which 1,059 acres will remain in its natural state
- about 2,000 acres of the former Hanford Construction Camp which housed at one time over 40,000 workers
- 2 abandoned townsites, Hanford and White Bluffs
- many support facilities for the Controlled Access Areas
- 32,000 acres for U.S. Bureau of Sport Fisheries and Wildlife Refuge
- 54,000 acres for Washington State Department of Recreation for Wahluke Wildlife Recreation Area

Table II.1-2 summarizes features of the 600 Area. None of the facilities in the 600 Area are generators of radioactive waste. Parts of the 600 Area, however, are or were involved in the Waste Management Operations Programs.

(a) Also referred to as the 1400 Area.

TABLE II.1-2

PREVIOUSLY UTILIZED ACREAGE OF THE 600 AREA

Description	Size or Capacity	Existing Disturbed Acreage (Acres)
Hanford Camp (abandoned and razed)	1920 Acres	960
213 Storage	28 Acres	28
Old Central Shops	224 Acres	190
Army Anti-Aircraft (razed) Sites and/or World War II implacements	219 Acres	78
Graveled leveled areas not used in parking	354 Acres	338
Borrow Areas--1 acre or more in size	1448 Acres	1118
Fill Areas	266 Acres	200
Disturbed Surface--old railroad beds, fire breaks, or seismic test areas	212 Acres	212
Railroads with 35 ft wide roadbeds	178 Miles	755
Four-lane Blacktop Roadways with 80 ft widths	33 Miles	330
Two-lane Blacktop Roadways with 50 ft widths	155 Miles	939
Improved Gravel Roads	91 Miles	441
Telephone Lines ^(a)	144 Miles	436
Power Lines ^(a)	247 Miles	1497
Raw Water Lines	100 B/C and (and 100 D/DR) to 200 Areas	
Buildings	49 in use 6 abandoned	

(a) All lines have one dirt road plus fire break areas under the lines, 25 feet wide for phone lines and 50 feet wide for power lines.

II.1.1.2 Waste Management Facilities, Processes and Equipment

II.1.1.2.1 100 Areas

The shutdown of eight production reactors and the recent (1973) elimination of solid waste burials in the 100 Areas significantly decreased waste management activity in the 100 Areas. Most of the 100 Areas now generate essentially no waste. Waste management facilities of the 100 Areas are arbitrarily divided into the active and inactive areas.

N Reactor differs significantly from all earlier Hanford reactors. At N Reactor, the primary coolant circulates through the reactor and absorbs heat from the fuel elements but is not returned directly to the river. Instead, heat is transferred through heat exchangers to a secondary coolant loop which ordinarily produces the steam to power the electrical generators of the WPPSS. By not releasing cooling water from the reactor core directly to the river, the amount of radioactivity released to the river is greatly reduced.

II.1.1.2.1.1 Radioactive Liquid Waste Facilities

1301-N Crib and Trench

Figure II.1-34 outlines the 100-N Liquid Waste System. The major source of radioactive liquid waste released to the ground is the continuous bleed of primary coolant of the N Reactor. The cooling water is circulated through the reactor process tubes and over the fuel element surfaces repeatedly. Induced activity is minimized by purifying this water before injection into the primary coolant loop. However, the water accumulates radioactivity in the reactor coolant loop as follows:

FIGURE II.1-34 100-N LIQUID WASTE SYSTEMS

- induced activity in dissolved piping corrosion materials (iron, chromium, manganese, zirconium and cobalt)
- fission product releases from fuel elements with failed cladding
- fission products from the fissioning of uranium residue resulting from fuel cladding failures.

Radioactivity in the coolant loop is reduced by continuous bleed-off of part of the coolant and replacement of it with treated river water. The average bleed rate of 1,000 gpm allows the entire primary coolant volume of 150,000 gallons to be replaced every 2.5 hours. Ammonium hydroxide is added to primary coolant water during operation to raise the pH to the alkaline side of neutral. The bleed-off coolant water is then released to the 1301-N crib which measures about 125 by 290 feet. Figure II.1-34 shows the sources of liquid discharges to the crib, trench, and Columbia River. The total flow to the crib during normal reactor operation is 2,500,000 gpd from:

- 36-in. contaminated drain with about 2,000,000 gpd during reactor operations
- 12-in. line of about 500,000 gpd during reactor operations
- 3-in. drain from waste disposal valve pit, 350 gpd
- 6-in. auxiliary decontamination line from 109-N, intermittent.

The overflow from the crib is directed to the adjacent 1,600-ft long by 50-ft wide trench. Some flow from the crib and trench forms a surface seepage at the river bank referred to as the N Area Riverbank Springs. Over half the discharged water reaches the river in 4 to 10 days. The remainder follows longer flow paths and requires several weeks to several months to reach the river.

Most radioactive species discharged to the crib are retained in the soil by chemical reactions, precipitation, and ion exchange. Since the pH is on the alkaline side, the hydroxides and basic salts of zirconium, cerium, and other rare earth and transition elements precipitate and are

retained in the soil by filtration. Due largely to the type of clay minerals present in the region, ion exchange of the cations retains the long-lived radionuclides (^{60}Co , ^{90}Sr , ^{137}Cs) in the soil.

102-in. Discharge Line to the River

A 102-in. diameter discharge line terminates in the Columbia River about 500 feet out from water's edge during low volume river flows of ~50,000 cfs (Appendix II.1-D). The waste consists primarily of steam condenser cooling water discharged via the 102-in. line to the Columbia River channel. (Flow rates down the line with the reactor operating are about 225,000 gpm and with reactor shutdown are about 100,000 gpm.) The discharge points into the 102-in. line are detailed in Appendix II.1-D.

Decontamination Waste--1310-N Facility

Approximately 600,000 gallons of liquid waste are shipped to 200 Areas each year. The bulk of the waste is generated once a year when the N Reactor primary coolant piping is internally decontaminated to remove radioactive corrosion products and deposited materials. Decontamination is a once-through process in which 250,000 gallons of 8 wt% phosphoric acid is flushed through the primary coolant loop, and routed to the 1310-N tank.^(a) The primary coolant system is then rinsed with water and NaOH is added to the 1310-N tank to neutralize the phosphoric acid, increasing the 1310-N tank's waste volume to approximately 600,000 gallons. The resulting intermediate-level liquid waste is shipped to the 200 West Area in 20,000-gallon railway tank cars for evaporation to a solid and for in-tank storage.

II.1.1.2.1.2 Radioactive Solid Waste Facilities

Solid waste from 100-N Area was buried in trenches in other 100 Areas in the past. The waste contained dried salts and oxides of the activation and fission products found in solution in the primary coolant water. A

- (a) Twenty thousand gallons of 70 wt% phosphoric acid is added to demineralized water, giving 250,000 gallons of 8 wt% H_3PO_4 which is then flushed through the primary loop.

few metallic components, taken from the active reactor zone, containing zirconium, iron, and steel activated to $^{95}\text{ZrNb}$, ^{60}Co , and ^{54}Mn were also buried in these facilities. Waste containing transuranium elements and/or high concentration (10 mCi/g) of long-lived radionuclides (>5-year half-life) was shipped to the 200 Areas for burial. Since December 31, 1973, all solid waste has been shipped to the 200 Areas for disposal with the following exceptions:

- Contaminated Equipment Storage. An area was set aside for temporarily storing contaminated equipment removed from radiation zones prior to reuse or disposal.
- Dummy Storage Silos. Silos are in active use for storage of irradiated process spacers, called dummies because they resemble fuel elements but contain no uranium and are used as spacers. No contamination exists on the ground surface. Radiation level at the top of pit 1 is 25 mR/hr and at pit 2 is 35 mR/hr. The dose rate at the Radiation Zone Boundary is <1 mR/hr. Dummies are periodically removed.
- 100-K Area Silos. Two silos in the 100-K Area (each 8 ft in diameter and 24 ft deep) are used for disposal of metallic scrap from N Reactor's fuel storage basin. This waste consists of irradiated fuel element support hardware, bent spacers and other metallic refuse found in the storage basin. Ruptured fuel element fragments are not included in this waste.

II.1.1.2.1.3 Radioactive Gaseous Waste Facilities

The tritium and radioiodines formed in the reactor primary water are bled out of the primary loop into the ventilation exhaust air. Air that leaks in and is purged out of the reactor core graphite gas atmosphere contains ^{40}Ar which is activated to ^{41}Ar . This outleakage is also carried away by the building ventilation exhaust air. The ventilation air and gases exhausted from the building pass through high efficiency particulate

filters and charcoal absorbers before being discharged to the atmosphere from the 200-ft high ventilation stack at 150,000 cfm. (Results for 1972 are presented in Appendix II.1-B, Part 4.)

Some of the 100 Area gaseous radioactive waste originate in the 105/109-N facility as activation salts that are dried on the outside of the reactor piping and surrounding surfaces. Some of the radioactive salts are entrained by the air currents and are removed by high efficiency filters prior to discharge through the ventilation stack.

II.1.1.2.1.4 Inactive Areas

Radioactive waste management facilities in the five 100 Areas in which the reactors (8) were retired are largely the terminated cribs, trenches, ponds, burial areas and the contaminated facilities such as the reactors, spent fuel basins and effluent holdup basins. The status of these facilities is constantly monitored and maintained in their terminated state pending permanent disposition. Tables in Appendix II.1-B, Part 2 list all the cribs, burial plots, trenches and ponds. Very little work with radionuclides is currently in progress and the small quantity of low-level radioactive waste still being generated is also noted in this tabulation. Any radioactive solid waste generated is now transferred to the 200 Area for disposal.

No facilities or equipment for waste management of radioactive gases are needed or are now in service except at the 144-F animal farm facility performing plutonium inhalation studies. High Efficiency Particulate Air (HEPA) filters are installed at 144-F at the experimental enclosures and on the stack, which has a normal flow of 6,500 cfm to the atmosphere. The stack exhaust is continuously sampled. (Results for 1972 are presented in Appendix II.1-B, Part 4.)

II.1.1.2.2 200 Areas²

Due to the high rates of heat generation in the high-level boiling Current Acid Waste (CAW), produced from the Purex Plant processing of irradiated reactor fuel, solidification is not feasible without special processing because excessive temperatures would be encountered in the solids formed. Cesium-137 and ⁹⁰Sr, with half-lives of about 30 years, contribute much of the heat through their radioactive decay. Initially, decay of other fission products in the waste also generates sufficient heat to make the CAW boil even in the absence of ¹³⁷Cs and ⁹⁰Sr. However, due to the relatively short half-lives of the other radionuclides in the waste, the rate of heat generation drops to levels acceptable for solidification within about 5 years. Consequently, CAW is processed (in B Plant) to remove a majority of the cesium and strontium from the liquid waste and will be encapsulated as a solid for long periods in water cooled storage. The remaining liquid waste is neutralized and stored in double-wall tanks until sufficient radioactive decay allows solidification to salt cake.

Dilute nonboiling liquid waste is stored in tanks and/or evaporated to solid cakes in an effort to minimize liquid waste storage inventories and convert the waste to immobile forms as soon as practicable.

The following subsections treat these processes in more detail, as well as the disposal of the less radioactive waste generated in the fuel and waste processing operations. Waste output from 200 Areas operations³ is shown schematically in Figure II.1-35. Waste sources and products are indicated in Table II.1-3. As indicated in the table, waste is also received from other areas. These transfers are indicated on the flow-chart of Figure II.1-2.

II.1.1.2.2.1 B Plant Waste Fractionization and Encapsulation

B Plant removes ⁹⁰Sr and ¹³⁷Cs from high-level radioactive waste resulting from the processing of Hanford reactor fuels. The isolated strontium and cesium fractions are further purified, and will be doubly encapsulated

200 WEST AREA

FIGURE II.1-35(a) 200 AREAS WASTE OUTPUT - 1972

200 EAST AREA

FIGURE II.1-35(b) 200 AREAS WASTE OUTPUT - 1972

TABLE II.1-3
RADIOACTIVE WASTE SOURCES

Source	Type of Waste				Solid	Gaseous
	Liquid		Inter- mediate Level	Low Level		
	High-Level Boiling	Non- Boiling				
<u>200 EAST AREA</u>						
Purex Plant	X	X	X	X	X	X
B Plant	X	X	X	X	X	X
244-AR Vault	-	-	X	X	X	X
241-A, AX, AY Tank Farms	-	-	X	X	X	X
Critical Mass Laboratory	-	-	-	X	X	X
Semiworks	-	-	-	-	-	X
CR Vault	-	-	-	-	-	X
ITS-1 and 2 Concentrators	-	-	X	X	X	X
241-BX, BY and C Tank Farms	-	-	-	-	-	X
<u>200 WEST AREA</u>						
T Plant	-	X	X	X	X	X
242-T Concentrator	-	-	X	X	X	X
Laundry	-	-	-	X	X	X
231-Z	-	-	-	X	X	X
U Plant	-	-	-	X	-	X
Z Plant	-	X	X	X	X	X
UO ₃ Plant	-	-	X	X	X	X
222-S Laboratory	-	X	X	X	X	X
241-SX Tank Farm	-	-	-	X	-	X
Redox Plant	-	-	-	-	-	X
241-TX Tank Farm	-	-	-	-	-	X
242S Evaporator	-	-	-	X	X	X
<u>FROM OTHER CONTRACTORS</u>						
Pacific Northwest Laboratory	-	X	X	X	X	X
United Nuclear Industries, Inc.	-	X	X	X	X	X
Westinghouse Hanford Company	-	-	X	X	X	X
J. A. Jones Construc- tion Company	-	-	-	-	X	-

and stored in monitored water basins which provide both radiation shielding and cooling for the capsules.

Both currently-generated and stored self-boiling wastes are processed by B Plant. A flowchart for these operations is shown in Figure II.1-36. CAW from the Purex Plant are routed underground to B Plant via the 244-AR Vault. The solids are removed from the current acid waste and treated for removal of strontium, while the supernatant solution is processed for cesium removal by precipitation with phosphotungstic acid. The recovered cesium is further processed by ion exchange. Strontium is recovered by processing the acid waste through the solvent extraction system. Stored waste is processed similarly, with the exception that precipitation has already separated solutions into sludges and supernatant liquid in the storage tanks. After processing of the supernatant liquids for cesium removal, the alkaline sludges are sluiced from the tanks, acidified, and transferred by underground piping to B Plant for strontium removal. After clarification, the strontium is recovered by solvent extraction in four extraction columns.

Following recovery in B Plant, cesium and strontium solutions are purified and stored as liquids in stainless steel tanks equipped for cooling coils. Encapsulation of the cesium and strontium will be accomplished in the Waste Encapsulation and Storage Facility (WESF) scheduled for operation early in FY-1975. The cesium solution will be transferred to WESF and converted to cesium chloride solution by the addition of concentrated hydrochloric acid. This solution will be evaporated to yield solid cesium chloride which will be melted. The molten material will be vacuum transferred to stainless steel cylinders (capsules) where it will solidify as cesium chloride salt. After endcaps are welded on the capsules, they will be leak checked with helium, decontaminated and enclosed in outer capsules. Endcaps will be welded on the outer capsules and the welds tested ultrasonically. Completed capsules will be transferred to the underwater storage basin.

FIGURE II.1-36 WASTE FRACTIONIZATION FLOWSHEET

The strontium solution will be transferred to WESF where the strontium will be precipitated as strontium fluoride by the addition of sodium fluoride. The strontium fluoride will be separated by filtration, sintered and the dry powder packed into stainless steel cylinders. Encapsulation will proceed as described for cesium. The filtrate from the precipitation step will be returned to B Plant for rework or disposal. Figures II.1-37 and II.1-38 depict the respective flowsheets for cesium and strontium encapsulation.

All liquid effluent streams will be continuously monitored and routinely sampled. Storage basin water will be circulated within a given storage cell. If radioactivity is detected, the water will be transferred to B Plant for rework or disposal and the source of the contaminations determined and appropriate repairs made. Cooling water streams will empty into the B Plant cooling water header. If radioactivity is detected, the cooling water will be diverted and transferred to B Plant for disposition.

Gaseous effluents will be passed through HEPA filters to remove radioactive particulates, monitored, and exhausted to the atmosphere via a stack. Solid radioactive waste will be packed in barrels and placed in interim storage at B Plant.

FIGURE II.1-37 CESIUM CHLORIDE ENCAPSULATION PROCESS FLOW DIAGRAM

FIGURE II.1-38 STRONTIUM FLUORIDE ENCAPSULATION PROCESS FLOW DIAGRAM

II.1.1.2.2.2 Tank Farms Operations

High-level radioactive waste, produced in the chemical processing of irradiated Hanford reactor fuels, is stored in large underground tanks. Self-boiling waste produced by Purex Plant is stored in the 200 East boiling waste storage tank complex. Boiling waste produced at the Redox Plant was stored in the SX tank farm.

High-level waste is neutralized with sodium hydroxide or sodium carbonate, and then stored as an alkaline slurry. The neutralization precipitates a major portion of the fission products, resulting in a solids or sludge layer covered by supernatant liquid.

High-level waste stored in the A and AX tank farms is presently being processed by B Plant to remove the long-lived fission products. This yields nonboiling waste which can be solidified for in-tank storage as solid salt cake. Salt cake is not as mobile in the event of tank containment failure. For B Plant processing, the supernatant liquid is pumped off a given tank, exposing the sludge. The sludge is then broken into a slurry by sluicing with water or supernate, using specially designed high pressure nozzles. The slurry is pumped to holding tanks in the 244-AR Vault where it is allowed to settle, and the supernate is routed to B Plant for cesium removal. The solids are then dissolved by acidification, and that solution is sent to B Plant for strontium removal.

Supernatant liquid from tanks in the SX tank farm was processed by B Plant. Sludge temperatures in certain SX tanks are being controlled by air cooling, with offgasses being condensed and returned to the tanks. Sluicing of the sludges is not planned due to the age of the tanks and the possibility of liquid leakage.

No boiling waste is being generated at present, as the Purex Plant is not in operation. The only planned new source of boiling waste will be Purex CAW resulting from future processing of irradiated N Reactor fuel. This waste will be routed directly to B Plant for removal of long-lived

fission products. Due to decay heat from the remaining short-lived fission products, however, the processed waste will self-boil. It will require storage as a liquid until radioactive decay reduces the concentration of the shorter half-life radionuclides. Such processed waste will be suitable for solidification about 5 years after its generation.

Table II.1-4 presents a summary of tank farm data.³ The first tanks were for nonboiling waste. Figure II.1-39 is a schematic drawing of a typical nonboiling tank design; Figure II.1-40 presents some tank construction data and the waste characteristics for which the tanks were designed.³ These tanks are vented to the atmosphere through air-cooled reflux condensers. Instrumentation is provided to measure the sludge and supernate temperature, and the liquid and sludge levels in the tanks. A grid of dry wells in each tank farm is used to monitor the soil for radioactive materials, thus serving as a secondary leak detection system. Well sites and well design were dictated by the specific site conditions and the suggested flow path of liquids both above the water table and within the groundwater.

Newer tanks were built to contain waste with greater heat generating characteristics, as shown in Figure II.1-41. These tanks are of the same general construction as those described for nonboiling waste. Additional features are provided, however, to permit self-concentration. The vapors are routed through headers to a deentrainer and water-cooled condensers, which are vented to the atmosphere after passing through a wire mesh deentrainer, high efficiency filters, and exhaust blowers. As shown in the schematic of Figure II.1-42, condensates can be sent to an underground disposal site or can be returned to the waste tank to avoid overconcentration. These tanks, shown in Figure II.1-43, are provided with airlift circulators for the agitation of the tank contents to prevent localized temperature buildup in the supernate, and the resultant bumping caused by sudden steam release.

Each A and SX farm tank is closely encompassed by a complex of vertical and horizontal dry wells (Figure II.1-43) so that any leak may be

TABLE II.1-4
WASTE STORAGE TANKS

<u>Tank Farm</u>	<u>Tanks In Farm</u>	<u>Capacity/Tank (gal)</u>	<u>Capacity/Farm (gal)</u>	<u>Year Constructed</u>	<u>Cost/Farm^(a) (\$)</u>	<u>Cost/gal (\$)</u>
T	16	54,500 (4) 530,000 (12)	6,578,000	1943-44	3,087,000	0.469
U	16	54,500 (4) 530,000 (12)	6,578,000	1943-44	2,969,000	0.451
B	16	54,500 (4) 530,000 (12)	6,578,000	1943-44	3,019,000	0.459
C	16	54,500 (4) 530,000 (12)	6,578,000	1943-44	2,938,000	0.447
BX	12	530,000	6,360,000	1947-48	2,208,000	0.347
TX	18	758,000	13,644,000	1947-48	5,859,000	0.429
BY	12	758,000	9,096,000	1950-51	2,651,000	0.291
S	12	758,000	9,096,000	1950-51	3,961,000	0.435
TY	6	758,000	4,548,000	1951-52	1,846,000	0.406
SX	15	1,000,000	15,000,000	1953-54	3,983,000	0.266
A	6	1,000,000	6,000,000	1954-55	5,865,000	0.978
AX	4	1,000,000	4,000,000	1963-64	2,577,000	0.644
AY	2	1,000,000	2,000,000	1968-70	3,125,000	1.562
AZ	2	1,000,000	2,000,000	1971-75	6,200,000	3.100
	153		98,056,000		50,288,000	0.513 Avg

(a) Includes original tank farm cost plus improvements, including instrumentation, agitation systems, and transfer lines from separations plants. Operating costs are not included. The A and AX farm costs include the actual cost of \$761,000 for Project CAC-970, Essential Waste Routing System, and an estimated cost of \$280,000 for Project IAP-609, Purex Tank Farm Vent System Expansion. The costs for these two projects are equally divided between A and AX farms.

FIGURE II.1-39 TYPICAL STORAGE TANK FOR NONBOILING WASTE

FIGURE II.1-40 CHARACTERISTICS OF WASTE USED FOR DESIGN ON NONBOILING WASTE TANKS

FIGURE II.1-41 CHARACTERISTICS OF WASTE USED FOR DESIGN OF BOILING WASTE TANKS

FIGURE II.1-42. TYPICAL HIGH-LEVEL BOILING WASTE STORAGE FACILITY

FIGURE II.1-43. TYPICAL CONTROL AND SAFETY FEATURES FOR HIGH-LEVEL BOILING RADIOACTIVE WASTE STORAGE

detected by monitoring for radioactive material in the soil surrounding the tank. This is in addition to monitoring for liquid level changes in the tank. Each AX and AY farm tank has a drainage grid beneath the tank liner which connects to an associated leak detection well. The AY farm double-wall tanks have an annular space between the concentric steel liners equipped with liquid detection equipment.

A temperature element, liquid level instrumentation, and a radiation detector are located between tank and liner to monitor for any leakages from the primary tank. Any leakage which might be detected can be returned to the tank via an installed pump. Two additional tanks (AZ tank farm) similar to the AY farm tanks are under construction in the 200 East Area and three additional tanks in the 200 West Area. The design features of the double-wall tanks are shown in Figure II.1-44.

Extensive piping interties exist within and between tank farms so it is possible to transfer liquid to or from any tank in the system.

A total of 18 single-wall waste storage tanks have experienced confirmed leaks at the time this statement was prepared (Appendix II.1-C, Part 8). In each case, upon confirmation of the leak the tank contents were pumped to another tank as rapidly as possible.

In addition to these 18 confirmed leakers, another 14 tanks have been removed from service because of indications that the tank integrity was suspect. Reasons for questioning the operating quality of tanks have included: 1) excessive pitting or corrosion of the carbon steel tank liner as determined by photographic inspection techniques; 2) unexplained anomalies in leak detection measurements which might indicate leakage but which could not be confirmed as such; and 3) experience records with other tanks of the same age and service which would indicate that the effective useful life of such tanks had been reached.

Current operating policy at Hanford requires that tanks of questionable quality be pumped out and removed from further service as fast as spare tank space is made available by the current waste solidification program.

FIGURE II.1-44 DOUBLE-WALL BOILING WASTE TANK

Eleven tanks which have been filled with salt cake are no longer available for storage of liquid waste.

II.1.1.2.2.3 Waste Solidification and Stabilization

To ensure continued waste containment for long time periods, nonboiling high-level liquid radioactive waste is being converted to immobile solid salt cake. This is accomplished by evaporation and crystallization, and solids accumulation in existing storage tanks.

Currently, the four In-tank Solidification (ITS) systems in operation are ITS-1 and -2 in the 200 East Area and the 242-T and 242-S evaporators in the 200 West Area. Figures II.1-45, II.1-46, II.1-47 and II.1-48 provide schematics on the operations of these evaporator systems. Organic liquid waste is also stored in tanks pending acquisition of equipment to process it. The waste is primarily degraded solvent which can no longer be used in solvent extraction processes.

The primary function of the ITS systems is to concentrate the nonboiling waste to produce an immobile solid salt cake. Ideally, the feed stream would be concentrated as far as possible so that the inventory of concentrated bottoms is minimized and the maximum amount of solids is formed and precipitated. Each of the ITS systems (see Figure II.1-49 for the 242-S bottoms tank system) include a heat exchanger for water evaporation and a series of bottoms tanks (bottoms loop). After concentration in the evaporator, the bottoms stream is routed through the bottoms loop. Heat losses to the ground and the tank ventilation systems progressively lowers the bottoms temperature so that eventually the stream is saturated and solids are formed and deposited in the bottoms tanks. The saturated bottoms supernate stream is blended with fresh feed and recycled back to the evaporator.

FIGURE II.1-45 IN-TANK SOLIDIFICATION-1 SCHEMATIC

II.1-82

FIGURE II.1-46 IN-TANK SOLIDIFICATION-2 SCHEMATIC

II.1-83

FIGURE II.1-47 242-T EVAPORATOR SCHEMATIC

II.1-84

FIGURE II.1-48 242-S VACUUM EVAPORATOR-CRYSTALLIZER

FIGURE II.1-49 242-S BOTTOMS TANK SYSTEM

After the bottoms tanks are filled with solids and removed from the bottoms loop, they still contain residual supernate as interstitial liquor equal to approximately 30% of the solid salt cake volume. The major portion of this liquid needs to be removed since the integrity of the tank liner and shell cannot be assumed for long periods. The current program for accomplishing this liquid removal is via the installation of screened well points (salt wells) to the bottom of the tanks. However, to date, the pumping end point as determined by the minimum practical volume of remaining liquid in the waste tank has not been established. The saturated liquors pumped via salt wells from filled bottoms tanks will be routed for further concentration in the ITS systems.

An underground storage tank which is filled with salt cake from one of the ITS systems, and which has the maximum amount of interstitial or residual liquor removed, is considered stabilized for interim storage. Until the waste is stabilized the integrity of the tank and process lines are of primary importance and under continual surveillance. Liquid level measurements are taken in active tanks (having recent transfers to or from) twice per shift, and in inactive tanks once per shift. Material balances are made every 2 hours during transfers, and a final material balance is made at the completion of the transfer and drain back from line holdup. In-tank temperatures are monitored every shift.

A network of dry wells is in place or planned for every tank except those in the SX, AX, AY and AZ farms, which have external leak detection systems as an integral part of their construction. Additionally, laterals are located beneath A farm tanks and the majority of the SX farm tanks. These dry wells and laterals are monitored for radiation increases on a frequency determined by the status of the tank, e.g., whether the tank is active, inactive, in restricted use, etc.

Subsequent to the stabilization of solid salt cake in a tank for interim storage, it is planned to core-drill, analyze, and characterize the salt cake. Then the tank will be isolated by cutting and blanking all process piping to and from the tank, blanking all risers and equipping the tank with a filtered ventilation system. Subsequent surveillance of a stabilized, isolated tank will consist of periodically obtaining in-tank photographs, sampling and analyzing the vapor space, monitoring the in-tank temperatures, and monitoring the dry wells and laterals.

II.1.1.2.2.4 Liquid Waste Streams and Transfer Lines

The 200 Area activities of fuels processing, waste partitioning and plutonium processing require the transfer of large quantities of high-level radioactive waste within and between the Areas. The extensive systems and lines which show the sources and destinations of the radionuclides and available transfer lines are described in Appendix II.1-C Parts 3 and 4.

Stainless steel underground waste transfer lines in concrete encasements are in place between the 200 East and 200 West Areas for transfer of radioactive liquid waste between these areas (Appendix II.1-C). These lines are used to transfer neutralized high-level wastes between 200 East and 200 West Areas for processing, underground storage, evaporation and solidification.

II.1.1.2.2.5 Cribs and Ponds

Certain liquid effluents are released to the ground via underground structures called cribs. These effluent streams are primarily process and steam condensates which have a potential for releasing radioactivity upon process upset or equipment failure. The amount of radioactivity normally in these streams is very small; the concentration is generally less than 0.05 $\mu\text{Ci/ml}$ (except tritium). While some of these streams have been classified as intermediate-level liquid waste (5×10^{-5} to $100 \mu\text{Ci/ml}$), other streams have radioactivity concentrations well below AECM 0524 Table II guides for uncontrolled areas and have diversion capability if process upsets occur.

A crib is constructed by digging a ditch about 20 feet deep and up to 1400 feet long, backfilling with rock and covering with an impermeable membrane and soil. A pipe running the length of the crib is designed to distribute the liquid uniformly along the crib length (Figure II.1-50). The released liquid percolates through the soil. The soil column between the bottom of the crib and the groundwater is 150 to 300 feet thick and contains up to 50% silts and sand, having some clay content. Since percolation rates through these materials are slow, the liquid spreads laterally and involves much more soil than that directly beneath the crib. Formerly, when aqueous waste containing organic or complexing agents were discharged to the ground, the volume was limited to the point where it was believed that the soil could retain the material above the groundwater by capillarity.

FIGURE II.1-50 TYPICAL CRIB FOR AQUEOUS WASTE

A typical crib disposal site is shown in Figure II.1-51. While the coarse gravels have little capacity to sorb or filter radioactive materials, the clays have good ion exchange properties and make good filter beds. The soil columns in the 200 Areas exhibit cation exchange capabilities of 2.5 to 10 milli-equivalents/100 g of soil. The ion exchange capacity of the clays varies widely with the type of ion being sorbed (Figure II.1-52). Tritium and nitrate ions, for example, are only slightly sorbed, if at all. Ruthenium is held relatively well, but a fraction of the ruthenium is of such ionic form that little sorption takes place. The tritium, nitrate, and ruthenium then flow to the groundwater at essentially the same rate as the water discharged to the crib. These materials, Ru, ^3H , and NO_3 , may at times enter the groundwater directly below a crib at concentrations above the appropriate limits for drinking water but are rapidly diluted below such limits.

Cesium and strontium are tightly held by the soil, most being held within a few tens of feet below a typical crib. Plutonium is held very tightly by the soils, with essentially all of it held within 10 feet of the point of release.

An extensive network of wells is provided for sampling groundwaters. Groundwaters associated with waste disposal sites are routinely sampled and analyzed. When long-lived radionuclides, such as ^{90}Sr , ^{60}Co , or ^{137}Cs , are detected in the groundwaters at concentrations approaching 1/10 of the concentration guide⁴ for drinking water, the crib site is deactivated, and the process effluents are routed to a new crib. Only a few cribs were used to the point of reaching this limit. In those cases, the radionuclides are still observed to be bound to the soils near the point of entry to the groundwater system.

FIGURE II.1-51 SCHEMATIC OF TYPICAL CRIB FOR INTERMEDIATE-LEVEL WASTE

FIGURE II.1-52 APPROXIMATE SORPTION PATTERNS FOR TYPICAL HANFORD DISPOSAL CRIB

A total of 177 cribs have been provided for disposal of intermediate-level liquid waste since startup of the 200 Areas facilities. Of these, 144 have been deactivated, 8 have not been used, 10 are in standby, and 15 are currently being used for disposal of liquid waste from normal processing operations. The shutdown of most Hanford reactors and the resultant decrease in reactor fuels processing, coupled with additional waste treatment of several intermediate-level liquid waste streams, resulted in a major reduction in the quantity of radionuclides discharged to the ground via cribs during the past several years.

Approximately 80% of the process condensate overheads from concentration of Purex first cycle high-level waste is routinely recycled to the process. Total recycle of this stream is planned. Ammonia scrubber waste, previously routed to a crib, will be collected and routed to a waste evaporator for decontamination. Funds were requested to provide recycle of another Purex process condensate stream (from concentration of back-cycle waste) and to provide improved monitoring, diversion, and collection of Purex steam condensate for cleanup in the event this stream should become contaminated due to failure of process vessel heating coils. Process condensate overheads from the B Plant high-level waste concentrator will be batch collected, sampled, and analyzed prior to discharge, when the currently funded project is completed in CY-1975. If above discharge limits, this waste stream will be recycled. Improved monitoring, diversion, and collection of B Plant steam condensate for cleanup will also be provided by this project.

Process condensate overheads from the self-boiling 241-A, AX, and AY waste storage tanks are treated via an ion exchange column to remove ^{137}Cs and ^{90}Sr . Process condensate overheads from the ITS units 1 and 2 are also treated via an ion-exchange to remove ^{137}Cs prior to discharge.

Process condensates from the 242-T Waste Evaporator are batch collected and monitored; they can be recycled, if necessary. Liquid waste from the operation of Z Plant, containing essentially all of the plutonium-bearing liquid waste from that operation, is routed to underground waste storage tanks via the 242-T Waste Evaporator. Currently no appreciable quantity of plutonium is discharged directly to the ground. Process condensates from the new 242-S Waste Evaporator-Crystallizer are treated via ion-exchange to remove ^{137}Cs prior to discharge. All waste from this facility meets surface discharge limits. When currently funded plant modifications are in place, the total quantity of radioactive materials discharged to the ground via cribs should be reduced to less than 100 Ci and 13 g of calculated plutonium annually.^(a) Conceptual design of facilities are proceeding to reduce total annual discharges to less than 60 Ci (except tritium) and alternatively to meet drinking water standards for all discharges.

The chemical processing operations use very large quantities of water, most of which never come in contact with radioactive materials. This low-level aqueous waste, which is primarily cooling waters with some steam condensates, is discharged to ponds for evaporation and/or percolation through the ground to the groundwater. The upper limit of contamination of such discharges is set at 5×10^{-5} $\mu\text{Ci/ml}$ of mixed fission products.^(b) Radiation monitoring instruments, with alarms, are installed on most effluent streams flowing to pond discharge points to alert operating personnel to any abnormal radioactive release. Currently, radiation monitors on two streams (AR Vault steam condensate and cooling water and B Plant cooling water) will, in the event of abnormal levels, activate diversion valves routing the wastewater to unlined ditches instead of the larger pond areas. Funds are now

(a) The quantity of plutonium released is based upon the detection limit for plutonium. Therefore, the quantity reported is a hypothetical number determined by multiplying the plutonium concentration detection limit by the volume of liquid effluent discharged to the cribs in one year.

(b) In this context, "mixed fission products" signifies fission products having concentration ratios approximating those present in Hanford reactor fuels from 6 to 12 months subsequent to reactor discharge.

available to line these ditches for containment and rerouting of the contaminated wastewater for future decontamination, should diversion occur. Funds were requested in FY-75 Budget to provide similar capability for the Purex Plant wastewater.

Approximately, 13×10^{10} gallons of cooling water and steam condensates were discharged to 30 surface ponds and ditches in the 200 Areas since the start of chemical processing operations. Approximately, 360 acres of land were used for these waste disposal operations, with about 180 acres of this total still in use.

Radionuclides discharged to these sites, primarily from accidental releases due to equipment failures, are filtered or sorbed and held in the soil beneath the pond or ditch area except for ^{106}Ru and tritium. Where ponds or ditches were removed from service, contaminated sediments were either removed or buried in place. Liquid levels in currently used ponds are maintained to minimize exposure of any contaminated sediments to plant and animal life. (Figure II.1-53 shows a typical pond.)

II.1.1.2.2.6 Buried Storage

More than 5 million ft^3 of contaminated solid waste of widely diverse nature and contaminated to varying degrees with radioactive materials have been buried on the 200 Area plateau since 1944. This waste was buried in 19 sites using approximately 155 acres of land. Prior to 1968, essentially all of the waste buried at these sites was generated by the 200 Areas operating facilities. Since 1968, waste generated by 300 Area operations was also buried in the 200 Areas sites. Beginning in December 1973, waste from reactor operations in the 100 Areas was sent to the 200 Areas for burial. Small volumes of solid waste, generated by offsite AEC operations, were and will continue to be buried there.

Solid radioactive waste buried in the ground is considered to be in long-term storage. An exception is that waste buried after April 30, 1970, which contains or is suspected of containing transuranium nuclides; this is considered to be in interim storage (20 years). Large items of solid waste, such as failed equipment from locations where the presence

II.1-96

FIGURE II.1-53 SCHEMATIC VIEW OF TYPICAL POND RECEIVING LOW-LEVEL AQUEOUS WASTE

of transuranium nuclides can be safely ruled out, are packaged in concrete boxes and buried in industrial waste burial trenches. Small items of failed equipment and trash-type contaminated waste, from locations where the presence of transuranium nuclides can be safely ruled out, are packaged in cardboard cartons, wood boxes, or steel or fiber drums and buried in the so-called "dry waste" trenches. (A schematic drawing of the solid waste burial trenches is shown in Figure II.1-54.)

The various waste containers used provide containment of the radioactive contamination and minimize radiation exposure to personnel during temporary storage, handling, shipment, and burial operations. Once buried, no reliability is placed on the containers for confinement or retrievability of these materials. Although burial of the waste containers by backfilling the trench is normally done at the close of the day's receipt of solid waste, waste trenches are immediately backfilled whenever the dose rate at the edge of the trench reaches 100 mR/hr. Solid waste is normally covered with 10 to 20 feet of earth to prevent uptake of radionuclides by plant life or disturbance by burrowing animals. An exception, waste contained in concrete boxes or small drums, may have a minimum dirt cover of 4 feet provided that radiation levels at grade are less than 1 mR/hr. Periodic routine surveillance of filled burial trenches is provided to assure that the burial grounds are maintained to meet existing standards.

Solid waste, containing or suspected of containing transuranium nuclides buried after April 30, 1970, is packaged and buried in compliance with AECMC-0511. This directive states that "such wastes shall be segregated from other solid wastes and shall be packaged and buried so that they can be readily retrievable, as contamination-free packages, within an interim period of 20 years."

Formerly, the waste was packaged in iron drums and iron or concrete boxes and buried in special trenches. Subsequent evaluation of iron

FIGURE II.1-54 SOLID WASTE BURIAL TRENCHES

drums directly buried in Hanford soils indicated that failures could occur in less than 20 years and retrieval, as contamination-free packages, might not be possible. Two alternates to direct burial were implemented on a test basis, either of which will protect the containers from direct contact with the soil and will permit ease of retrieval.

A prototype concrete V-trench was built and filled with transuranic-bearing waste drums, as shown in Figure II.1-55. A metal cover and several feet of earth cover isolate the drums from the environment. This alternate provides protection of the drums from the soil and allows sampling of the storage trench atmosphere for radioactive materials and combustible gases, either of which would indicate drum failure.

Currently, a simpler alternate, pad storage, is being tested. The transuranic-bearing solid waste is segregated as combustible and non-combustible at the point of origin and placed in labeled drums. The segregated waste drums are placed on the storage pad in a stack four drums high; each layer of drums is separated by plywood treated with fire retardant. When drums are stacked to a volume of 24 feet by 24 feet by 12 feet, the stack will be covered with plywood and plastic-reinforced nylon sheeting prior to covering with 4 feet of earth. Capability for sampling the storage atmosphere is also provided. (A schematic of this storage alternate is shown in Figure II.1-56.)

Small items of transuranic-bearing solid waste, containing fission products capable of generating high dose rate gamma emissions, are packaged and shipped in shielded casks. This waste is discharged from the casks to caissons, as shown in Figure II.1-57, and the caissons can be retrieved.

Some of the Purex processing equipment is so large and becomes so contaminated in service, that its transport to a burial ground would require abnormally high exposure of operating personnel. Such equipment is placed on flatcars and pushed into the solid waste storage

ADVANTAGES

PROTECTS DRUMS FROM SOIL

STORAGE CONDITIONS CAN BE MONITORED

FIGURE II.1-55 CONCRETE LINED V-TRENCH USED FOR RETRIEVABLE
TRANSURANIC WASTE STORAGE

FIGURE II.1-56 THE TRANSURANIC SLAB (Alternate Method for Retrievable Transuranic Waste Storage)

FIGURE II.1-57 SOLID WASTE BURIAL CAISSONS

tunnels appended to the Purex Plant. A schematic of a Purex solid waste storage tunnel is shown in Figure II.1-58. An inventory of stored waste is given in Appendix II.1-C, Part 6.

Currently, two methods for reducing the volume of solid waste are being practiced. Some waste from the laboratories and from the 234-5-Z Building Plutonium Finishing operation is compacted prior to storage to provide a volume reduction of approximately four to one. Funding is being requested to provide volume reductions of all combustible waste by incineration.

II.1.1.2.2.7 Ventilation Equipment

Gaseous effluents from the 200 Areas facilities are limited to airstreams containing relatively low concentrations of radionuclides, either in gaseous or entrained particulate form. Multiple filtration is relied upon to remove particulate matter, while a "silver reactor" and/or wet scrubbers are used to remove radionuclides such as radioiodine and oxides of nitrogen. Figure II.1-59 shows a typical ventilation flow pattern for a chemical processing plant. Air is drawn through a washer and filter and supplied to a processing area. The air flows, sequentially, from less contaminated to more contaminated zones. After passing through the most contaminated zone, the air flows through an exhaust duct to high efficiency particulate filters and then through a stack to the atmosphere.

A wide variety of high efficiency filters is used, as indicated in Table II.1-5.

FIGURE II.1-58- TUNNEL FOR STORAGE OF RADIOACTIVE EQUIPMENT

FIGURE II.1-59 SCHEMATIC OF VENTILATION OF TYPICAL SEPARATIONS PLANT

TABLE II.1-5
VENTILATION FILTERS

<u>Type</u>	<u>Plant</u>	<u>Rated Efficiency, %^(a)</u>
Three-Stage Glass HEPA ⁵	Z Plant	99.99+
Two-Stage Glass HEPA ⁸	B Plant, AR Vault	99.99
Two-Stage Glass Fiber ^{6,7}	Purex	99.9
Sand ⁶	T Plant, U Plant, B Plant Backup	99.5

(a) For 0.3 μm particles.

Process chemicals and radioactive contaminants are entrained by air that comes in close contact with process materials. These gases are segregated into separate vent systems according to process requirements and compatibility of the process gases. The gases are processed for removal of noxious materials in a variety of ways:

- by Iodine Absorber (Purex)
- by Ammonia Scrubber (Purex, B Plant)
- by NO_x Absorber (Purex, UO_3 Plant)
- by HF Scrubber (Z Plant)

Once the noxious materials are reduced to within acceptable levels, the process vent gases are exhausted to the ventilation system for additional filtration and return to the atmosphere.

II.1.1.2.3 300 Area

II.1.1.2.3.1 Radioactive Waste Management

The 300 Area liquid waste handling systems provide for retention of some liquids containing above trace amounts of radioactivity for transport to and subsequent treatment in the 200 Area or the 100-H Area. Other liquids containing only trace amounts of radioactivity are discharged to ponds. The use of 100 H solar evaporation treatment was instituted in 1973 on an intermittent basis but will be fully operational in June 1974. It will accommodate that portion of the fuel processing effluent containing uranium and copper. The plutonium and fission product waste is generated in laboratories and test facilities conducting research and development work on separation processes, waste solidification and reactor fuels.

All solid and liquid radioactive wastes, including uranium, are now sent to the 200 Areas for disposal except for some low-level uranium contaminated liquid waste and slightly contaminated animal waste sent to 300 Area ponds. Radioactive airborne effluent waste in the 300 Area is filtered and monitored prior to release through stacks.

Radioactive Waste Liquids⁸

All radioactive liquid waste generated in the 300 Area is retained and shipped to 200 Areas for disposal with two minor exceptions noted above (Appendix II.1-E, Part 3). Some effluents contaminated with uranium are released to the process water ponds. Discharges to ponds during 1972 were about 2.8×10^6 gallons/day, consisting of about 11,000 gpd from the life sciences facility and the remainder from the fuel fabrication area and the systems shown on Figures II-1-60 through II-1-62. Temporary storage of radioactive liquids prior to shipment to the 200 Areas is provided by the 340, 340-A, and 340-B Waste Retention and Neutralization Facility (Figure II.1-63). The three buildings, constituting a total area of 3800 ft², provide facilities also for chemical neutralization and transfer of the radioactive waste into tankers.

FIGURE II.1-60 CONTAMINATED LIQUID WASTE COLLECTION SYSTEM

FIGURE II.1-61 RETENTION WASTE SYSTEM (307 BASINS)

FIGURE II.1-62 300 AREA NORMALLY UNCONTAMINATED WASTE SYSTEM

II.1-111

FIGURE II.1-63 340 AND 340A BUILDING INTERMEDIATE-LEVEL WASTE STORAGE TANK

The main building houses a large rectangular concrete pit 21-ft deep containing two stainless steel, 15,000-gal neutralization tanks, valves, and transfer pumps. The pit area, which is covered by removable concrete blocks, adjoins the operation gallery and sampling room.

The annex building, 340-A, contains six 8,000-gal stainless steel waste storage tanks. Three 5,000-gal tanker trucks can be accommodated in the load-out addition. Two 20,000-gal tank cars can be accommodated in 340-B, a railroad tank car load-out facility.

A separate underground waste sewer from a limited number of sinks and drains in Buildings 308, 309, 324, 325, 326, 327 and 329 serves this system. The line is a cathodically protected underground network of stainless steel piping leading directly to the 340 Waste Management Facility (Figure II.1-60)

Normally Uncontaminated (Retention) Liquid Waste

A second liquid waste retention system, the 307 Retention Basins, provides a collection point for normally uncontaminated liquid waste from laboratories which may, inadvertently, contain low-level radioactive waste material. The four basins are of reinforced concrete construction with the tops just above grade. Capacity of each is about 50,000 gallon. Basins 1 and 2 are provided with a neoprene lining to simplify decontamination if required. Basins 3 and 4 have bare concrete surfaces and are used only in case of emergency. A continuous in-line β/γ liquid effluent monitor samples the waste stream just ahead of the influent into the 307 Basins. This monitor signals an alarm in the nearby 325 building equipment room and automatically shuts off the basin's discharge pump to a pond when a radionuclide concentration is detected.

Basins 1 and 2 are provided with a series of baffles which form a serpentine flow path. The time for free flow through the basin by the serpentine route is sufficiently long to allow an adequate counting interval for the sample in the monitor. The discharge pump can be shut down automatically by this equipment prior to any release of radioactivity to the ground. Normally the contents of the basins are discharged to the ponds. (Figure II.1-62 is a schematic of the system.) A continuous sampler removes a representative sample from the influent lines to the basins. Samples are taken to the laboratory weekly for alpha and beta/gamma analysis for backup to the monitor.

Buildings 325-A and 324 on this system are provided with Waste Water Diverter Systems (similar to the waste water system described above). In these buildings, cooling water from equipment containing large quantities of radioactive materials is monitored by the Waste Water Diverter System monitor prior to release to the retention waste system. If a rupture in a cooling coil should allow contamination of the cooling water, the Waste Water Diverter will signal an alarm and divert the contaminated water to a 20,000-gal underground catch tank for verification and appropriate disposal without taxing the 307 basin waste management complex. Underground piping connects the normally uncontaminated process waste from Buildings 308, 309, 324, 325, 326, 327, and 329 in a second separate sewer system discharging into the first of the four 307 Facility Retention Basins (Figure II.1-61).

High-Level Radioactive Liquid Waste

High-level radioactive liquid process waste is retained for transfer to the 200 Areas using shielded stainless steel casks. Cask capacities range from half liter to 500 gallons. Normally these are transported directly from the laboratory generating the waste via the highway to the 200 Areas for disposal. Special vehicles are required, as the large casks weigh up to 17 tons.

Radioactive Solid Waste

Active facilities for long-term management of solid radioactive waste do not exist in the 300 Area as no solid radioactive waste is now buried, or incinerated in this area. All radioactive solid waste is transferred via truck and highway from the laboratories or facility where radiation work is performed to the 200 Areas for disposal. Each transfer of solid waste to the 200 Areas is performed according to written procedures and is permanently recorded.

All radioactive solid waste is divided into transuranic and nontransuranic solid waste as it is accumulated. Since the former contains some radioactivity from elements whose atomic number is greater than 92, this waste is handled separately and in special disposal containers. The latter is known to contain no radioactivity from transuranic elements and is packaged in several ways. Low-level radioactive waste may be sealed in plastic-lined cardboard containers whereas high-level radioactive waste may require large concrete casks for containers.

Retired Solid Waste Storage Facilities

Since fuel fabrication began at Hanford, approximately $7.5 \times 10^5 \text{ ft}^3$ of solid waste containing approximately 10 Ci of uranium contamination have been placed into the 300 Area burial sites. Thorium contaminated waste is less than 0.5 Ci and is segregated from uranium (i.e., a different trench). Most of the 300 Area contaminated waste is in a matrix of bonding materials on fabrication components, scrap material and equipment as surface contamination.

Of the approximately $7.5 \times 10^5 \text{ ft}^3$ of solid waste, approximately 90,000 ft^3 are surface contaminated metallic, concrete, and asphalt materials. The remaining approximately $6.6 \times 10^5 \text{ ft}^3$ occupy approximately $1 \times 10^5 \text{ ft}^3$ of underground space. The volume reduction occurs as a result of the weight of the solid waste and the soil overburden.

The sites are listed in Appendix II.1-E, Part 2, along with the size, date of deactivation, general description of the contents and the depth to the water table. Figure II.1-64 shows their location.

Radioactive Gaseous Waste

Each laboratory or facility in which radioactive materials are handled or processed is equipped with its individual exhaust treatment system. Wherever practical, airborne radioactive materials are removed from exhaust gases near the hood, glove box, or cell in which they are generated.

The exhaust treatment systems in every facility utilize high-efficiency particulate air filters which are tested to meet at least a 99.97% efficiency for particles 0.3 μm and greater in diameter. The filters are tested following installation and on a scheduled frequency thereafter. Where required, a charcoal absorber is used as a collector for radioactive iodine. All expended filters from the facilities or laboratories in which radioactive materials are handled or processed are treated as radioactive solid waste.

II.1.1.2.4 Waste Management Facilities and Activities Planned and Under Construction FY-1973 - FY-1975

The current program has as its continuing objective the reduction of radioactivity in all effluent systems to the lowest technical, economical and practical levels and includes the following action:

II.1.1.2.4.1 100 Areas

<u>N Reactor Control Rod Coolant Dump System</u>	\$75,000
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Valves and piping will be provided in the N Reactor Control Rod Coolant System to provide a positive way to discharge this stream to the 1301-N crib, thus further reducing the potential for discharging small amounts of radioactivity to the river.

FIGURE II.1-64 300 AREA WASTE STORAGE AREAS

N Reactor Gravity Drain and Disposal Basin

\$445,000

An Emergency Disposal Basin will be installed east of the existing 1301-N crib. The purpose is to provide an adequate emergency cooling water disposal capacity in case of 1) an emergency dump of the N Reactor primary loop to the dump tank followed by once-through cooling, and/or 2) a cooling system break inside the 105-N or 109-N Buildings and a concurrent drain pump failure. Emergency drainage sufficient to prevent direct overflow of contaminated water to the Columbia River and to prevent possible water damage to the 105-N and 109-N Buildings will be provided. The Basin will provide a soil column 25 to 30 feet deep between the bottom of the basin and the average groundwater level for absorption of radioactivity.

N Reactor Ventilation Loop Seal Improvement

\$325,000

A redundant confinement valving system will be installed in the N Reactor building ventilation system to provide positive reliable secondary closures in the vent openings and thus assure containment of vapors and gases which would only be generated under unlikely conditions.

II.1.1.2.4.2 200 Areas

In-Tank Solidification Systems, Auxiliaries

\$2,500,000

The project provides additional concentrate routing facilities to permit transfer of slurries from the 242-S Evaporator to existing tanks in the 241-U Farm.

Waste Management Effluent Control

\$1,000,000

Four waste effluent streams, 1) 244-AR cooling water, 2) B Plant cooling water, 3) B Plant steam condensate and 4) B Plant process condensate will be provided with lined trenches, monitoring, and automatic diversion facilities such that in event of accidental contamination of these streams, they will be contained and recycled rather than released.

Contaminated Soil Removal Facility

\$1,000,000

This project will remove plutonium-containing soil from the underground disposal crib 216 Z-9 for packaging and restorage in facilities affording retrievability provisions.

Purex Ammonia Scrubber

Waste Concentration Facilities

\$405,000

The amount of radioactivity in the Purex Ammonia Scrubber waste which is discharged to a covered trench will be reduced significantly by providing for routing of all of this stream to an existing concentrator system. The decontaminated condensate will be routed to a crib and the concentrated radioactivity will be routed to underground tanks.

Tank 241-C-106 Sluicing Facilities

\$400,000

Tank 241-C-106 contains a considerable amount of ⁹⁰Sr-bearing sludge which originated as entrainment from sludge washing operations associated with removal of sludges from the 241-A, AX tank complex. This project will provide facilities for removal of the sludge from which the strontium will be recovered in B Plant. The recovered strontium will then be solidified, encapsulated and stored in the encapsulation plant facilities.

Additional Waste Concentration And Salt Cake Storage Facilities

\$30,000,000

This project would provide a waste evaporator system, additional underground storage tanks for cumulative capacity of at least three million gallons of highly radioactive waste, routings for new tanks and existing underground storage tanks, underground lines, encasements, pumps and auxiliaries, which are needed for the waste concentration program and for minimizing the potential for leakage of radioactive liquids to the ground.⁹

Provision of the proposed facilities will allow acceleration of the waste solidification program. The liquid waste in 30 of the older waste tanks, some of which are associated with the existing waste concentration systems,

can be emptied at least one year sooner for solidification by evaporation-crystallization. Also, most of the liquid waste can be stored in single-wall 200 East Area waste tanks of later improved design or the new double-wall waste tanks provided by this project instead of the older tanks which otherwise would be utilized. This will reduce the potential for future leaks.

Purex Condensate Recycle

\$405,000

This project will provide for recycling condensates from the 1) backcycle concentrator as extractant for the first uranium cycle and as the scrub solution for the first decontamination cycle, and 2) first uranium cycle concentrator as the final uranium cycle extractant.

With the proposed facilities all process condensates except the final uranium concentrator condensate, which is well within release limits established by the AEC, would be recycled within the Purex Plant. This will provide for a significant reduction in the amount of radioactive material discharged to ground.

Waste Tank Leak Detection Laterals

\$330,000

A set of three laterals will be provided about nine feet below the bottom of the 102-S and 103-S waste tanks to permit radiation monitoring of the ground for early detection of possible leaks. These tanks serve as the feed and dump tanks for the 242-S Waste Evaporator.

Ground Monitoring Wells

\$100,000

Additional wells will be drilled at selected strategic locations to enhance the existing routine groundwater monitoring capability.

Encase Waste Lines 232-Z to 241-Z

\$50,000

A short run of existing piping which transports incinerator scrubber waste from the plutonium incinerator building to a sump will be replaced with an encased pipeline thus affording double containment provisions.

Waste Management Effluent Control

\$3,500,000

This project provides facilities to maintain and to extend protection against the accidental release of radioactivity in certain effluent streams from the Waste Fractionization Facility (B Plant) and the Chemical Processing Facility (Purex Plant). The facilities include: 1) a replacement ventilation filter for B Plant, including an underground concrete filter cell equipped with replaceable prefilters and two stages of high efficiency particulate air (HEPA) filter banks and a corrugated metal instrument building above the cell; 2) improvements, including prefilters and HEPA filters for treating ventilation air from the sample gallery, and the organic treatment and acid fractionization cells of the Purex Plant; 3) diversion facilities to detect contamination which may accidentally enter normally nonradioactive cooling water streams and steam condensate from the Purex Plant and to divert such an affected stream to either a lined and covered reservoir or to existing waste tanks for decontamination; 4) replacement Purex Plant ventilation air filter designed for a flow rate of 125,000 cubic feet per minute and consisting of a prefilter and secondary high efficiency filters in a concrete cell with a corrugated metal instrument building above the cell.

B Plant Gallery and Vessel Vent System

Ventilation Improvements

\$70,000

This project will provide new ventilation exhaust fans and single-stage, high-efficiency filters for the ventilation exhaust from the B Plant operating, pipe and electrical galleries and would provide sampling facilities for the filtered vessel vent exhaust.

These additions will reduce the potential risk of releasing radioactive materials from the operating areas to the environment. The vessel vent exhaust sampling system will provide for detecting filter failure. The gallery ventilation filters will protect the environment from potential release of contamination from the operating areas.

242-T Evaporator Effluent Improvements

\$200,000

In order to reduce the risk of releasing radioactive materials to the environment, the project provides the 242-T Building process cells (feed, evaporator, and condensate) with filtered supply and exhaust ventilation systems consisting of 1) supply air: preheater, two stages of roughing filters, and ductwork, and associated service piping, instrumentation and controls; and 2) exhaust air: preheater, prefilter, parallel two-stage, HEPA filters, parallel exhaust fans, stack, ductwork and associated service piping, instrumentation and controls.

Exhaust Ventilation Improvements 222-S

Laboratory - Purex

\$445,000

A new bank of HEPA filters will be installed in a new enclosure to further protect the environment by providing additional filtration of the exhaust air ventilation from contaminated and potentially contaminated zones of the 222-S Laboratory Building. New ductwork, fans, stack and accessories will also be provided.

II.1.1.2.4.3 300 Area

Laboratory Ventilation Exhaust Addition

325 Building

\$485,000

The 325 Building Laboratory will be provided with new local exhaust filter plenums containing HEPA filters, fire detection sensors and fire suppression equipment, thus adding a second stage of filtration to the existing single stage system. Improved reliability will result and the potential for release of radioactivity via the ventilation system will be correspondingly reduced.

300 Area Liquid Waste Disposal

\$190,000

The existing process waste system will be provided with new leaching trenches, a sampling station and two monitoring wells. The new leaching

trenches will replace the existing process ponds, thus eliminating the possibility of leaching the minerals which have accumulated over the years to the river.

Replace and Upgrade 300 Area Contaminated Waste Line \$400,000

The existing entire radioactive contaminated sewer system consisting of a 6-inch trunk line fed by smaller 3- and 4-inch lines will be replaced and upgraded to eliminate the possibility of line deterioration resulting in the release of radioactivity to the ground.

II.1.1.2.4.4 Decontamination of B-C Crib Controlled Area

The AEC evaluated the surface contamination problem and plans to conduct a pilot study of equipment and techniques to decontaminate the B-C Crib Controlled Area by removing radioactively contaminated animal excrement and soil from the surface of the test area. Conceivably this could return the test area to an acceptably controlled condition so that public access could be permitted with few restrictions. The B-C Crib Controlled Area (Appendix II.1-A), is an old sand dune area covered with natural desert plants, primarily rabbit brush, bitterbrush and sagebrush with some thin stands of grass. (The B-C Crib Controlled Area should not be confused with the 216 B/C Crib [Figure II.1-65] and trench area.)

II.1.1.2.4.5 P-11 Facility Cleanup \$300,000

The objective of this project is to clean up the P-11 site and restore the area so that it will not pose an environmental hazard to people or animals, thus allowing alternative uses of the land area, if so desired.¹⁰

The P-11 Facility served as a laboratory for plutonium criticality studies prior to 1952. It consisted of two buildings: the 123 Building (a converted original Hanford area residence) and the 120 Building. The 123 Building, which served as the control house, is already razed and involved no plutonium contamination. The 120 Building, which is a

FIGURE II.1-65 B/C CRIBS (216-B-14 AND UP)

single-story metal building about 32 feet by 42 feet in plan, contained a critical assembly room, a small chemistry laboratory, storage and tank room, and a change room. Work in this facility was discontinued in 1952 after a fire destroyed a part of the interior of the structure. The Facility's location is shown in Appendix II.1-A.

During the cleanup, harmful effects to the biota will be minimized. As a result of the cleanup, potential airborne contamination and subsequent migration of radioactive material in the event of a range fire or other natural incident will be eliminated. The removed radioactive materials will be stored and controlled the same as similar waste in the 200 Areas.

II.1.1.3 Plant Water Usage

Sanitary and process water for the Hanford Reservation Operations are supplied from a number of different locations (Table II.1-6). The 100-B pumphouse, with the 100-D as backup, supplies water to 100B-C, 100-D, 100-H, 100-F, 100-K and 200 Areas. All of these areas are shown on Figure II.1-1. A water plant at 100-N Area supplies sanitary and process water to both 100-N and the WPPSS Generating Station located adjacent to 100-N plant. The 300 Area pumphouse supplies all water needs for the 300 Area. The City of Richland water supply system is intertied to the 300 Area system as an emergency backup. Various wells in the 600 Areas on the site supply both sanitary and process water.

An average of 433 cfs (1.4% of annual average flow) of Columbia River water is continuously withdrawn, mainly for cooling purposes. Most of this water is discharged directly back to the river as nonradioactive disposal. In addition, approximately 34.7 cfs (less than 0.03% of the total annual average flow) of Columbia River water is withdrawn and discharged to the ground as sanitary and industrial wastes. Wells supply approximately 73,000 gal/day for sanitary and minor irrigation use which is almost entirely discharged to the ground also.

TABLE II.1-6
PLANT WATER USE

<u>Plant or Facility</u>	<u>Source of Supply</u>	<u>Primary Use</u>
100-B	Columbia River 100-B Pumphouse	Process water
100-D	Columbia River 100-D Pumphouse	Process water
100-K	From 100-B Pumphouse	Process water
100-N	Columbia River-100-N Pumphouse	Process, sanitary and cooling water
100-F	From 100-B Pumphouse	Process water
200 Areas	100-B Pumphouse Well 299-E26-6 Wells 299-E28-11 and 15	Process and cooling water Emergency Sanitary supply to high tanks Emergency process supply
300 Area	Columbia River 300 Area Pumphouse	Process and sanitary 331 Fish Ponds
FFTF	Wells 699-S0-7 699-S0-8 699-S1-7B	Construction and Sanitary
Atm. Physics	100-B Pumphouse	Sanitary
609 Fire Sta. (100 Area Central)	100-B Pumphouse	Sanitary
609 A Fire Sta. (200 Area Central)	100-B Area	Sanitary
6652C (Aeronomy)	Rattlesnake Springs	Sanitary
6652I (Ale Hq)	Well 699-26-89	Sanitary and Irrigation
Emergency Relocation Ctr.	Well 699-S18-51	Sanitary
BY Telephone Exchange	Well 699-50-28A	Sanitary
Hanford Road Maintenance	Well 699-Han-9	Industrial and Sanitary
Vernita Park	Wells 699-72-101A, B and C	Sanitary and Irrigation

II.1.1.4 Waste Inventories

Multiple disposal sites have been used at the Hanford plant, during the 30-yr history of the operation, for radioactive waste disposal. The choice of disposal site is based on many factors including, half-life and toxicity of the elements involved, quantity of material to be discarded, proximity to water table and/or the Columbia River, and optimum personnel radiation exposure and contamination control. Many of these sites have been terminated.

II.1.1.4.1 Contained Solids and Liquids

II.1.1.4.1.1 Disposal Sites

The approximate inventories of solid waste disposal in the 100 Areas through 1972 summarized below are shown in Appendix II.1-B, Part 3. These inventories are corrected for decay through the end of 1972.

<u>Radionuclide</u>	<u>Quantity (Ci) (decayed through 1972)</u>
Long Half-Life (>1 Year)	
^{60}Co	25,900
^{90}Sr	34
^{239}Pu	0.38
Short Half Life (<1 Year)	
^{65}Zn	1,000
^{54}Mn , ^{95}Zr	3,500

The approximate inventories of solid waste disposal in the 200 Areas through 1972 summarized below are shown in Appendix II.1-C, Part 6.

<u>Radionuclide</u>	<u>Quantity</u>
U	5.9×10^8 g
Pu	3.7×10^5 g
^{90}Sr	1.2×10^4 Ci
^{106}Ru	3.2×10^3 Ci
^{137}Cs	1.3×10^4 Ci
Other radioactive materials	3.5×10^5 Ci

II.1.1.4.1.2 Facilities

Inventories of radioactive materials estimated to be contained in non-operating reactors and reactor facilities through 1972³ as summarized below are shown in Appendix II.1-B, Part 3.

<u>Radionuclide</u>	<u>Quantity (Ci)</u>
Reactors	
^{60}Co	74,100
Reactor Facilities	
^{90}Sr , ^{137}Cs , ^{239}Pu } ^{152}Eu , ^{60}Co	800
^{59}Fe	2,000
	150,000

Inventories of radioactive materials estimated to be contained in the two Purex equipment storage Tunnels through September 1973 as summarized below are shown in Appendix II.1-C, Part 6.

<u>Radionuclide</u>	<u>Quantity</u>
Mixed Fission Products	29,600 Ci
^{90}Sr	1,340 Ci
^{106}Ru	8 Ci
^{137}Cs	1,440 Ci
^{60}Co	15,000 Ci
^{239}Pu	<500 g

The estimated decayed inventory of radioactive materials stored in tanks in the 200 Area through 1980¹¹ are summarized below.

<u>Radionuclide</u>	<u>Quantity (Ci)</u>
^{90}Sr	47×10^6
^{137}Cs	28×10^6
^{239}Pu	2.2×10^4

II.1.1.4.2 Liquid Discharges to Soil

The estimated radioactive material inventories in the 100-N Area crib through 1972³ as summarized below are shown in Appendix II.1-B.

<u>Radionuclide</u>	<u>Quantity (Ci)</u>
⁶⁰ Co	2,000
⁵⁴ Mn	800
¹³⁷ Cs	350
Misc. isotopes	575

The estimated radioactive material inventories in the 100-F animal waste leaching trench through 1972¹² as summarized below are shown in Appendix II.1-B.

<u>Radionuclide</u>	<u>Quantity (Ci)</u>
⁹⁰ Sr	4
²³⁹ Pu	0.08

The estimated radioactive material inventories in 200 Area ditches, ponds and cribs through 1972¹³ (decayed) as summarized below are shown in Appendix II.1-C, Part 6.

<u>Radionuclide</u>	<u>Quantity 200 Area</u>
Beta	1.6×10^5 Ci
⁹⁰ Sr	3.1×10^4 Ci
¹⁰⁶ Ru	2.7×10^3 Ci
¹³⁷ Cs	3.5×10^4 Ci
⁶⁰ Co	$<2 \times 10^2$ Ci
²³³ U	$<1 \times 10^3$ g
U _{nat}	1.2×10^8 g
Pu	1.9×10^5 g

II.1.1.4.3 Radionuclides Stored Beneath Selected 200 Area Cribs

A detailed study of radioactive waste beneath a specific disposal site (216-S-1 and 2 Cribs) was made in 1956. In 1966, the site was again evaluated as part of a larger study which involved the drilling of 30 wells totaling 4988 feet to explore the soil sediments beneath 11 major and typical waste disposal sites.^{14,15}

Both of the above studies concluded that the major amount (greater than 99% of the long-lived radioisotopes) is stored in the subsoil within a few tens of feet below the bottom of the disposal facilities and well above the water table. The details of the exploration of radionuclide distributions beneath these waste disposal sites are summarized in Appendix II.1-C, Part 5.

Exploratory wells were drilled in 1966 at the following sites:

• 216-A-5 crib	• 216-B-3 ponds
• 216-A-8 crib	• 216-S-7 cribs
• 216-A-24 crib	• 216-S-9 crib
• 216-A-25 ponds	• 216-T-28 crib
• 216-B/C cribs and trenches	• 216-Z-9 cribs
• 216-BY cribs	• 216-Z-12 cribs

Summaries of the results are also presented in Appendix II.1-C, Part 5.

Inventory Estimates Above the Water Table

During 1971, data from the 1966 drilling were used to define an empirical relationship from which the quantities of ruthenium, cesium and strontium in the lowermost 50 feet of the vadose zone were estimated. Forty-two cribs were identified where possible quantities of these long-lived radioisotopes might exist. The total inventory calculated for the lowest 50 feet of the vadose zone was about 2000 Ci of ruthenium and about 400 Ci of strontium plus cesium.¹⁶

II.1.1.4.4 Inventory in the Saturated Groundwater

On the basis of the concentration measurements for gross beta and tritium and nitrate ion plumes given in Figure II.1-66, -67 and -68, an order of magnitude estimate was made of the total curies or kilograms in the unconfined groundwater aquifer. These estimates are based on more detailed contouring of the contamination plumes (for the month of December 1972) than appears in the cited figures. The concentration measured at the water table was assumed to be constant over the saturated thickness of the unconfined aquifer, an assumption which has not been verified. After the aquifer area was divided into 1000-ft square cells, the amount of contaminant in each cell was summed. The results were as follows:

Gross Beta (^{106}Ru)	6400 Ci
Tritium	3.5×10^7 Ci
Nitrate	2.2×10^8 kg

The radiological status of the groundwater near the surface of the unconfined aquifer is monitored regularly. The results are reported semiannually. The gross beta (ruthenium) plumes and the tritium plumes are mapped in Figures II.1-66 and II.1-67 for the latter half of 1972.

FIGURE II.1-66 AVERAGE GROSS BETA (AS ^{106}Ru) CONCENTRATIONS,
JULY-DECEMBER 1972 (Concentration Guide: 10 pCi/ml)

FIGURE II.1-67 AVERAGE TRITIUM (^3H) CONCENTRATIONS, JULY-DECEMBER 1972
(Concentration Guide: 3000 pCi/ml)

FIGURE II.1-68 AVERAGE NITRATE ION (NO_3^-) CONCENTRATIONS
JULY-DECEMBER 1972 (Drinking Water Standard: 45 mg/l)

The tritium plumes correspond to the nitrate plumes of Figure II.1-68 that emanate from the 200 Areas and the 100-N Area. The remainder of the tritium-contaminated groundwater in the northern part of the project is due to previously operating reactors.

The major trends of the groundwater flow paths are illustrated by these plumes. Dispersion, radioactive decay, and a minor amount of sorption to modify the convective transport of these contaminant "tracers." The gross beta activity plumes in Figure II.1-66 are not spread as far as the tritium or nitrate plumes, primarily because ruthenium (half-life of 1 year), which is the major beta emitter, is decaying faster than the current rate of travel away from the disposal sites.

Other radionuclides are observed in the unconfined aquifer in the immediate vicinity of the disposal sites at 100-N Area, 200 East and West Areas, and the 300 Area. At the 100-N Areas, the radioactivity in the groundwater from ground disposal of waste is predominantly tritium, ^{131}I , ^{106}Ru , ^{90}Sr , and ^{60}Co . At the 200 Areas, the groundwater activity in addition to ^{106}Ru and tritium, is due to ^{60}Co , ^{90}Sr , ^{137}Cs , and U. At the 300 Area, the predominant radionuclide in the groundwater is uranium from fuel fabrication and laboratory waste disposal. Table II.1-7 shows the highest average concentrations of radionuclides other than tritium listed by disposal site for 1972.

TABLE II.1-7

HIGHEST GROSS BETA, Co-60, Ru-106, Sr-90, Cs-137,
AND GROSS ALPHA CONCENTRATIONS IN THE GROUNDWATER
UNDER THE AREAS LISTED BY DISPOSAL SITE

	Average Concentration (pCi/ml)		Analytical Limit	Concentration Guide
	Jan-June 1972	July-Dec 1972		
<u>Gross Beta</u> (as ¹⁰⁶ Ru)			0.08	10
<u>100 Areas</u>				
Active Sites				
1301-N Crib	1.9	1.1		
Inactive Sites				
105, D/DR Crib, Storage Basin, Trenches	<0.08	0.12		
<u>200 Areas</u>				
Active Sites				
216-S-23	18	13		
216-B-50	3.9	4.3		
216-A-30	0.8	2.0		
216-A-36B	3.1	2.0		
Inactive Sites				
216-S-9	77	46		
216-S-1	23	26		
216-S-13	18	17		
241-BX-1,2	5.5	5		
241-BY-1,2	4.7	3.8		
<u>300 Area</u>				
Active Sites				
307 Retention Basin				
Transfer Line	6	0.32		
North Process Pond	<0.11	0.15		

TABLE II.1-7 (Continued)

	Average Concentration (pCi/ml)		Analytical Limit	Concentration Guide
	Jan-June 1972	July-Dec 1972		
<u>^{60}Co</u>			0.02	30
<u>100 Areas</u>				
1301-N Crib	0.054	<0.15		
<u>200 Areas</u>				
Active Sites				
216-B-50	9.0	10.3		
216-B-57	2.4	2.9		
Inactive Sites				
216-Z-7	2.3	1.5		
<u>^{106}Ru</u>			0.06	10
<u>100 Areas</u>				
1301-N Crib	0.18	0.07		
<u>200 Areas</u>				
Active Sites				
216-S-23	17	15		
216-A-30	0.8	2.3		
216-A-36B	3.1	2.1		
Inactive Sites				
216-S-9	76	56		
216-T-26	3.3	3		
<u>Gross Alpha</u>			0.02	5
<u>200 Areas</u>				
Inactive Sites				
216-S-13	1.41	2.57		
216-S-21	0.07	0.06		
216-A-27	0.04	0.035		

TABLE II.1-7 (Continued)

	Average Concentration (pCi/ml)		Analytical Limit	Concentration Guide
	Jan-June 1972	July-Dec 1972		
<u>300 Area</u>				
North Process Pond	0.1	0.09		
<u>¹³⁷Cs</u>			0.02	20
<u>100 Areas</u>				
1301-N Crib	<0.02	<0.11		
<u>200 Areas</u>				
Active Sites				
216-B-46,50	0.64	0.55		
216-A-36-B		0.042		
Inactive Sites				
216-A-24	0.076	0.15		
216-S-9	<0.07	<0.06		
<u>⁹⁰Sr</u>			0.03	0.3
<u>100 Areas</u>				
1301-N Crib	0.12	0.13		
<u>200 Areas</u>				
Active Sites				
216-A-36-B	0.064	0.064		
216-A-10	<0.032	0.033		
Inactive Sites				
216-S-1	19.2 ^(a)	19.3 ^(a)		
216-S-2	0.15	0.12		
216-A-5	<0.032	0.042		

(a) Appendix II.1-C, Part 5.

II.1.1.4.5 Unplanned Releases

During the period 1945 through 1973 a number of unplanned radioactive contamination releases to the environment occurred. Details of many of these are abstracted in Appendixes II.1-B, Part 5, II.1-C, Part 8 and II.1-E, Part 5. These listings include unplanned releases which are known or believed to be in excess of 0.1 Ci of fission products or 0.1 g of plutonium. When possible, ground surface contamination was removed, covered or otherwise stabilized to preclude further spread in the environment.

Appendix II.1-B presents abstracts of unplanned environmental release incidents which occurred in the reactor (100) areas. Typical incidents included windborne radioactivity spread from dry cooling water retention basins and fuel element failures resulting in radioactivity releases from ventilation stacks. In excess of 2600 Ci of short-lived fission products are known to have been released to the environment as a result of incidents at Hanford reactor sites. Fire in a remote laboratory facility released about 4 g of plutonium.

The largest number of unplanned environmental release incidents occurred in the chemical processing (200) areas. The quantities of radioactive materials released are detailed in Appendix II.1-C. The typical incident involved leakage of waste solutions from tanks or lines or emission of gaseous or particulate radioactivity from stacks. In one incident, several hundred gallons of uranium solution soaked into the ground alongside a Hanford road after the overturn of a tank truck. This contamination has since been removed to the point that radiation control is no longer required. The largest release was the 106-T tank leak which released 40,000 Ci of ^{137}Cs , 14,000 Ci of ^{90}Sr and 4 Ci of plutonium to underground soils. No offsite or groundwater contamination resulted.

A number of environmental release incidents occurred in the 300 Area laboratory complex (Appendix II.1-E). 300 Area incidents resulted in the release of about 843 Ci of mixed fission products. Most of these incidents involved gaseous or particulate releases from stacks but the majority of radioactivity released occurred in a single incident which leaked fission products to the ground.

II.1.1.5 Waste Handling System and Operating Experience - Radioactive

II.1.1.5.1 Gaseous Radioactive Material Releases

The results of analyses of all exhaust air streams likely to contain radioactive materials are summarized below for 1972.²

Data for specific facilities are presented in Appendix II.1-C, Appendix II.1-D, and Appendix II.1-E.

100 Areas (1972)

	^{41}Ar	^3H	^{131}I
Total Release, Ci	1×10^5	2.7×10^1	1.3×10^{-2}
Average Concentration, $\mu\text{Ci/cc}$	5.2×10^{-5}	1.4×10^{-8}	6.8×10^{-12}
	^{133}I	^{90}Sr	^{239}Pu
Total Release, Ci	5×10^{-2}	$<4.5 \times 10^{-6}$	$<3.7 \times 10^{-7}$
Average Concentration, $\mu\text{Ci/cc}$	2.6×10^{-10}	$<6.6 \times 10^{-14}$	$<5.4 \times 10^{-15}$

200 Areas (1972)

	Alpha Assumed Pu	Alpha Assumed U	Beta	^{131}I
Total Release, Ci	5.2×10^{-3}	$9.1 \times 10^{10-5}$	8.7×10^{-1}	2.1×10^{-1}
Average Concentration, $\mu\text{Ci/cc}$	3.9×10^{-13}	6.6×10^{-8}	6.5×10^{-11}	2.8×10^{-6}

300 Areas (1972)

	Alpha	Beta	^{131}I
Total Release, Ci	$<6.6 \times 10^{-5}$	$<3.4 \times 10^{-3}$	$<1.2 \times 10^{-2}$
Average Concentration, $\mu\text{Ci/cc}$	$<1.1 \times 10^{-14}$	$<5.8 \times 10^{-13}$	$<2.5 \times 10^{-12}$

II.1.1.5.2 Liquid Radioactive Material Releases to Columbia River

The quantity of radioactive materials released to the Columbia River at 100-N² as summarized below are shown in Appendix II.1-B, Part 4.

Radioactive Materials Released to Columbia River 100-N Area

	$\frac{{}^3\text{H}}{\text{---}}$	$\frac{{}^{24}\text{Na}}{\text{---}}$	$\frac{{}^{51}\text{Cr}}{\text{---}}$
Total Release, Ci	7×10^3	5×10^2	2.5×10^1
Concentration, $\mu\text{Ci/cc}$	2.5×10^{-3}	1.4×10^{-6}	6.8×10^{-8}
	$\frac{{}^{56}\text{Mn}}{\text{---}}$	$\frac{{}^{239}\text{Np}}{\text{---}}$	$\frac{\text{Misc}}{\text{---}}$
Total Release, Ci	6×10^2	9.0×10^1	1.8×10^2
Concentration, $\mu\text{Ci/cc}$	1.6×10^{-6}	2.4×10^{-7}	

II.1.1.6 Waste Handling Systems and Operating Experience Nonradioactive

II.1.1.6.1 Nonradioactive Gaseous Releases¹⁶

II.1.1.6.1.1 100 Areas

Three oil-fired boilers, that provide standby power at the 100-N Area, release SO₂ and NO₂ to the atmosphere via stacks from each unit. No scrubbers or separators are used. (The pollutants released to the atmosphere are summarized in Table II.1-8.) The 100-K Area central heating plant has been deactivated. Separate unit heaters are utilized at each facility in other 100 Areas except 100-D in which experimental work is conducted and electrical heat is used. In 100-D and 100-F Areas, oil-fired package steam boilers burning an estimated 250,000 gpy each, discharge directly to the atmosphere.

II.1.1.6.1.2 200 Areas

One major heating and power plant is operating in the 200-E Area and another is operating in the 200-W Area. In addition, a portable steam generator is operated in the 200-E Area tank farms. Atmospheric releases are summarized in Table II.1-8.

II.1.1.6.1.3 300 Areas

A central powerhouse in the 300 Area provides up to 365,000 lb/hr of steam for building heat and limited process heat in some facilities. The four oil-fired units normally in use are supplied from a large underground storage tank. Three of these discharge through individual ducts at roof level.

The two coal-fired units now being returned to routine service are fed from an uncovered large surface supply maintained by railcar shipments. The two coal-fired and one oil-fired units are discharged through a cyclone separator and a 150-ft high stack to the atmosphere.

TABLE II.1-8

SOURCES AND EMISSIONS OF NONRADIOACTIVE
POLLUTANTS TO THE ATMOSPHERE
CY-1972

	<u>200-E</u> <u>Power Plant</u>	<u>200-W</u> <u>Power Plant</u>	<u>300-Area</u> <u>Power Plant</u>
Fuel	Coal	Coal	Coal
Combustion configuration	spreader stoker	spreader stoker	spreader stoker
Consumption (tons)	57,000	35,000	10,500
Sulfur Oxides (tons)	650	400	120
Nitrogen Oxides (tons)	430	260	80
Particulates (tons)	3,400	2,000	650
Aldehydes (pounds)	300	200	50

TABLE II.1-8

(continued)

	100-N Power Plant		300 Area Power Plant	
Fuel (oil)	#6 Residual	#2 Distillate	#6 Residual	#2 Distillate
Combustion Configuration	Tangentially Fired	Tangentially Fired	Horizontally Fired	Horizontally Fired
Consumption (gallons)	8,500,000	94,000	2,200,000	1,100,000
Particulates	100 tons	1,400 pounds	25 tons	8 tons
Sulfur Dioxide	1000 tons	2,000 pounds	250 tons	25,000 (pounds)
Sulfur Trioxide (pounds)	25,500	30	6,500	350
Carbon Monoxide (pounds)	1,700	20	450	200
Hydrocarbons (pounds)	25,500	300	6,500	3,300
Nitrogen Oxides (tons)	170	1.88	90	40
Aldehydes (pounds)	8,500	200	2,200	2,200

Exhaust Gas Flow for Main Heating Plants

100-N	$1. \times 10^{10}$ ft ³ /year
200-E	3.4×10^{10} ft ³ /year
200-W	2.1×10^{10} ft ³ /year
300	2.3×10^{10} ft ³ /year

TABLE II.1-8

(continued)

	<u>200-E Steam Plant</u>	<u>100-D Steam Plant</u>	<u>100-K Steam Plant</u>	<u>100-F Steam Plant</u>	<u>400 Area Steam Plant</u>	<u>3000 Area Steam Plant</u>
Fuel	#2 Dist	#2 Dist	#2 Dist	#2 Dist	#2 Dist	#2 Dist
Combustion Configuration	Horiz. Fired	Horiz. Fired	Tang. Fired	Horiz. Fired	Horiz. Fired	Horiz. Fired
Consumption (gallons)	54,000	250,000	290,000	270,000	11,000	120,000
Particulates (pounds)	800	3,800	4,300	4,000	160	1,800
Sulfur Dioxide (pounds)	1,200	5,700	6,500	6,000	250	2,700
Sulfur Trioxide (pounds)	20	80	90	90	5	40
Carbon Monoxide (pounds)	10	50	60	50	2	20
Hydrocarbons (pounds)	160	750	860	800	30	360
Nitrogen Oxides (pounds)	4,300	20,000	11,500	21,600	900	9,600
Aldehydes (pounds)	100	500	600	540	20	240

333 Building
Metal Etch Line

Nitrogen Oxides - 14 tons

II.1.1.6.2 Nonradioactive Liquid Disposal

II.1.1.6.2.1 Sanitary Waste

100 Areas

Each area includes several sanitary waste systems including separate septic tanks draining into tile fields. The rates of sanitary sewage discharged to the ground for 1972 are listed in Table II.1-9.

TABLE II.1-9

SEWAGE DISPOSAL TO GROUND

<u>Plant</u>	<u>gpd</u>
100-N	22,500
100-K	2,750
100B-C	180
100-D	2,400
100-F	2,700

200 Areas

All facilities in the 200 Areas with sinks, rest rooms, showers, or lunchrooms are on a sanitary sewer system discharging into septic tanks which overflow into tile fields. The rate of sanitary sewage discharge to the ground for 1972 is 99,000 gpd.

300 Areas

Sanitary waste is liquid waste from change rooms with sinks and showers, restrooms, toilet facilities, janitor sinks and lunchrooms. All permanent 300 Area buildings with one or more of these accommodations are on a separate sewer system delivering sewage to septic tanks with a total volume of about 8,500 ft³ (Figure II.1-69). The

II.1-147

FIGURE II.1-69 300 AREA SANITARY SEWER SYSTEM

effluent from the septic tank flows to one of two leaching trenches approximately 600 feet long and 10 feet wide.

Flow through the sanitary sewer system varies from 350,000 gpd in the winter to 600,000 gpd in the summer. A weir between the septic tank and the leaching trench measures the volume of sewage. This is continuously recorded and the record inspected daily. Samples are taken routinely between the trenches and the river and analyzed for coliform, BOD and turbidity.

Miscellaneous Facilities

The rates of sanitary sewage discharged to the ground via tile fields adjacent to facilities for 1972 are summarized in Table II.1-10.

TABLE II.1-10

SEWAGE DISPOSAL TO GROUND

<u>Plant</u>	<u>gpd</u>
609 Bldg. Fire Station	1,250
609-A Building Fire Station	800
Hanford Road Maintenance	200
600 Area (Atmos. Physics)	2,900
6652-C Aeronomy	900
6652-I (ALE)	900
BY Telephone Exchange	6
FFTF	60,000
WPPSS-N Area	10,000

II.1.1.6.2.2 Industrial Liquid Waste

100 Areas

Four of the 100 Areas discharge water directly to the river. For 14 discharge points, a discharge permit application was filed with the Corps of Engineers who, in turn, transferred it to EPA. The application has not been processed with the EPA. (The discharge applications are shown in Appendix II.1-D.) No waste abatement is applied to any discharge

as essentially no chemicals or radionuclides are released. Table II.1-11 and the figures in Appendix II.1-D describe these releases.

TABLE II.1-11

DIRECT DISPOSAL TO THE COLUMBIA RIVER

<u>Plant</u>	<u>gpd</u>
100-N	283,000,000
100-K	4,530,000
100B-C	755,000
100-D	792,000

Approximately 2,000,000 gpd of industrial waste which contains minor amounts of chemicals, shown in Table II.1-12, and radioactive material (discussed in previous section) are discharged to the ground at the 100-N Area via 1301-N Crib. No industrial liquid waste is discharged to the ground in the deactivated 100 Areas.

TABLE II.1-12

1301-N Crib - 1972

Volume Released 7.6×10^6 ℓ/d

Sulfate	3.5 mg/ ℓ
Aluminum	80 $\mu g/\ell$
Calcium	13 mg/ ℓ
Chromium	10 $\mu g/\ell$
Iron	50 $\mu g/\ell$
Magnesium	2 mg/ ℓ
Nitrate	0.1 mg/ ℓ
Ammonia	1.8 mg/ ℓ
Nitrite	0.140 mg/ ℓ
Strontium	80 $\mu g/\ell$
pH	7.7
Total Solids	67 mg/ ℓ

200 Areas

Approximately 16,800,000 gpd of industrial waste are discharged to the ground in the 200 Areas via ponds and cribs. (The discharge points are described in Appendix II.1-C.) These discharges, primarily cooling waters containing minor amounts of chemical and radioactive pollutants, are controlled between a pH of 7.0 and 8.0.

300 Areas

Industrial waste includes cooling water, process water and other non-sanitary waste. Discharge of uranium and small quantities of radioactive waste which contains less than $5 \times 10^{-5} \mu\text{Ci}/\text{cm}^3$ is permitted. The average concentration is about $1 \times 10^{-7} \mu\text{Ci}/\text{cm}^3$. Each facility in the area with significant quantities of process and cooling water is connected to the separate process sewer system which discharges directly into one of two retention ponds (Figure II.1-70). These ponds, covering approximately six acres each, are used alternately, the North Pond being currently used. The North Pond comprises three smaller divided bays and one large bay. Water enters the ground through percolation at the bottom of the pond. The first bay (nearest the influent) of the pond contains an oil stop to permit the recovery of spilled oil. A representative weekly sample of pond water is obtained at the pond inlet. Volume to the ponds averages about 3,000,000 gpd. The average concentrations of chemicals released to the ponds in 1972 are summarized in Table II.1-13. A new trench with a bottom area of $15,000 \text{ ft}^2$ is under construction and will replace the retention ponds by August, 1974.

Three locations in the 300 Area discharge directly to the river. These discharge points are covered by a permit application. (The discharge permits are shown in Appendix II.1-D.) These discharges include 27,000 gpd of filter backwash from the 300 Area water treatment plant and 1,150,000 gpd of 331 building fish pond effluent. The 309 building drain discharges air conditioning water.

FIGURE II.1-70 PROCESS SEWERS AND RETENTION PONDS

TABLE II.1-13

NONRADIOACTIVE CHEMICALS RELEASED

300 Area Process Pond - 1972

Volume Released 3×10^6 gpd cooling water pH 7.8

<u>Chemical</u>	<u>Average Concentration for 1972 ppm</u>
Chlorine	12.0
Copper	2.1
Iron	0.11
Fluorides	2.1
Nitrates	61.0
Sulphates	28.0
Chromium+6	0.011
Uranium	0.130

II.1.1.6.2.3 Oil and Chemical Waste

At Hanford, approximately 23,000 gallons of nonradioactive contaminated waste oil from machine and automotive operations are generated annually (Table II.1-14) and are used to stabilize dust on plant roads and parking areas. No other disposal is considered for this waste oil as dust stabilization is a necessary activity.

Approximately 450 gallons of waste oil contaminated with radioactive materials are generated annually. The oil is immobilized with absorbent material in areas and buried in approved burial grounds.

An additional 700 gallons of cutting oil, containing about 98% water and contaminated with uranium, are used in concreting uranium scrap for disposal or offsite shipment. Several installations (100-N, 100-B, 100-K, 100-F Areas and 300 Area) along the Columbia River use and store oil and other potentially hazardous pollutant chemicals. However, spill prevention and control measures are incorporated into

TABLE II.1-14

DISPOSAL OF USED OIL

<u>Contractor</u>	<u>Gal/yr Non-radioactive Contaminated Used Oil</u>	<u>Gal/yr Radioactive Contaminated Used Oil</u>	<u>Disposal Method</u>	<u>Disposal Cost Contaminated Dollars/yr</u>	<u>Disposal Cost Non- Contaminated Dollars/yr</u>
BNW	100		A		43.00
		250	B	200.00	
		150	C	500.00	
UNI	1160		A		240.00
		770	D	-0-	
HEDL	6600		A		1200.00
		50	B	37.50	
ARHCO	13000		A		520.00
JAJ	2200		A		32.00
TOTAL	23060	450/770	B/D	737.50	2035.00

-
- A. Use to stabilize dust on plant roads and parking areas.
 - B. Put in barrels with absorbent and buried.
 - C. Put in double containers with absorbent and buried.
 - D. Used in solidification agent and shipped offsite

the design and operation of the storage and handling facilities so that existing controls would either prevent or limit the flow of these materials to the river, thus presenting no hazard to the public or the environment.

Routine evaluation of water quality upstream of N Reactor shows that the river burden, in tons per day, includes:

<u>Chemical Measured</u>	<u>Daily River Burden (ton/day)</u>
SO ₄	4,300
NO ₃	130
Cl	180
Na	<u>400</u>
TOTAL	5,010

Procedures have been defined to minimize the quantity of any accidental spills of chemicals or fuel oils. These include the following:

- Control of filling, discharge, inspection, and maintenance of storage vessels is to be accomplished by trained operators and vendors who follow precautionary operating procedures.
- Complete records are to be maintained on all orders, receipts, and use of chemicals. Quantities, concentrations, laboratory analyses, delivery dates, costs, etc., are to be kept on all chemicals received.
- Measurements are to be taken before and after vessel loading, with physical inspection of the vessels also to be made at that time. Once each year, a complete physical inspection of chemical and oil storage vessels is to be made. Valves are to be inspected on a routine preventive maintenance schedule.

- Equipment Maintenance Standards require an internal inspection of diesel fuel storage tanks and day tanks every three years. Since these tanks, if ruptured, pose the largest single potential threat to navigable water, this requirement is deemed to be preventive. In addition, the dikes for diesel fuel and the open trench at 100-N, between the river and the tanks (to collect such a loss), are to be maintained as preventive systems.
- Once each year, audits are to be made by a project Environmental Engineer to insure that inventory control requirements were met. These audits are to include review of records and physical systems as described above.

Systems for preventing accidental spills into the Columbia River from operations at Hanford are built into the design, operation, and maintenance of the facilities. Although confident that a spill of oil and other potentially hazardous pollutant chemicals will not reach the river in amounts that represent a hazard to the public or the environment, the AEC has maintained extensive procedures for many years for coping with any emergencies that might arise at the site, including such things as liquid spills. The procedures detail the actions to be taken and the requirements for internal and external notification. In the case of accidental spills to the river, the procedures require notification to downstream water users and, as appropriate, Federal and State pollution control agencies, the Coast Guard, and the Corps of Engineers.

The numerous potentially hazardous chemical substances, listed in Appendix II.1-F, are of the 200 Area waste streams. Several of these are discharged to the atmosphere as gases, including liquid nitrogen, carbon dioxide and ammonia. In addition, a portion of the nitric acid is discharged to the atmosphere as oxides of nitrogen. Fumes, mists and vapors from chemical makeup tank vents probably contain traces of most of the process chemicals listed.

The aqueous chemical sewer streams contain varying amounts of all the process chemicals. Since many of these materials can be expected to interact in a dilute aqueous solution, prediction of all of the potential products is a formidable task. Oxidizing agents such as potassium permanganate or sodium nitrite will react with materials such as ferrous sulfamate or hydrazine to form more stable compounds. Acids and bases will react to form salts. The vast bulk of these chemicals are retained in the process waste streams, so that the reaction products enter the underground waste tanks.

Water quality measurements of the unconfined and confined aquifers are obtained routinely by utilizing test wells on the Hanford Reservation. Semiannual maps of the nitrate ion concentration near the surface of the unconfined aquifer are published. (The map for the last 6 months of 1972 appears in Figure II.1-68.) Since the nitrate ion is not absorbed on the soil, it shows the extent of wastewater movement, thus indicating where radionuclides contained in the wastewater should be found. In Figure II.1-68, the major plume is from the 200 Areas disposal operations. However, plumes are also beneath the 300 Area and emanating from the 100-N Area. The plume at the 100-F Area is presumably from continued disposal of BNW Animal Lab waste. The isolated plume south of 100-N and east of 100-K Area is probably due to previous reactor operations. A residual nitrate background of up to 6 mg/liter in the groundwater north of Gable Mountain and Gable Butte is due to pre-Hanford operations agricultural activities. Similarly, occasionally detectable nitrate ion is in the groundwater between the Yakima River and the Columbia River.

II.1.1.6.3 Nonradioactive Solid Waste Disposal

II.1.1.6.3.1 Toxic Waste

Toxic nonradioactive waste includes harmful chemicals such as beryllium, asbestos, mercury, carcinogens, cyanides, dichromates, cobalt, selenium, cadmium and arsenic.

Beryllium waste is disposed of in the same manner as transuranic waste. Combustible toxic waste is disposed of by high-temperature incineration in small combustion chambers which are followed by dual scrubbers. Non-burnable solid or liquid toxic materials are packaged and buried in the 200 Areas in controlled areas.

II.1.1.6.3.2 Pyrophoric Waste

This waste category includes the alkali metals, phosphorus, hydrides, uranium fines and zirconium. Alkali metals are stored under inert gas, and disposed of by burning at the 3718-F building in the 300 Area. Each of the others is separately stored in oil or liquids prior to conversion to nonpyrophoric oxides.

II.1.1.6.3.3 Salvageable Scrap

Salvageable scrap including lumber, metal turnings, and similar materials, plumbing parts and fixtures, electrical wiring, conduits and fixtures, and certain other building fixtures and materials are surveyed for radioactive contamination and if clean are collected in appropriate containers throughout the plant. Periodically these containers are transported to Central Stores excess yards where the salvaged materials are processed for public sale.

II.1.1.6.3.4 Trash

Solid waste generated in offices, lunchrooms and laboratories throughout the plant includes paper products and food scraps, but excludes material contaminated with radioactive nuclides or noxious chemicals. The combustible dry waste is placed in portable containers conveniently located at buildings housing personnel. This waste is determined to be approximately

90% paper products and is 97% combustible. The waste volume is reduced by a factor of three by compaction, and the reduced volume of waste is buried in a centralized sanitary landfill facility operated by ARHCO. The total compacted volume for the waste is forecast to be 360,000 ft³/yr.

II.1.1.6.4 Sanitary Sewage and Industrial Waste (Future Plans)

The sanitary sewage disposal quantities are anticipated to remain relatively constant over the next five years.

II.1.1.6.4.1 200 Area

The new 242-S evaporator will add approximately one billion gallons of water per year to the ground in 200-W Area for a period of approximately three years. A proposed evaporator would discharge a like amount of cooling water for the same period to the ground in the 200-E Area.

II.1.1.6.4.2 300 Area

Chemicals from the 300 Area reactor fuel fabrication processes will be collected in a stainless steel tank, neutralized and transported to 100-H Area where they will be deposited in a large concrete basin. After the water evaporates, the sludge will be retained for possible future recovery of metals. This operation is planned to begin in June 1974. As a consequence of this action, the concentration of the following ions in the 300 Area process waste ponds is expected to be reduced by about 80%: chromium +6, copper, fluoride, nitrate, and uranium. Since the uranium is the principal radionuclide in the ponds, the radioactivity is expected to be reduced by a similar amount.

Changes in laboratory operations are anticipated as work on the Liquid Metal Fast Breeder Reactor (LMFBR) program progresses. Among those changes is installation of an alkali metal cleaning facility, which will affect waste water discharged to the 300 Area process pond slightly. An increase in volume of 215,000 gal/mo (0.2% of current flow) and very slight increases in sodium ion and sulfate ion concentrations are anticipated.

II.1.1.6.4.3 400 Area

Present plans include construction of a Radiation and Repair Engineering Facility (RAREF) in the Fast Flux Test Facility. It is estimated that the RAREF will discharge up to 40,000 gallons of water once every three weeks to the 400 Area Leaching pond. The RAREF effluent will be monitored to ensure that it is free of radioactivity but will contain 10 mg/l sodium ion from nonradioactive cleaning operations.

II.1.2 Environmental Measurements and Monitoring Programs

II.1.2.1 Operational Programs - Radiological

The Hanford Environmental Surveillance Program is a multifaceted operation, performing several different tasks both onsite and offsite. The primary task is the computation of dose to local population groups from all exposure pathways that may show the presence of radioactivity from Hanford operations, in order to determine compliance with AEC Manual Chapter 0524¹⁷ radiation dose standards. Measurement is made of the radioisotopic concentrations in local air, water and foodstuffs, along with direct radiation measurements. Onsite and offsite monitoring also provide estimates of radiological impacts on the biosphere, in addition to providing indications of unusual results or trends which might indicate loss of control of radioactive waste disposal operations. A major groundwater monitoring program also provides continuing information on movement of contaminants in the groundwater beneath the project. Waste disposal sites, both active and retired, are audited for any changes of conditions.

The data collected is available in routine reports issued by the Environmental Evaluation staff. Groundwater data and evaluations are reported in the series, "Radiological Status of the Groundwater Beneath Hanford Project for...", the latest issue being BNWL-1752¹⁸ for July-December, 1972. Data from locations within the plant boundaries are presented in the annual "Environmental Status of the Hanford Reservation for..." report series, the most recent report being BNWL-B-278¹⁹ for 1972. Data from off-plant locations are presented in the annual "Environmental Surveillance at Hanford for..." series of reports, the latest being BNWL-1727^{20, 21} for CY-1972.

A summary of the Hanford Environmental Surveillance program is given here; the complete Surveillance schedule for CY-1973 can be found in BNWL-B-234,²² with frequency and required analyses of all the samples taken. The bulk of the radioactive analyses are performed by the

United States Testing Company, with the remainder being done by BNW. Table II.1-15 is a summary listing of the program.

There are 45 air samplers both onsite and offsite that provide samples of airborne particulates routinely analyzed for gross beta; samples from 19 of these locations are also counted for total alpha. These air samplers are composited in 13 different groups (by geographical sector) for a gamma scan on a monthly basis. In addition, 38 of these sampler locations are monitored for airborne ^{131}I using charcoal cartridges. One tritium monitoring location is in current operation, with an increase in number of locations expected as site operations warrant.

External penetrating radiation is measured at 64 locations, both onsite and offsite, using thermoluminescent dosimeters. The dosimeters are changed bi-weekly or monthly depending upon their location. External radiation is also measured with portable instruments at selected points on the shoreline of the Columbia River on a weekly or monthly basis. Exposure from penetrating radiation from immersion is measured in the Columbia River upstream and downstream of plant facilities with the thermoluminescent dosimeters. A sensitive dose-rate monitor continuously measures the radiation level at the river water surface, and includes an automatic alarm and safety features.

Soil and vegetation samples are taken at 23 locations on an annual basis. River sediment samples are taken at two locations, also annually. The soil and vegetation are analyzed for uranium, ^{90}Sr , ^{239}Pu and are given a gamma scan for specific radionuclide identification. The sediment samples are sectioned and each layer given a gamma scan.

Surface water samples are taken from the Columbia River at several points, as well as from the wastewater ponds and ditches on the Hanford site. The Columbia River measurements are made on four integrated and two grab samples weekly. Drinking water samples are taken at Richland, plus two onsite locations. The river water integrated samples are analyzed for ^3H , total beta, total alpha, ^{131}I , ^{239}Pu , and for specific

TABLE II.1-15

ROUTINE ENVIRONMENTAL SURVEILLANCE SCHEDULE CY-1973

Type of Sample	Type of Analysis	Cont	WATER									
			Frequency ^(a)									
			D	SW	W	SM	M	BM	Q	SA	A	
Columbia River Water	Radioactivity	1			1		4		1			
	Chemical		1		3		8					
	Biological						4					
Sanitary Water	Radioactivity				3							
	Chemical				2(b)							
Waste Water	Radioactivity				1		10					
	Biological						1					
Groundwater Wells	Radioactivity						2	3	134	103		
	Chemical						2	45	138	84		
AIR												
Filters	Radioactivity				11	26						
Scrubbers	Radioactivity				2	1						
Charcoal Cartridge	Radioactivity				3	7						
OTHER												
Radiation Level	Dose Rate		1	3		18	46					
Shoreline Survey	Dose Rate				1	1	25					
Ground Control Plot	Radioactivity		1			16	26	6	13	3		
Road Survey	Radioactivity						11		4			
Aerial Survey	Radioactivity									5		
Railroad Survey	Radioactivity										1	
Milk	Radioactivity					7	1					
Fish Columbia River	Radioactivity				1							
Wild Fowl	Radioactivity								10	100		
Mammals	Radioactivity						1		3	7		
Soil	Radioactivity										35	
Vegetation	Radioactivity										23	
Foodstuffs:												
Meat	Radioactivity						1			1		
Eggs	Radioactivity						1			1		
Chicken	Radioactivity								1	1		
Produce	Radioactivity										14	
Oysters	Radioactivity						1					

(a) Samples were taken continuously, daily, semi-weekly, weekly, semi-monthly monthly, bi-monthly, quarterly, semi-annually or annually.

(b) Samples routinely analyzed and reported by the Hanford Environmental Health Foundation.

nuclides by gamma scan. The river water grab samples are analyzed for ^3H and total beta. The sanitary water integrated samples are given total alpha, total beta and gamma measurements.

The groundwater is routinely measured²² at 141 wells for tritium and gross beta. Other specific radioanalyses are made at several locations. Sampling frequency varies from bi-monthly to semi-annually depending on the location of the well. In general, only the shallower, unconfined aquifer is sampled, but the deeper, confined aquifers are sampled at a few wells.

Selected fauna are sampled onsite, with a frequency depending on the type collected and location. Whitefish are collected from the Columbia River and samples composited bi-weekly, with measurements by gamma scan and specific analysis for ^{32}P and ^{90}Sr . Deer, three collected during each hunting season, are analyzed for ^{90}Sr , ^{239}Pu and gamma emitters. Rabbits, muskrats and mice as available are collected at the liquid waste disposal sites and are analyzed for ^{90}Sr , ^{239}Pu , natural uranium, and gamma emitters. Ducks, geese, and pheasant are collected along the Columbia River during hunting seasons; flesh samples are analyzed for ^{90}Sr and gamma emitters. At wastewater ponds, ducks are collected during the year; the particular analyses depend on the location where the samples were collected, but always include ^{90}Sr and a gamma scan.

Foodstuffs are collected from local farms and commercial establishments. Leafy green vegetables are collected during the growing season and are given a gamma scan plus a ^{90}Sr analysis. Eggs, chickens, and beef are collected when available and given the same analyses as leafy green vegetables. Oysters from a commercial source at Willapa Bay, Washington, are analyzed for ^{65}Zn on a monthly basis.

Milk samples are taken at two grocery stores and at 10 local farm sources. The two commercial sources get milk from different milksheds, one in eastern, the other in western Washington. These samples are collected bi-weekly at the farms and monthly from the commercial sources. The milk

is analyzed for ^{131}I , ^{90}Sr , and given a gamma scan. Cattle forage, hay, or pasture grass is collected with each milk sample but is only analyzed when other positive results suggest it.

Potential surface contamination from Hanford operations is monitored by four different methods. Sixty-two special ground plots are surveyed with a portable beta-gamma monitoring instrument (GM counter) for changes in background measurements. All of the major Hanford roadways are monitored monthly for particulate contamination with a truck-mounted gamma detector. Using the same detector, the railroad right-of-way is monitored on an annual basis. A bi-annual aerial survey, using sensitive scintillation gamma monitoring instrumentation, is made on controlled flight patterns around the site.

In addition to the routine surveillance program, additional sampling and monitoring capabilities are provided to the Hanford site in cases of unusual operating conditions or releases. As a minimum, the response includes an intensified sampling schedule plus additional samples for detailed analysis.

A special aerial survey was made to determine whether aerial gamma surveys could adequately measure the activity of high specific activity gamma emitters contaminating large surface areas. The survey successfully measured the ^{137}Cs activity and the total gross gamma activity over areas from less than one square kilometer to 20 square kilometers. Also ^{241}Am was successfully measured over areas wherein the ^{137}Cs was sufficiently low. Microcuries per square meter were measured as low as 0.1 for ^{137}Cs and ^{241}Am . Other radionuclides such as ^{60}Co were also detected. An aerial neutron survey was tried, though its efficiency limited detection to areas having more than ten kilograms plutonium per 4,000 square meters.

As privately owned nuclear facilities increase operations at Hanford, the routine program will be modified further to provide additional information required to differentiate the effluents from the AEC contractors and the private facilities. Typically these modifications to the program would be increased air sampling between the different facilities, external gamma dosimetry, and surface or groundwater sampling, if these media are involved.

The states of Oregon and Washington have for some years maintained statewide radiological surveillance programs, including some measurements pertinent to Hanford operations. Included are sampling of Columbia River water, shellfish, milk from milksheds in adjacent counties, groundwater near the WNP-2 reactor site, and more recently, ambient radiation measurements in the city of Richland. Published reports of the results of these activities in general confirm results reported from the Hanford surveillance program.

II.1.2.2 Operational Programs - Ecological

Prior to the government acquisition of the land area known as the Hanford Reservation 30 years ago, essentially no data was available concerning the ecology of the area. St. John and Jones in 1928 published an annotated list of the vascular plants of Benton County and provided a general description of major vegetation types in relation to soil and topography.

Studies of local aquatic populations and potential radiation effects began at Hanford under the sponsorship of the Manhattan Engineering District before the first reactor was in operation. A broad spectrum of ecological studies, both aquatic and terrestrial, continued on a greatly expanded basis under the AEC. With some exceptions, these studies were of limited duration and were pursued more for general scientific knowledge than for strict application to the Hanford site. In the course of this work, however, a mass of ecologically-related data accumulated that not only provides baseline information but also is used to guide the biological sampling portion of the radiological program.

Continuing ecologically-oriented monitoring programs are at present concerned with the censuses of waterfowl onsite and of salmon spawning beds in the Columbia River within and adjacent to the site boundaries. These programs are expected to continue indefinitely. Examples of current studies of more limited duration are included on the following pages.

II.1.2.2.1 Aquatic Ecology

II.1.2.2.1.1 Columbia River Studies

Anadromous Fish

Since 1947, the Columbia River from Richland to the vicinity of Priest Rapids has been surveyed from the air to estimate the size of the salmon spawning population in this area.^{23,24} A number of factors influence the population changes observed since 1947. In general, the number of spawning chinooks in this reach of the river increased until 1969 after which they fell off slightly in 1970 and 1971, quite markedly in 1972 and increased again in 1973. These studies were instigated to determine if the Hanford Project Operations adversely affected this population. The greatest increase occurred during the time the most reactors were in operation, but there is no evidence that this increase was the result of Hanford activities.

Radionuclide Decline

When the last plutonium production reactor was shut down in January 1971 (except for the dual purpose N Reactor), a study was initiated to investigate the decline and retention of Hanford produced radionuclides in the Columbia River ecosystem. Radionuclide concentrations in most segments of the ecosystem declined quite rapidly compared to previous years where the single pass reactors were in operation. Continuing studies reveal the virtual disappearance of ⁴⁶Sc, ⁵⁴Mn, and ¹³⁷Cs in the biota and the presence of extremely low levels of ⁶⁰Co and ⁶⁵Zn.^{25,26} Studies are in progress to describe the cycling of these elements in the food-web. Laboratory studies are being conducted to examine the uptake and retention of radionuclides by periphyton from the water, and the transfer of radionuclides from the sediments into the water and periphyton.^{27,28}

II.1.2.2.1.2 Radioactive Waste Pond Studies

Gable Mountain Pond

Ecological studies in Gable Mountain Pond were initiated in 1972 to define the potential for offsite movement of radioactivity via the aquatic food-web. The body burdens of radionuclides in controlled populations of goldfish and waterfowl are being measured to obtain the levels and rates of radionuclide accumulation. The spatial distribution of radioactive materials in the pond sediments is also under investigation. Over 85% of the gamma radioactivity is in the upper 2 inches of sediments with ^{137}Cs accounting for over 90% of this activity.

U Pond

The distribution of ^{239}Pu and ^{241}Am is being studied in the aquatic biota in U Pond, which has received processing waste for more than 30 years. Initial efforts are being made to measure the levels of these transuranics in the sediments, water and in the benthic, plankton, and nektonic communities. To establish the baseline ecology of this pond, a number of limnological parameters are being measured including temperature, pH, dissolved oxygen, alkalinity, insolation, water transparency, and primary productivity. Sampling is based on a statistical blocking design which will allow for analyses of variance, regression, and correlation of the radioecological and limnological data.

II.1.2.2.2 Terrestrial Ecology

Ecological measurement and monitoring programs are expected to continue on the Hanford Reservation. The ALE Reserve provides a place for long term studies of the dynamics of secondary plant succession and related changes in animal populations. Studies aimed at estimating primary productivity in climax and seral plant communities will also measure environmental variables such as precipitation, soil moisture, air and soil temperatures and the details of mineral uptake by plants and transfer to animals. The ALE Reserve will continue to play an important role in evaluating the long term response of plants and animals to induced environmental stresses such as cattle grazing, added increments of moisture, selective herbicides, fires, and ionizing radiation to selected components of the shrub steppe ecosystem.

Terrestrial ecology studies at Hanford relevant to management and storage of radioactive waste include the following list, several of which are discussed below.

- floristic and faunistic lists of important biota
- identification of rare and endangered species
- mapping of major plant communities
- seasonal migration patterns of waterfowl use of the Columbia River and ponds
- successional trends in plant communities' response to fire and plowing and other kinds of soil disturbance
- tagging mule deer fawns to determine the dispersal patterns from the Hanford Reservation
- population dynamics of Columbia River Canada Goose populations
- primary productivity and mineral uptake by plants from soil in climax and seral plant communities
- population dynamics of rodent populations

- the abundance and role of microorganisms and invertebrate fauna in the steppe ecosystem
- food webs of the steppe ecosystem
- uptake of radionuclides by plants from soils in field conditions.

II.1.2.2.2.1 Isotope Behavior in Experimental Field Plots

Small field plots treated with ^{137}Cs and ^{90}Sr 18 years ago were observed for movement of isotopes downward into the soil profile and for determining the uptake of isotopes from soil by crop plants and associated weeds.

Over the years, ^{90}Sr moved downward to depths of 10 inches while ^{137}Cs is mostly confined to the surface inch or two. After 18 years, the isotopes are still available to plants. These studies are continuing to ascertain the long-term effect of aging and weathering on isotope uptake by plants and the rate of movement in the soil profile.

II.1.2.2.2.2 Ionizing Radiation, LD_{50/30}, Doses to Small Mammals

The LD_{50/30} doses of acute ionizing radiation were determined for the small mammals (mice and voles) characteristic of the Hanford Reservation; values range between 500 and 900 rads. The great basin pocket mouse is the most radioresistant while the grasshopper mouse is the most radiosensitive.

II.1.2.2.2.3 World Wide Fallout on the Hanford Reservation and Surrounding Area

Radionuclides derived from nuclear weapons tests are present in small quantities and ubiquitously spread over the land water surfaces of the earth. The accumulation of fallout ^{137}Cs in the steppe plant communities of the Hanford Reservation is about five times less than forest communities in the nearby Cascade Mountains. Studies of fallout have

value in assessing environmental radioactivity associated with waste management practices as compared to adjacent areas without nuclear facilities.

II.1.2.2.2.4 Population Dynamics of the Canada Goose

The nesting success of the Canada Goose is documented for a quarter of a century. Over the years the number of nesting pairs of geese fluctuated, but the hatchability of eggs is as high or higher than areas without nuclear facilities. Studies of the Canada Goose are continuing and will provide a valuable base for ecological monitoring involving power reactors presently being constructed on the Hanford Reservation.

II.1.2.2.2.5 Use of Waste Ponds by Ducks and Geese

Waste ponds on the Hanford Reservation are attractive to migratory flocks of ducks and geese. A surveillance of transient populations indicates that mixtures of species including puddle and diving ducks and fish-eating ducks regularly use the ponds during autumn months. As many as 1100 ducks and geese rest on the ponds on a particular day. The role of ducks and geese in transferring radionuclides from waste ponds offsite is a part of the aquatic studies program.

II.1.2.2.2.6 Laboratory Studies that Support Field Surveillance

The uptake of plutonium, americium, curium and neptunium by plants from soil, especially plants that are common in waste management zones, are studied in the laboratory. The uptake of these radionuclides in decreasing order is $Np > Am > Cm > Pu$; however, this order can be changed by changing the chemical form of the isotopes. Generally, tumbleweed accumulates more radionuclides than cheatgrass.

II.1.2.2.3 Hydrology

II.1.2.2.3.1 Columbia River

Surface water samples are taken from the Columbia River at Vernita, 100-F Area, 300 Area, North Richland and Richland, as well as from the wastewater ponds and ditches on the Hanford site.²² The Columbia River measurements are made on four integrated and two grab samples weekly. Drinking water samples are taken at Richland, plus two onsite locations. The river water integrated samples are analyzed for ^3H , gross beta, gross alpha, ^{131}I , ^{239}Pu , and for specific nuclides by gamma scan. The river water grab samples are analyzed for ^3H and gross beta. The sanitary water integrated samples are given gross alpha, gross beta and gamma measurements.

Water quality measurements on the Columbia River water samples include pH, dissolved oxygen, turbidity, coliform, enterococci, BOD, and nitrate ion.

River flow rates are obtained from continuous USGS river stage measurements at a gauge station immediately downstream from Priest Rapids Dam. The river elevations are available immediately onsite via telemetering. Continuous temperature monitoring is also done at the Priest Rapids gauge station and by telemeter at Richland. State Water Quality Standards²⁹ are applicable to the Hanford reach of the Columbia River (Appendix II. 1-G, Part 2).

Surface water monitoring data and discussion are presented in the annual "Environmental Status of the Hanford Reservation for CY-1972"¹⁹ and the annual "Environmental Surveillance at Hanford for CY-1972" report series.^{20, 21}

II.1.2.2.3.2 Groundwater

The periodic hydrological measurements on the groundwater system of the unconfined and confined aquifers consist of water quality analyses, water level measurements and water temperature profile logging. Water

quality analyses are made on semiannual samples from six wells on the Reservation. Water level measurements are made quarterly at about 330 wells on the Reservation covering both the unconfined and uppermost confined aquifer. Water table maps for the unconfined aquifer are prepared from these measurements. Temperature logs of the wells are made at intervals that average 5 years apart. Figure II.3-19 shows the latest groundwater temperature distribution measured.

The groundwater is routinely measured²² at 141 wells for tritium and gross beta. Other specific radioanalyses are made at several locations. Sampling frequency varies from bimonthly to semiannually depending on the location of the well. In general, only the shallower, unconfined aquifer is sampled, but the deeper, confined aquifers are sampled at a few wells.

Groundwater data summaries, contamination maps, and evaluations are reported in the series, "Radiological Status of the Groundwater Beneath Hanford Project for....," the latest issue being BNWL-1752¹⁸ for July-December, 1972.

II.1.2.2.4 Meteorology

The principal onsite meteorological monitoring program is operated at the Hanford Meteorology Station (HMS). This station is centrally situated on a plateau of the AEC Hanford complex at an elevation of 733 ft MSL (Figure II.1-71). Other onsite meteorological monitoring programs were conducted for limited periods.

II.1.2.2.4.1 Hanford Meteorology Station

Records have been kept at the HMS from 1944 to the present.³⁰ The data include standard surface observations as specified in Federal Meteorological Handbook No. 1³¹ as well as other measurements specifically taken to describe the atmospheric diffusion climatology of the Hanford site.

This monitoring program includes eight levels of wind measurements and ten levels of air temperature measurement from a 410-ft steel tower. Surface observations of temperature and humidity are taken about 75 feet northwest of the tower. About 1500 feet west of the tower is a pyranometer, a precipitation gauge, and an instrument shelter with maximum and minimum thermometers. Table II.1-16 shows current (1973) sensor height information for the HMS.

TABLE II.1-16
INSTRUMENT HEIGHT LOCATIONS

<u>Instruments</u>	<u>Surface (ft)</u>		<u>Tower Levels (ft)</u>								
	<u>3</u>	<u>7</u>	<u>20</u>	<u>50</u>	<u>100</u>	<u>150</u>	<u>200</u>	<u>250</u>	<u>300</u>	<u>350</u>	<u>400</u>
Humidity	X										
Wind Speed and Direction		X		X	X	X	X	X	X		X
Air Temperature	X		X	X	X	X	X	X	X	X	X

FIGURE II.1-71 HANFORD METEOROLOGICAL SENSOR FACILITIES

At the HMS site upper level wind measurements were made by the standard pilot balloon-theodolite method (Pibal) for over 25 years. Some of these observations are summarized for climatological use. Pilot balloon data are presently taken twice a day at 1200 and 2400 PST.

With the exception of precipitation, all instrumentally measured parameters are recorded on charts at the HMS. These data are transferred to computer punch cards as hourly averages, where appropriate, and transferred and stored on magnetic tape from which data summaries are tabulated as required.

II.1.2.2.4.2 Arid Lands Ecology (ALE) Reserve Meteorological Station

The AEC's ALE Reserve comprises approximately 120 square miles located along the north and northeastern slopes of Rattlesnake Mountain. Since March 1968 to the present, and on a continuing and expanding basis, BNW has been recording various climatological data on ALE with the types of instruments currently in use listed³² as:

Soil temperature:

- Weathermeasure two-point thermometers, mercury in plastic sensors
- Kahlsico two-point thermometers, mercury filled bulb sensor

Air temperature and relative humidity:

- Bendix-Friez standard hygrothermographs
- Weathermeasure standard hygrothermographs

Precipitation:

- Taylor visual gauge, 5-in. capacity
- Weathermeasure propane-heated tipping bucket recorders

II.1.2.2.4.3 Hanford Radio-Telemetered Automatic Weather Station Network

A ten-station^(a) network of radio-telemetered automatic weather stations is installed and continuously operated on the Hanford Reservation, with approximately 10 mile spacing between stations. Meteorological parameters measured are wind speed and direction, and temperature. The central station programmer and data acquisition equipment are housed at the HMS. This network is operated primarily as a real time information base for accident assessment capabilities, although data from the network were used in several studies (Figure II.1-71).

(a) The actual number of stations in operation has varied during the history of the operation.

II.1.2.2.4.4 N Reactor Meteorological Tower System

A second fully instrumented micrometeorology tower system is operated by UNI. This tower is located about eight miles north of the HMS and is about 300 feet lower in base elevation. The data system³³ consists of a central station near the control room of the N Reactor and a remote station near the river bank approximately 450 feet northeast of the 100-N Area exclusion fence.

The remote station comprises a 300-ft (91 m) tower, sensors, digitizing electronics, and a microwave transmitter. Four boom levels are on the tower: near the surface and nominally at 50 (15 m), 200 (61 m), and 300 feet (91 m). Each boom supports a horizontal wind-speed sensor, a horizontal vane slightly above the boom, and an aspirated platinum resistance temperature detector slightly below. All sensors have essentially a 5-second time constant. The placement of all sensors is shown in Table II.1-17.

TABLE II.1-17

SENSOR HEIGHTS WITH RESPECT TO BASE

<u>Nominal Level</u>	<u>Wind, Speed & Azimuth</u>	<u>Temperature</u>
Surface	8.0 ft (2.4 m)	5 ft (1.5 m) ^(a)
50 ft	51.5 ft (15.7 m)	48.5 ft (14.8 m)
200 ft	201.5 ft (61.4 m)	198.5 ft (60.5 m)
300 ft	301.0 ft (91.7 m)	298.0 ft (90.8 m)

(a) Actually approximately 4 feet above ground surface directly below sensor.

The central station consists of a microwave receiver, demodulating and timing electronics, data formatting circuits, real-time data displays, and an incremental digital tape recorder. The real-time data displays include analog meters, strip printer and a nixie data display. A digital clock monitors the timing accuracy of the system.

II.1.2.2.4.5 Washington Public Power Supply System Nuclear Plant No. 2

The WPPSS Nuclear Plant No. 2 (WNP-2) site is located about 15 miles ESE of the HMS. Since March 1972 to the present, and on a continuing basis, WPPSS has been recording meteorological data including wind direction, wind speed, temperature, and relative humidity. The WNP-2 site is equipped with a three-cup anemometer and vane. The site also has primary and redundant instrumentation for measuring dry bulb temperature and relative humidity.

WPPSS is erecting a 240-ft (70 m) meteorology tower from which humidity, and wind data will be recorded on a permanent basis. The meteorological Data Recording System will consist of an array of tower mounted sensing instruments, a group of continuously operating strip chart recorders, a magnetic tape recorder and supporting power supplies and controls. The variables and their location to be measured are:

- Wind speed at 240 ft aboveground (100 m)
- Wind direction at 240 ft
- Wind speed at 33 ft (10 m)
- Wind direction at 33 ft
- Wind speed at 7 ft (2 m)
- Wind direction at 7 ft
- Air temperature difference between 33 and 240 ft
- Air temperature difference, 7 - 33 ft
- Air temperature difference, 7 - 240 ft
- Ambient air temperature at 240 ft
- Ambient air temperature at 33 ft
- Ambient air temperature at 7 ft
- Dew point temperature at 7 ft
- Precipitation at ground level
- Wind direction sigma at 240 ft (tape only)
- Wind direction sigma at 33 ft (tape only)
- Wind direction sigma at 7 ft (tape only)

II.1.2.2.4.6 Fast Flux Test Facility (FFTF)

An onsite wind speed and direction measurement system is operated at the FFTF located about 17 miles southeast of the HMS at an elevation of approximately 550 feet MSL. This consists of a Weather Measure Sensor system #W1034 mounted on a 13-ft mast.

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II.2 ANTICIPATED BENEFITS

The Hanford Plant was designed, built, and originally operated to produce plutonium for nuclear weapons. The waste management programs initially established were the first in the world to cope with massive quantities of radioactive materials. They were established under conditions of expediency during time of war. Since that time, a continuing research and development program has provided new technology and new waste management equipment and materials. Throughout all programs, the prime concern has been the isolation of radioactive materials from man's environment. Today large quantities of radioactive waste exist which cannot prudently be abandoned. Therefore, waste management in some form is required. Waste to be generated by the projected operation of N Reactor and Purex will not add substantially to the current total inventory. Discontinuing N Reactor and/or Purex plant operations would not alter the need for a continuing radioactive waste management program.

The anticipated primary benefit from the Hanford Waste Management Operations is to continue isolation from man's environment of the already generated and the yet to be generated radioactive materials. New technologies and new equipment are added to the Hanford Waste Management facilities, as practicable, to reduce even further the amounts of materials released to the environment. The waste management programs provide manpower and facilities to perform research and development not only for the long-term disposal of Hanford generated waste, but also for the nuclear power industry. Also, the operation of the Hanford waste management program makes possible production of plutonium for the U.S. defense needs, Research and Development, and provides steam to the Washington Public Power Supply System for the generation of 860 megawatts of electricity for the Northwest power pool. The waste management activities also support a variety of ecological and biological studies on the movement of radionuclides in the environment.

In addition to the benefits of providing improved technologies for future waste management programs, extensive technology in monitoring and evaluating the movement of radioactive materials in the environment was and is being developed at the Hanford site. Particularly, instrumentation to measure minute tracer quantities of materials in air, water, and soils were developed and are now in use. Modeling methods to "trace" movement of materials, and biological and life sciences research were developed and are being used to identify transfer mechanisms of radionuclides between various components in the environment. Specific attention is paid to such factors as bioconcentration, particle resuspension, absorption factors in the human body for various modes of radioactive material intake, and related data that permits complete evaluation of the radiological consequences of the Hanford Waste Management Operations. Benefits from all of this work during the past 30 years are available and are being used directly by the private power industry and by those interested in monitoring and evaluating environmental pollution and environmental control practices.

II.3 CHARACTERIZATION OF THE EXISTING ENVIRONMENT

II.3.1 Plant Location

The Hanford site covers approximately 570 square miles located in the Pasco Basin, a semiarid region of southeastern Washington State (Figure II.3-1) in the rain shadow of the Cascade Range. This section of the State has a sparse covering of natural vegetation primarily suited for grazing, although large areas near the site have gradually been put under irrigation during the past few years. Most irrigated farms near the Hanford Plant obtain water from the Yakima River or from the Columbia River.

The Hanford Reservation boundaries lie between 46° 18' and 46° 48' north latitude and 119° 17' and 119° 52' west longitude.¹ The project area is mostly within Benton County with portions of Franklin and Grant Counties also included. The Columbia River flows through the northern edge of the Hanford site and forms part of the eastern boundary. The western-most boundary is approximately 30 miles due east of Yakima, Washington, while the closest population center, Richland, Washington, is located about 3 miles from the most southern portion of the boundary.

II.3.2 Regional Demography

The 1970 estimate of the population distribution varies from 160,000 to 250,000 people within a 50-mile radius of three separate points within the Reservation boundaries. These points are:

- the Hanford Meteorological Station located between the 200 East and 200 West Fuel Reprocessing Areas
- the 100-N Reactor Area
- the 300 Laboratory and Fuel Fabrication Area.

FIGURE II.3-1 THE HANFORD SITE

Figure II.3-2 shows the 1970 U.S. Census Populations of nearby communities with the circle of a 50-mile radius from the Hanford Meteorological Station (HMS) superimposed. Additionally, estimates were made for 1973, 1977, 1981 and 2000,²⁻⁷ based upon 1970 census information, current birth rate trends, and an estimate of net migration into or out of the state as economic and employment opportunities change over the forecast period. The forecast does not reflect the population expansion which would result from the creation of a nuclear park or a more intensive utilization of nuclear energy for power generating and other purposes. It is assumed that the Hanford Reservation will remain under the control of the U.S. Atomic Energy Commission (AEC) and that no persons will reside within the Reservation boundaries. The population residing in the unincorporated area was calculated on the basis of population density in the portion of a specific census district which lies within the site area. This assumes an even distribution of population throughout the unincorporated areas of each census district. It was further assumed that the rate of population growth was the same for both incorporated and unincorporated areas.

For 1970, an estimated 246,000 people were living within a 50-mile radius of the HMS; 227,000 within 50 miles of the 100-N Area; and 162,000 within 50 miles of the 300 Area. The distribution of this population appears in Figures II.3-3, -4 and -5, and also in Appendix II.3-A.1 with the projected populations to the year 2000.

II.3.3 Land Use

Before the arrival of Europeans, the native Indian tribes lived largely on fish from the Columbia River and on natural plant products. The earliest use by white immigrants of the Hanford site was for stock-grazing, following a seasonal pattern. In the first decade of the twentieth century, several small, privately irrigated farms were put into cultivation. The Hanford Irrigation Project, taking water from the river above Coyote Rapids (upstream from 100-K Area), supplied a

FIGURE II.3-3 ESTIMATED GEOGRAPHIC DISTRIBUTION OF THE 1970 POPULATION WITHIN A 50-MILE RADIUS OF THE HANFORD METEOROLOGICAL STATION

FIGURE II.3-4 ESTIMATED GEOGRAPHIC DISTRIBUTION OF THE 1970 POPULATION WITHIN A 50-MILE RADIUS OF THE 100-N AREA

FIGURE II.3-5 ESTIMATED GEOGRAPHIC DISTRIBUTION OF THE 1970 POPULATION WITHIN A 50-MILE RADIUS OF THE 300 AREA

small but flourishing irrigated orchard and farm economy along the river as far downstream as the Hanford townsite until the government purchased the land to construct the Hanford Engineer Works.

The nature and extent of present land use is discussed here on the basis of arcs described from the HMS. Land areas included in a 50-mile radius from the other two plant areas are also covered.^{8,9} Figure II.3-1 is an aerial photograph in which the general pattern of agricultural usage is visible as the darker, regular-shaped areas.

Figure II.3-6 shows the Hanford site map with sector markings overlaid. Starting from a line directly north from the HMS, the 0 to 10-mile zone is entirely within the Hanford site boundaries. The area south of the Columbia River is under AEC control and is a limited access area. Land north of the river is controlled by the Bureau of Sport Fisheries and Wildlife as a game refuge. All of this zone between the 0 and 150-degree radials is limited access area under control of the AEC. Most of the zone between the 150 and 270 degree radials consists of the Arid Lands Ecology (ALE) Reserve, which is also limited access AEC land under the control of Battelle, Pacific Northwest Laboratories. Between the 270-degree radial and the starting radial, land south of the Columbia River is AEC-controlled limited access while north of the river the game refuge is again encountered.

Again starting from the 0 degree radial, the 10 to 20-mile zone is a continuation of the game refuge with some areas open for fishing, shot-gun and bow hunting during daylight hours. Further north, this zone includes the eastern-most portion of the Wahluke Slope and the Saddle Mountains. Between the Wahluke Branch Canal and the Columbia River, the zone consists of lands in the Columbia Basin Project which are irrigated or are being developed for irrigation. The area west of the river is limited access Hanford site. Leaving the site boundary, the land is mainly unirrigated land used for grazing cattle and sheep. South and west of the Columbia River, in the vicinity of Priest Rapids Dam, is the U.S. Army Yakima Firing Range. This is undeveloped, unpopulated land. Northwest of Priest Rapids Dam and Reservoir is the

FIGURE II.3-6 HANFORD SITE LAND USE

Wahluke Slope portion of the Columbia Basin Project. This area is partially irrigated with the rest (outside the Hanford Reservation) expected to be irrigated in the next 10 years.

The 20 to 30-mile zone on the 0 degree radial is north of the Saddle Mountains and is irrigated farmland, part of the Columbia Basin Project. (The estimated percent of acreage by crop in all irrigated areas within a 50-mile radius of 100-N Area is presented in Table II.3-1.) The area from lower Crab Creek to northwest of Othello is generally undeveloped. From Othello south to the Columbia River, the land is irrigated farmland. On the west side of the river is the City of Richland. West from Richland, the 20 to 30-mile zone includes the Yakima River and the towns of Prosser, Sunnyside, Grandview and Mabton. Land along the Yakima River is primarily in orchard use. Higher land away from the valley floor is used primarily for grazing livestock with some land used for grain crops. At approximately the 270-degree radial, the Yakima Firing Range is again encountered. At 320 degrees is the Ginkgo Petrified Forest, a national landmark.

At the 0-degree radial, the 30 to 40-mile zone consists of an undeveloped area of sagebrush and sand dunes. At 20 degrees, the Potholes Reservoir, a recreation area surrounded by sand dunes, is located south of Moses Lake. Between 30 and 150 degrees, this zone encompasses a major portion of the Columbia Basin Irrigation Project. At approximately the 150-degree radial, the Columbia River is encountered, with the City of Pasco on the north side and the City of Kennewick on the south side. South and west of Kennewick, the 30 to 40-mile zone runs south of the Horse Heaven Hills. Although this land is primarily used for dry-land wheat farming, there are about 88 sections (56,320 acres) where permits have been granted for private irrigation development. Crossing the Horse Heaven Hills, the zone includes part of the Yakima Valley containing the towns of Granger, Toppenish, Zillah and Wapato. This land is largely in orchards and other truck crops, with livestock grazing at the higher elevations. Northeast of Yakima is the Yakima Firing Range, east of which lies irrigated farmland of the Columbia Basin Project.

TABLE II.3-1

ESTIMATED PERCENT OF ACREAGE BY CROP IN THE
IRRIGATED AREA WITHIN 50 MILES OF THE 100-N AREA¹⁰
1962-1968

<u>Crop</u>	<u>Percent of Total Acres</u>
Alfalfa Hay	30.26
Wheat	15.36
Sugar Beets	7.92
Potatoes (Late)	5.84
Pea Seed	5.61
Dry Beans and Edible	5.58
Irrigated Pasture	5.37
Potatoes (Early)	3.07
Silage	2.41
Barley	2.40
Corn for Grain	2.11
Alfalfa Seed	1.81
Corn, Sweet (Processing)	1.63
Peppermint	1.17
Oats	0.85
Other Hay	0.76
Clover, Seed (All Kinds)	0.74
Peas, Green (Processing)	0.71
Beans, Lima (Processing)	0.40
Spearmint	0.27
Apples	0.24
Lentils	0.20
Onions, Dry	0.20
Mixed Grain	0.18
Radish Seed	0.13
Asparagus	0.11
Cantaloupes	0.10
Carrots	0.10
Cherries	0.10
Grapes	0.10
Merion Blue Grass Seed	0.10
Nursery Stock	0.10
Orchard Grass, Seed	0.10
Pears	0.10
Rutabagas	0.10
Rye	0.10
Sorghums	0.10
Soy Beans	0.10
Watermelons	0.10
All Others	3.37

At the 0-degree radial, the 40-mile radius to the 60-mile radius includes the towns of Ephrata and Soap Lake; also included is the southern end of Grand Coulee, a national landmark. The land is primarily rangeland with some irrigated farmland around Soap Lake. The town of Moses Lake is in this zone at approximately the 20-degree radial. Between the 20 and 90-degree radials is a large portion of land planned for irrigation development as a part of the Columbia Basin Project. At approximately 70 degrees between the 45 and 60-mile radius, the land is used for non-irrigated wheat production. Between the 90 and 120-degree radials and extending to the 75-mile radius, the land is used for nonirrigated wheat production. An exception is the area at the confluence of the Snake and Columbia Rivers where private irrigation projects are underway. The 40 to 60-mile zone also includes the Town of College Place and part of Walla Walla. Moving west and south, the land is irrigated along the Walla Walla River and produces alfalfa and sugar beets. Land on both sides of the Columbia River below McNary Dam hold private irrigation projects totaling approximately 345 sections (220,800 acres). Between the 200 and 260-degree radials, the land is very rugged and, for the most part, undeveloped. At the 260-degree radial, the Yakima Valley is entered with the City of Yakima at 270 degrees. Crossing the Umtanum Ridge and the Manastash Ridge, the Kittitas Valley is entered. This is an area of both irrigated and dry-land farming and cattle production. At 330 degrees, a portion of the Wenatchee National Forest is found.

II.3.4 Water Use

An estimated 200,000 acre-ft of water are taken annually from and near the Columbia River within 50 miles of the 100-N Area. This estimate is based on the best available source of data for wells and surface water pumpage. It is important to state, however, that these are "paper water rights" and are therefore estimated to be twice the actual pumpage, even though not all of the wells in actual use are listed. Water rights received after 1969 are not reflected, and not all of the people who

have been pumping ground and surface water have applied to the state for water rights. However, the data give an adequate upper limit to current water usage for 50 miles downstream of the 100-N Area. (Details of this data, taken from records of the Department of Ecology, State of Washington, Spokane, Washington, are available in Appendix II.3-A.)

In the next 65 miles of downstream flow, the Columbia River forms the border between Washington and Oregon. Private irrigation development is extensive on both sides of the river. Land which is now irrigated or expected to be irrigated in the next 5 to 10 years totals approximately 277,000 acres. Assuming that all of this land were put into a high water use crop such as alfalfa, an estimated 1,155,000 acre-ft or 372 billion gallons of water would be required during the normal irrigation period (April to October).^{11,12,13}

II.3.5 Historical and Archeological Sites and Natural Landmarks

No historical or archeological sites of national importance exist within the Reservation boundaries. The National Register of Historic Places¹⁴ lists only three historical sites within approximately 50 miles of the Hanford site. These are:

- Marmes Rockshelter, located 1 mile north of Lyons Ferry on the west side of the Palouse River, Franklin County
- Olmstead Place State Park, 4 miles east of Ellensburg, near the Kittitas Highway, Kittitas County
- Whitman Mission National Historic Site, 6 miles west of Walla Walla, off U.S. 410, Walla Walla County.

The National Registry of Natural Landmarks¹⁵ lists two sites which are within 50 miles of the Hanford site:

- Ginkgo Petrified Forest, located in Kittitas County 29 miles east of Ellensburg
- Grand Coulee, located in Grant County between the Towns of Grand Coulee and Soap Lake.

While further archeological sites are not of national significance, many less unique sites are in the area.^{16,17} The Columbia River shoreline, from Vantage in the north downstream to Umatilla, is rich with Indian artifacts. Many campsites and fishing grounds within the Reservation boundary were traditionally used as wintering areas from prehistoric times until the area was evacuated in 1943. Registered archeological sites within a 50 mile radius of the meteorological tower are identified in Figure II.3-7; the majority of these sites lie close to the Columbia and Snake Rivers. Some of these sites are described in Appendix II.3-A. Large portions of the land area at greater distances from the rivers have never been surveyed for archeological sites.

Other natural landmarks in the area, which are not of national significance, include the Saddle Mountains immediately to the north. This range of hills running east-west includes Sentinel Mountain (2,625 feet) and Wahatis Peak (2,969 feet). The Columbia River, which flows through the northern portion of the Hanford site and then along the eastern boundary, provides another natural landmark as do the White Bluffs rising 200 to 300 feet along the eastern shoreline. The southwestern edge of the Reservation is marked by the Rattlesnake Hills and Rattlesnake Mountain (approximately 3,400 feet). Gable Mountain and Gable Butte, within the Reservation, are a marked geological feature. A parallel series of northwest-southeast trending ridges, notably Yakima and Umtanum Ridges, extend from the Reservation boundary to the foothills of the Cascade Range. Several major dry coulees open into the Reservation on the eastern boundary and in part serve as natural drainage channels from irrigated lands.

II.3.6 Geology^(a)

Geology is the study of the origin and development, through natural processes, of the earth. When the geologic formations are adequately

(a) Appendix II.3-B provides a more detailed description of the geology of the Hanford Reservation.

FIGURE II.3-7 NUMBER AND LOCATION OF KNOWN ARCHEOLOGICAL SITES
WITHIN A 50-MILE RADIUS OF HANFORD METEOROLOGICAL
STATION

understood, the variations in their chemical and physical properties take on an identifiable pattern and become logically explainable. The permeability, transmissivity, and exchange capacity of the formations and their component units are the principal parameters affecting the disposal of radioactive liquid waste to the ground. Those parameters vary appreciably from formation to formation and within formations, but are predictable once the nature and extent of the formational units are understood. Consequently values for those parameters often can be estimated even where specific measurements have not been obtained or cannot readily be obtained. Conversely, when data ("samples" of the area) are obtained and values calculated, the geologic information often permits a determination of the validity of the value, and of how representative it may be of the formational unit.

Study of the geological history and development of an area often identifies operative but not obvious processes that may affect various activities. For example the past history of and projected reoccurrence of earthquakes, landslides, climatic changes, floods, volcanic eruptions and comparable natural catastrophes may become clear. Therefore, the geology of the Hanford Reservation is of interest in evaluating the overall safety and suitability of storage of radioactive waste on the Reservation.

Eastern Washington is dominated by the Columbia Basin geologic province, the northernmost extension of the Columbia River Basalt Plateau.¹⁸ The basin encompasses about 50,000 square miles of southeastern Washington and adjacent parts of Idaho and Oregon. It is underlain by the vast field of flood lavas of the Columbia River Basalt Group. Today those lavas and the ground surface generally dip radially inward toward the Pasco Basin, which is the near-central, physiographic low of the larger Columbia Basin.

The Pasco Basin evidently was formed by slow and prolonged subsidence concomitant with filling of the basin by basaltic lavas.¹⁹ Inauguration of uplift of the northern Cascade Range, possibly 15,000,000 years ago, probably combined with basining in south-central Washington to divert the ancestral Columbia River from a westward course to the ocean to a south-westerly course into and through the Pasco Basin.

Basaltic lavas were emitted largely peripheral to the basin. At least the latter ones advanced into the basin from a probably dominantly southeast source,²⁰ forcing the Columbia River westward. Continued downwarping resulted in a return of the river to the basin center. Developing volcanicity, accompanying the southward progression of uplift of the Cascades and the beginning of uplift of the anticlinal ridges in southern Washington, resulted in an increasing accumulation of volcanic debris, especially in the synclinal valleys. As the ridges rose, they were periodically buried by volcanic debris from the Cascades and the northwestward advancing lava flows. Ultimately the anticlines rose too high and locked the Columbia River into the Pasco Basin. The latest basalt flows then were emitted from local fissures into the lowest points of the Basin.²¹

At least some faults formed probably as an early phase of deformation.²² Once the axes of tectonic activity developed, folding predominated. Faults, though common in the region, are largely restricted to the anticlinal ridges, showing minimal evidence of recent offset, and apparently reflecting stress relief where folding was insufficient for that release.²³

A southward progression of uplift also appears to have occurred in central Washington with the more northerly anticlinal ridges (Umtanum Ridge and Saddle Mountains) rising earlier than those to the south (Horse Heaven Hills).¹⁹

The Horse Heaven Hills in time rose to obstruct the Columbia River course from the Cascades to the Blue Mountains. A flattening of gradient of the river caused the deposition of the sediments of the

Ringold Formation, ultimately to an altitude of about 1000 feet. Then the Columbia River began to incise its channel through the Horse Heaven Hills at a rate faster than uplift. Once the Columbia River base level was lowered, the river eroded the Ringold Formation sediments beneath the Hanford Reservation and developed a land surface that sloped gently from an altitude of about 600 feet on the west to 400 feet on the east.²⁴ On this surface a thick deposit of caliche developed, attesting to the then semiarid climate.²⁵

Late in the Pleistocene epoch, catastrophic floods emanated from glacial Lake Missoula and other glacier-dammed lakes and repeatedly scoured the Pasco Basin. The floods stripped much of the eolian silt and underlying caliche from the basin. They also left a series of interconnecting channels, resembling the Channeled Scabland, carved into the Ringold Formation surface beneath the Hanford Reservation.²⁴

Two of the floods were gigantic by any standards, involving about 500 cubic miles of water with a calculated maximum flow rate between 9 and 15 cubic miles/hr. The first of these floods is dated at 18,000 to 20,000 years ago and the second at about 12,000 years ago.²⁶ Evidence suggests that the earlier flood rose to 1,200 feet above mean sea level and the latter to about 900 feet above sea level, the result of hydraulic damming in Wallula Gap and downstream constrictions.

Aggradation resulting from the floods reached a level of about 700 feet altitude in the basin center where the effective width is greatest and the water was most slowed. The deposits are generally graded, both vertically and laterally. The coarsest sediments are in the northern reaches of the Reservation. Finer sediments prevail southward in the wider parts of the basin, with the finest sediments on the basin margins and on the flanks of the enclosing hills. The deposits of each flood also tend to be finer-grained upward, reflecting the decreased velocity of the flood waters as they ponded.

The sediments coarsen toward Wallula Gap, where the water velocities were again greater because of the basin's narrowing cross sectional profile and because of the volumes of water, including the Snake River, entering the Pasco Basin at downstream points. The basin fill there accumulated to a maximum altitude of about 500 feet.

Subsequent to the deposition of the basin fill sediments, the Columbia River cut its way across the Reservation, shifting generally northeastward as it lowered its base level and its grade. Estimates of its lateral rates of shift range up to a foot per year. Today residual channels cross the northeast part of the Reservation attesting to that shift. In the process of eastward shifting and concomitant with down-cutting, several benches or terraces were modified. They are best displayed in the southern part of the Reservation south of the Hanford Wye road junction. There, the uppermost terrace lies at an altitude of 500 to 540 feet and the lower at 400 to 440 feet, with the escarpment or boundary between the two paralleling the Columbia River and about 4 to 5 miles from the river.

Subsequent to the river shift, wind action established two sets of dunes that now cross both terraces indiscriminately. The first set forms a belt that extends from the junction of Cold and Dry Creek Valleys to a point halfway to the Yakima Horn, thence east-northeast immediately north of the Hanford Wye road junction to the Columbia River. There they form a belt four miles wide immediately south of the Hanford townsite to a point opposite Ringold on the east bank of the Columbia River. They evidently originated in Cold Creek Valley by deflation of the valley and wind transport of the sands to the east-northeast.²⁶

The second group of dunes focuses on the area between the Yakima Horn and North Richland, with the dune belt dying out to the northwest and southeast. The dunes trend northeastward. Their eastward convergence with the more northerly belt indicates a somewhat different direction

of the prevailing winds at different locations. To a large extent this is topographic control, due to the presence of wind gaps and anticlinal ridges in the wind's path.

Both sets of dunes evidently developed 4000 to 8000 years ago in the dry and warm climate of the Altithermal geological period, and have in part stabilized as a result of subsequent climatic changes.²⁶ They also attest to the continued eastward migration of the Columbia River and to the lack of its presence on the Hanford Reservation in the time since dune emplacement. Otherwise, the dunes would have been breached.

The eastward shift of the Columbia River evidently is continuing in the northern reaches of the Reservation. Thus the northern reaches of the White Bluffs (north of the Hanford townsite) are being actively undercut. Landslides into the Columbia River have occurred and will occur as the bluffs are oversteepened.

II.3.7 Seismology^(a)

Eastern Washington is in a region of low to moderate seismicity lying between the western Washington and western Montana zones of considerably greater seismicity.^{27,28} On the basis of the damage that has been experienced since 1840, the U.S. Coast and Geodetic Survey (ESSA) designated eastern Washington as Zone 2 seismic probability, implying the potential for moderate damage from earthquakes. Periodic revisions between 1948 (the date of first issuance of the risk map) and 1969 did not change the potential for eastern Washington, although damage potentials for other parts of the country were upgraded (Figure II.3-8). Currently western Washington and western Montana are in a Zone 3 category, implying the risk of considerable damage. The categories are incorporated in the Uniform Building Code.

(a) Appendix II.3-C provides a more detailed description of the seismology of the Hanford Reservation.

FIGURE II.3-8 SEISMIC RISK MAP

Hanford facilities are exposed to the possibility of earthquake damage from two sources: 1) the active seismic zones of western Washington and 2) closer shocks originating in the seismic zone that includes Walla Walla. However, the underlying sands and gravels in the Hanford Reservation provide excellent protection against damage. As far as can be determined, earthquake intensities greater than four on the Modified Mercalli Scale (MM-IV) have not assuredly occurred in the immediate Hanford area, although intensities as high as MM-V or MM-VI were observed at surrounding towns.²⁹

The strongest shock of historic record to occur in western Washington was the 1949 earthquake originating in the Puget Sound channel just off Steilacoom, about 150 miles from Hanford. Intensities from MM-VI to MM-VII were experienced at distances of 150 miles.²⁹ Four shocks in western Washington between 1932 and 1946 had maximum intensities of MM-VII.

The eastern Washington earthquakes occurring in historic times have not been as intense as those in western Washington, nor as frequent. In 1936, the Walla Walla area experienced an MM-VII shock. In 1934 at Ellensburg and in 1957 near Othello, "Seismic Swarms" of small shocks occurred. An intensity of MM-VI was reached in some of these, but the shocks were highly localized. The closest felt earthquake of historical record occurred at Corfu, 31 miles north of the 300 Area, in 1918. Goods fell from shelves and small landslides reportedly occurred.³⁰

The great Alaska earthquake of 1964 and recent shocks in western Washington were not felt as strongly at Hanford as in surrounding localities. Hanford, moreover, is not located in a historically active seismic zone (Figure II.3-9). These considerations indicate that the area is one of the safest in the state.

For building purposes, the Hanford area was included in Zone 2 in the seismic probability map adopted as part of the Uniform Building Code by

FIGURE II.3-9 EARTHQUAKE ZONES OF WASHINGTON

the International Conference of Building Officials. It implies the potential of only moderate damage as deduced from the historical record.

The seismic risk maps are based upon the worst damage that has been experienced; in most cases this has occurred on poorly consolidated and saturated sediments that are the most prone to earthquakes. Hence, a optimistic damage potential is indicated for sites utilizing less earthquake-responsive ground. In compensation, the maps consider an historical record of about 100 years, during which the low population density of the area may have resulted in there being no record of some minor quakes and certainly no damage. The true earthquake potential then may be somewhat higher or lower than suggested by the Seismic Risk Map.

Figure II.3-9 shows the active fault zones in Washington deduced from earthquake activity. East of the Cascades the trends are largely north-south, parallel to the Cascades, and divide the state into separate geographical, structural and tectonic provinces.

In eastern Washington, clearcut relationships of epicenters to specific surface faults or structures capable of faulting are not yet recognized. The suggested low rate of tectonic deformation for more than 10 million years¹⁹ does not indicate any cause for concern. Much of the stress resulting from the continuing low rate of tectonic deformation appears to be dissipated from random epicenters along joints and bedding planes.

On the assumption that an MM-VII quake (magnitude 5.5) were to occur at the northwest end of the Rattlesnake-Wallula fault zone, ground acceleration of 13% g could be expected beneath most of the Hanford Reservation.³¹ A design basis of 25% g on the Hanford Reservation thereby allows for an MM-VIII intensity quake (magnitude up to 6.8) for an earthquake epicentered at the same site. No such quake has ever been recorded in eastern Oregon or Washington.

The siting of nuclear facilities over the synclinal troughs introduces the maximum distance from all hypothesized faults capable of earthquake

generation. If, in addition, the Ringold Formation and Pasco Gravels are compact and undisturbed, the site is certain to pose few problems. An appreciable to high degree of conservatism appears present by acceptance of the MM-VIII quake (magnitude 6.8) and the resulting 25% g acceleration for facility design purposes.

II.3.8 Hydrology^(a)

II.3.8.1 Surface Water

The surface water bodies located within the boundaries of the Hanford Reservation consist of the Columbia River, various ditches and ponds in and near the 200 Areas and three ponds located in the 300 Areas (Figure II.3-10). Two ephemeral streams, Cold and Dry Creeks, appear for a short time only after heavy rainfall or snowmelt.

II.3.8.1.1 Columbia River

The river reach from Priest Rapids Dam (river mile 397) to the head (approximately river mile 351) of the reservoir behind McNary Dam is the last free-flowing reach of the Columbia River within the United States. The main channel is braided around the island reaches, and submerged rock ledges and gravel bars cause repeated pooling and channeling. The river-bed material is mobile, dependent on river velocities; it is typically sand, gravel, and rocks up to 8 inches in diameter. Small fractions of silts and clays are associated with the sands in areas of low velocity deposition, becoming more dominant approaching the upstream face of each river dam.^{32, 33, 34}

The Columbia River in this reach has widely varying flow rates due to regulation by the power producing Priest Rapids Dam just upstream (Figure II.3-11). Flows during the summer, fall and winter vary from a low of 36,000 cubic feet per second (cfs) to as much as 160,000 cfs each day. The long-term annual average flow at Hanford is about 120,000 cfs,³⁵

(a) Appendix II.3-D provides a more detailed description of the Hydrology of the Hanford Reservation.

FIGURE II.3-10 SURFACE WATER AREAS ON HANFORD SITE

FIGURE II.3-11 COLUMBIA RIVER BASIN

but during low flow periods, daily flows average 80,000 to 90,000 cfs. The mean annual flow rate for 1972 at Hanford was 159,500 cfs. In recent years, peak flows during the spring runoff have ranged from 160,000 to 550,000 cfs; the maximum flood peak of record is 693,000 cfs in 1948.

The river width in the Hanford reach varies between 400 and 600 yards depending upon flow rate and position along the river.³⁶ The depth at the deepest part of the measured cross-sections varies approximately from 10 to 40 feet, with an average around 25 feet. Daily fluctuations in depth caused by Priest Rapids regulation can be as much as 10 feet above Vernita and 5 feet at Hanford. The maximum velocities measured vary from less than 3 feet per second (fps) to over 11 fps, again depending upon the river cross-section and flow rate.

Temperature measurements of the Columbia River have been continuously recorded both above and below the Hanford Project for many years. Figure II.3-12 shows the temperature data just below Priest Rapids Dam and at Richland for 1972.³⁷ The maximum daily temperature for 1972 was 19.3°C (66.7°F). The annual average was 10.9°C (51.6°F) below Priest Rapids Dam and 10.1°C (50.2°F) at Richland. The maximum river temperature of record at Priest Rapids is 20.7°C (69.3°F) in August, 1958. The annual mean temperature for 1960-69 was 10.8°C (51.4°F).

Samples for chemical analysis of Columbia River are taken routinely at Priest Rapids Dam, at Vernita, the 300 Area, and at Richland.³⁸ Table II.3-2 gives annual summaries of this data for 1972. Several investigations studied the effect of reactor effluent on chemical quality of the water. One report³⁹ includes analyses of river samples taken semimonthly at Vernita (downstream of Priest Rapids Dam but upstream from the Hanford Reservation) and within the Hanford boundaries but downstream of reactor effluent discharges. Statistical comparison of the mean sample values showed no significant differences at the 90% confidence level in any of the species except hexavalent chromium.

FIGURE II.3-12 1972 MONTHLY AVERAGE TEMPERATURE COMPARISON FOR PRIEST RAPIDS DAM AND RICHLAND

TABLE II.3-2

AVERAGE CHEMICAL CONCENTRATIONS IN THE COLUMBIA RIVER AT
PRIEST RAPIDS DAM, OCTOBER 1971 TO SEPTEMBER 1972

<u>Chemical</u>	<u>Concentration</u>
Calcium	19. (mg/l)
Magnesium	4.3 (mg/l)
Sodium	2.1 (mg/l)
Potassium	1.4 (mg/l)
Chromium	0 (a)
Copper	2.6(a) (μg/l)
Lead	8.0(a) (μg/l)
Total Mercury	0.9(a) (μg/l)
Zinc	32.0(a) (μg/l)
Bicarbonate	72. (mg/l)
Sulfate	13. (mg/l)
Chloride	1.5 (mg/l)
Kjeldahl Nitrogen	.29 (mg/l)
Ammonia Nitrogen	.07 (mg/l)
Nitrite	.006 (mg/l)
Nitrate	.26 (mg/l)
Ortho-Phosphorus	.013 (mg/l)
Total Phosphorus	.037 (mg/l)
Total Alkalinity	59. (mg/l)
Hardness	66. (mg/l)
Non-Carbonate Hardness	06.8 (mg/l)
Specific Conductance	158. (micro-mhos)
pH	7.8 (units)
Dissolved Solids	107. (mg/l)
Color	15. (Platinum - Cobalt units)

(a) partial data only

II.3.8.1.2 Yakima River

The Yakima River is a small river with annual flow rates between 1,300 and 20,000 cfs. This river passes near the borders of the Hanford Reservation on the southern side. It is of little importance to the Hanford operations since no direct water withdrawal or disposal is made. However, its entrance into the Columbia River at Richland diverts the main river away from the southern shore from the mouth of the Yakima to Kennewick.

Continuous flow data in the vicinity of Hanford is available from a water stage recorder located at Kiona (approximately 20 miles west of Richland). Data from this station shows a minimum and maximum flow of 1,420 cfs and 20,200 cfs, respectively for 1972. The mean flow for 1972 was 6,696 cfs.³⁵ Water quality measurements are routinely made on Yakima River water at Kiona.³⁷

II.3.8.1.3 Ponds and Ditches

The Hanford Reservation contains a number of man-made ditches and ponds which are used for the disposal of low-level radioactive liquid waste, certain industrial waste, and cooling waters from various processes. (A complete list of these ditches and ponds, together with physical dimensions and radioactive inventory, is included in Appendix II.1-C, Part 2.)

Besides these man-made ponds, there exists one natural pond, West Lake (also shown in Figure II.3-10). The size of this pond is a direct function of the elevation of the groundwater in that area; the average size is about 10 acres. No waste is being discharged to this pond.

The 300 Area ponds receive manufacturing process and cooling water from fuel fabrication processes, and small amounts of laboratory waste, including waste from the 331 Building laboratories and effluent liquor

FIGURE II.3-13 HANFORD RESERVATION WELL LOCATION MAP

from the animal pen septic tanks (Figure II.3-10). Sanitary waste from from laboratory office and manufacturing facilities is routed to a septic tank, with overflow to leach trenches. No intermediate- or high-level radioactive wastes are routed to any of the 300 Area ponds.

II.3.8.2 Groundwater

II.3.8.2.1 Background and Geological Summary

During the past 30 years over 1500 wells have been drilled at Hanford:⁴⁰

- for water supply
- to provide quantitative data for evaluating the chemical and physical properties of the underlying material
- for measuring the hydrological characteristics of the various sediments
- for foundation engineering design
- for monitoring waste disposal facilities
- for monitoring the radiological status of the groundwater.

Figure II.3-13 shows the location of the wells currently available for hydrological measurements.

Three principal rock types underlie the Hanford Reservation:

- unconsolidated silts, sands, and gravels
- semiconsolidated lake and stream sediments (Ringold Formation)
- dense, hard basalt which forms the bedrock beneath the area.

The lithologic character and water bearing properties of the several geologic units occurring in the Hanford region are summarized in Table II.3-D-11 in Appendix II.3-D. In general, groundwater in the surficial sediments occurs under unconfined or water-table conditions although locally confined zones exist. Water in the basalt bedrock occurs mainly under confined conditions. In some areas, the lower zone of the Ringold Formation is a confined aquifer separated from the unconfined aquifer by thick clay beds and possessing a distinct hydraulic potential.

II.3.8.2.2 The Unconfined Aquifer

The unconfined aquifer consists of both glacio-fluviatile sand and gravel deposits and the Ringold silts, clays and gravels. Since these materials are very heterogeneous, often greater lithologic differences appear within a given bed than between beds. The aquifer bottom is the basalt bedrock in some areas and silt/clay zones of the Ringold Formation in other areas. There are certain "erosional windows" where a possibility exists for hydraulic communication between the unconfined and confined aquifers, but quantitative data on magnitudes and locations of interflow have not been obtained. Clearly, however, the bottom of the unconfined aquifer is not a continuous surface.

The impermeable boundaries are the Rattlesnake Hills, Yakima Ridge, and Umtanum Ridge on the west and southwest sides of the Hanford Reservation (Figure II.3-14). Gable Mountain and Gable Butte also impede the groundwater flow, as well as other small areas of basalt outcrop above the water table. The Yakima River recharges the unconfined aquifer along its reach from Horn Rapids to Richland. The Columbia River forms a hydraulic potential boundary which is mainly a discharge boundary for the aquifer. However, the groundwater flow from 1 to 3 miles inland from the Columbia is affected by seasonal river stage fluctuations.^{41,42,}

The major source of natural recharge is precipitation on Rattlesnake Hills, Yakima Ridge, and Umtanum Ridge which outcrop to the south and west of the Reservation. The natural recharge due to precipitation over the lowlands of the Hanford Reservation is not measurable as the evaporation potential during the summer months greatly exceeds total precipitation. Data on migration of moisture from natural precipitation in deep soils (below 30 feet) show movement rates less than 1/2 in./yr at one measurement site.^{43,44,45}

The major artificial recharge of groundwater to the unconfined aquifer occurs near the 200 East and 200 West Areas. The large volume of process water disposed to ponds at these sites caused the formation of

**FIGURE II.3-14 HANFORD RESERVATION WATER TABLE MAP
July, 1972**

significant groundwater mounds (Figure II.3-14) in the water table since the start of Hanford Operations. Other local groundwater mounds formerly existed at each reactor site along the Columbia River. The mound at the still active 100-N Area is the only one of these remaining. A minor recharge mound exists at the 300 Area.

Significant aquifer characteristics for the unconfined aquifer are the hydraulic conductivity, the storage coefficient, and the effective porosity. The hydraulic conductivity relates the quantity of groundwater flow to the gradient of the hydraulic potential while the effective porosity gives the fraction of porous media volume that is available to transmit groundwater flow. The storage coefficient relates a change in the water table elevation to a change in the volume of water contained in the aquifer per unit horizontal area. In the limit, the storage coefficient is equal to the effective porosity of the soil through which the water table moves. These parameters have highly heterogeneous distributions over the Hanford Reservation.

Qualitatively the hydraulic conductivity, storage coefficient, and effective porosity distributions are a function of the different geologic formations in the unconfined aquifer. Ancestral Columbia River channels incised in the Ringold Formation are filled with more permeable glaciofluvial sediments. Channels of highly permeable sediments have been identified extending eastward along the northern and southern flanks of Gable Mountain and extending southeastward from the 200 East Area to the Columbia River.⁴⁶ These permeable channels are reflected in the groundwater flow pattern of the region.

Quantitative measurements of the hydraulic conductivity were made at locations over the Hanford Reservation using a variety of techniques.^{46, 47, 48} Excluding the clay zone, the values obtained for the Ringold Formation range between moderate values of 6 to 200 ft/day. In sharp contrast are the very large hydraulic conductivities of glaciofluvial sediments--ranging from 1,200 to 12,000 ft/day.

The storage coefficient is much more difficult to measure in the field. Values for this parameter from 0.0008 to 0.2 were estimated for the Hanford area from field tests, but the quality of these values is poor. A typical range of storage coefficient for unconsolidated sediments is 0.05 to 0.4.

Effective porosity can be measured with some difficulty in the field using either tracer or well-logging techniques. No field measurements have been made of this parameter on the Hanford Reservation.

The present state of the unconfined groundwater aquifer is characterized by the contour map of the hydraulic potential or the water table. (The map for July 1972 appears in Figure II.3-14.) The depth to the water table varies greatly from place to place depending chiefly on local topography, ranging from less than 1 to more than 300 feet below the land surface. Beneath most of the 200 Area disposal sites the depth to the water table averages about 250 feet. The current estimate of the maximum saturated thickness of the unconfined aquifer is about 230 feet.

From 1944 through 1972, the chemical processing plants discharged to ground over 130 billion gallons (4×10^5 acre-ft) of wastewater and cooling water with a profound effect on the regional water table. Figure II.3-15 shows the water table map before plant operations as interpreted from the earliest water level measurements in Hanford wells. A series of water table maps prepared over the years is included in Reference 49. Historical well hydrographs in Figure II.3-16 show the development and fluctuation of these mounds with time. Rising groundwater levels have been measured as far as 16 miles away from the recharge site (Figure II.3-16c).

For any groundwater potential map (water-table map), flow paths can be drawn illustrating the direction of groundwater movement at the time that the particular map represents. These flow paths are also called instantaneous streamlines. A parcel of water will follow one of these streamlines only as long as the potential contours remain the same. A

FIGURE II.3-15 HANFORD RESERVATION WATER TABLE MAP
January, 1944, Hindcast

FIGURE II.3-16 WELL HYDROGRAPHS

slowly changing water table configuration will cause that parcel of water to follow the slowly changing instantaneous streamline. Its resulting path from one point to another is called a pathline. The rate of change of the groundwater potential contours is slow enough so that the instantaneous streamlines do not move significantly over a period of several years in most places. Figure II.3-17 shows the July 1972 water table map with some instantaneous streamlines. This figure illustrates the movement of groundwater from the areas of natural and artificial recharge down to the Columbia River to the east and north.

The groundwater saddle or divide under the 200 East Area gives the possibility of both northward and southeastward transport from the 200 East and 200 West processing areas. Radioactive contaminants are convected in the direction of groundwater movement upon reaching the water table. Thus, the site of infiltration is of critical importance in evaluating the fate of any radioactive waste that gets into the groundwater. Ultimately all groundwater in the unconfined aquifer flows into the Columbia River except for that small amount which is lost to the atmosphere by evapotranspiration.

Tracer tests for field measurement of groundwater velocities were conducted at four locations, with results ranging from 11 to 170 ft/day.^{46, 50, 51}

FIGURE II.3-17 HANFORD RESERVATION WATER TABLE MAP
WITH STREAMLINES JULY 1972

The chemical quality of the groundwater in the unconfined aquifer is measured semiannually at seven locations. Sodium, calcium, and sulfate ions are measured as well as pH. Chromium and fluoride ions associated with fuel manufacturing operations are analyzed for 300 Area wells. Finally, nitrate ion, which is a waste product from the manufacturing and chemical separations operations, is monitored over the entire Hanford Reservation. Semiannual maps of the nitrate ion concentration near the surface of the unconfined aquifer are published. The map for the last 6 months of 1972 appears in Figure II.3-18.⁵² Since the nitrate ion is not sorbed on the soil, the map shows the extent of wastewater movement, thus indicating where radionuclides should be found that are contained in the wastewater.

The temperature of the groundwater in the unconfined aquifer has been measured on an intermittent basis. The most recent temperature logs of the wells were obtained in January 1974. Figure II.3-19 shows distribution of the groundwater surface temperature under the Reservation. The local thermal anomalies can be caused by vertical flow within a well casing. At one time, reactor groundwater mounds contained water on the order of 70-90°C.⁵³ The residual heat from these mounds can be seen in Figure II.3-19 under the northern part of the Reservation.

The radiological status of the groundwater near the surface of the unconfined aquifer is monitored regularly and reported semiannually. The gross beta (ruthenium) plumes and the tritium plumes are mapped in Figures II.3-20 and II.3-21 for the latter half of 1972.⁵² The major trends of the groundwater flow paths are illustrated by the contaminant plumes. Dispersion, radioactive decay, and a minor amount of sorption act to modify the convective transport of these "tracers".

II.3.8.2.3 The Confined Aquifers

From the limited amount of research that has been done to date, it appears that a number of confined aquifers are underneath the Hanford

FIGURE II.3-18 AVERAGE NITRATE (NO_3^-) CONCENTRATIONS
July-December 1972 (Drinking Water
Standard - 45 mg/l)

FIGURE II.3-19 GROUNDWATER TEMPERATURES AT THE SURFACE OF THE UNCONFINED AQUIFER

FIGURE II.3-20 AVERAGE GROSS BETA (AS ^{106}Ru) CONCENTRATIONS
July-December 1972 (Concentration Guide -
10 pCi/ml)

FIGURE II.3-21 AVERAGE TRITIUM (^3H) CONCENTRATIONS
July-December 1972 (Concentration Guide -
3000 pCi/ml)

Reservation. Relatively impermeable confining beds commonly include the individual basalt flows, where they are continuous and greater than about 50 feet thick, and the silts and clays of the lower part of the Ringold Formation. Within the basalt sequence, groundwater is transmitted primarily in the interflow zones, either in sedimentary beds or in the scoria and breccia zones forming the tops and bottoms of the flows.^{53, 54} Some of the basalt flows in the Pasco Basin have been eroded, particularly in the anticlinal ridges. In some locations the basalts are highly jointed and contain breccia, pillow and palagonite complexes through which groundwater can move. Consequently, hydraulic potential differences between water bearing zones in the upper part of the basalt sequence are small over hundreds of feet of depth. The lowermost Ringold Formation silts and clays are of various thickness and distinct hydraulic potential differences have been observed below the silts and clays and the unconfined aquifer. About 90 wells on the Hanford Reservation have been drilled to basalt. Thus data on the confined aquifers in the basalt flows are scarce and much more data must be gathered to fully characterize the confined aquifers.

One recharge area that has been identified is from the Yakima River at Horn Rapids. The piezometric map in Figure II.3-19 suggests recharge from the upper Cold Creek Valley, with flow toward a potential trough under the Columbia River. The Columbia Basin Irrigation Project to the northeast and east, and the Columbia River behind Priest Rapids and Wanapum Dams to the northwest, both where basalt is exposed and where it is covered by unconsolidated deposits which are saturated perennially. There is a site of possible minor recharge adjacent to Gable Butte and Gable Mountain anticline near the center of the Reservation.

The piezometric or hydraulic potential map for the confined aquifer below the Ringold clays (Figure II.3-22) was based on measurements made in 1970. In general the hydraulic potential observed in the confined

FIGURE II.3-22 PASCO BASIN UPPERMOST CONFINED AQUIFER POTENTIAL MAP - 1970

aquifer zones above the basalt is greater than in the overlying unconfined aquifer. The main exception is in the vicinity of the 200 Area recharge mounds which have raised the potential in the unconfined aquifer. Groundwater flow in this confined aquifer is also to the southeast with possible discharge into the Columbia River somewhere below Lake Wallula. However, the flow rates are expected to be quite small due to the low transmissivity range of this water bearing zone. Groundwater in the lower confined aquifers does not appear to cross the major anticlinal divides that define the Pasco Basin.⁵⁵

In 1970 and 1971, 23 wells that penetrate the uppermost confined aquifer were pump tested and transmissivity values calculated. Values of transmissivity range from $2.3 \text{ ft}^2/\text{day}$ to $2400 \text{ ft}^2/\text{day}$. Corresponding hydraulic conductivities based on estimated aquifer thicknesses are from less than $0.1 \text{ ft}/\text{day}$ to about $15 \text{ ft}/\text{day}$. Some data on the aquifer properties of the lower confined aquifers are available from the ARHCO deep drilling project well ARH-DC-1.⁵⁶ This well was drilled to a depth of 5661 feet and is located near well 699-49-48 in Figure II.3-22. At this well the basalt from 362 to 1200 feet deep has a transmissivity of about $695 \text{ ft}^2/\text{day}$. A sedimentary unit contained in this zone from 830 to 936 feet has a transmissivity of about $355 \text{ ft}^2/\text{day}$. A dense basalt zone from 960 to 1090 feet has a transmissivity of $0.2 \text{ ft}^2/\text{day}$. There is one significant water-bearing zone, 10 feet thick, occurring at 3230 feet with a transmissivity of about $68 \text{ ft}^2/\text{day}$.

Water bearing sedimentary interbeds were centered at 500, 650, and 900 feet and ranged from 25 to 100 feet thick. The bed at 900 feet was about 100 feet thick consisting of well-sorted medium sand of moderate permeability. Its hydraulic conductivity is about $3.5 \text{ ft}/\text{day}$, making it the most productive aquifer penetrated by this well.

Only one measurement of the storage coefficient in the confined aquifer above the basalt has been made. The results at Well 699-14-E6 gave values ranging from 0.0005 to 0.0007 comparable to those measured in the Ringold Formation.

The water quality and radiological status of the groundwater in the confined aquifers have been measured with less detail and regularity than for the unconfined aquifer. The well sampler system is susceptible to cross contamination and vertical flow between aquifers. Sample results are inconsistent. A program is being developed for improved sampling of the confined aquifer. The most extensive measurements have been for the tritium content. Table II.3-4 gives the results of the most recent (1968-1970) tritium measurements. Most values are below the routine tritium detection limit for water samples from the unconfined aquifer (500 to 700 pCi/liter). In conclusion, a major barrier to investigation of the confined aquifers under the Hanford Reservation is a lack of suitable well structures that are capable of yielding reliable hydraulic potential measurements and representative confined groundwater samples.

II.3.8.2.4 Aquifers North and East of the Columbia River

Very little data are available on the groundwater aquifers to the north and northeast of the Columbia River. The confined basalt aquifers underlie this area as well as the present Hanford Reservation. The unconfined aquifer exists only under the parts of the Wahluke Slope between the higher bluffs and the Columbia River. The Ringold Formation and glaciofluvial sediments form this aquifer.

The Saddle Mountains form the northern boundary to the confined aquifers and are a potential recharge site from precipitation due to basalt flow outcropping. The Columbia River behind Priest Rapids Dam and Wanapum Dam and the Columbia Basin Irrigation Project are other probable recharge areas. The Columbia River forms the primary discharge boundary for the unconfined aquifer. Seasonal riverbank storage and discharge also occurs as on the Hanford side of the river.

The remaining sources of recharge to the unconfined aquifer are the irrigation wasteways and ponds that have been created. There are no observation wells monitored by the AEC to record the recharge effects of these ponds. The water table elevations in the unconfined aquifer

TABLE II.3-4

TRITIUM IN HANFORD WELLS TAPPING THE CONFINED AQUIFER ABOVE THE BASALT

<u>Well Number</u>	<u>Samples Results^(a) (pCi tritium/liter)</u>	<u>Volume Pumped Prior to Sampling (gallons)</u>
199-H4-2	600 ± 70 730	NM 95,000
299-W11-2-P	3,900 + 320 - 640	500
699-S11-E12A	610 ± 29	Flowing Well
699-2-33-P	<500	NM
699-10-E12-P	<500 1,500 ± 56 <500 <500	NM 1,600 700 700
699-14-E6-P	550 + 77 610 - 35	2,000 NM
699-14-38-P	640	NM
699-15-15A	540	NM
699-20-E12-P	<500	NM
699-20-E5-P	<500 <500	NM NM
699-24-1-P	760 <500	NM NM

(a) The Concentration Guide for public drinking water, as given in the AEC Manual Chapter 0524 Appendix, Table 2, is 3×10^6 picocuries per liter.

NM - Not Measured.

Detection limit 500 to 700 pCi/liter

near the Columbia River range from 370 to 405 ft MSL at the four available observation wells. The hydraulic potentials in the wells that penetrate the confined aquifers average about 50 feet higher. These wells are also perforated in several basalt aquifers precluding representative potential measurements.⁵⁴

The limited amount of information available indicates that the groundwater in the unconfined aquifer across the Columbia River moves toward the river and discharges into it. Some evidence indicates that groundwater in the confined aquifer may be flowing under the present riverbed to a trough of low potential. This flow, mixed with confined aquifer groundwater from under the Hanford Reservation, then moves downstream, with some discharge into the Columbia River through the unconfined aquifer, controlled by the hydraulic conductivity of the confining beds.

Water quality data for the groundwater across the Columbia River consists only of nitrate measurements for the confined aquifers. No nitrate concentrations above the routine detection limit (0.5 mg/liter) have been observed. Analyses for gross alpha, gross beta, and tritium have been made. The measurements of radionuclide concentrations in the confined aquifers have also shown no observable results.

II.3.8.2.5 Hanford Hydrology Program Review

The AEC and its contractors at Hanford make periodic program reviews of the Hanford site hydrology in order to direct and improve the work. A comprehensive review of the groundwater management and environmental monitoring programs at the Hanford Reservation was initiated in 1973. (See Appendix Section II.3-D-3; page II.3-D-77.)

II.3.9 Meteorology^(a)

II.3.9.1 General Climate

The Hanford climate is mild and dry, with occasional periods of high winds. Summers are generally hot and dry; winters are not as dry and are relatively mild for this latitude. Table II.3-5 contains a condensed summary of climatological observations at the HMS, (Figure II.3-23) located between 200 East and 200 West Areas (Figure II.1-1). Both averages and

(a) A more detailed description of the meteorology of the Hanford Reservation is given in Appendix II.3-E.

FIGURE II.3-23 410 FOOT TOWER AT THE HANFORD METEOROLOGICAL STATION

TABLE II.3-5

AVERAGES AND EXTREMES OF CLIMATIC ELEMENTS AT HANFORD
(Based on all Available Records to and Including the Year 1970)

	TEMPERATURE (°F)												DEGREE DAYS (BASE 65°F)				PRECIPITATION (INCHES)																						
	1912-1970 AVERAGES						1912-1970 EXTREMES						1945-1970 TOTALS				1912-1970 TOTALS																						
	DAILY MAXIMUM	DAILY MINIMUM	MONTHLY	HIGHEST MONTHLY	YEAR	LOWEST MONTHLY	YEAR	RECORD HIGHEST	YEAR	RECORD LOWEST	YEAR	RECORD HIGHEST	YEAR	RECORD LOWEST	YEAR	MEAN MONTHLY	MAXIMUM MONTHLY	MINIMUM MONTHLY	YEAR	MEAN MONTHLY	MAXIMUM MONTHLY	MINIMUM MONTHLY	YEAR	MAX. IN 24 HOURS	YEAR	SNOW, ICE PELLETS (FEET)													
																										MEAN MONTHLY	MAXIMUM MONTHLY	MINIMUM MONTHLY	YEAR	MAX. IN 24 HOURS	YEAR	MAXIMUM DEPTH	YEAR						
Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year	
Year	64.8	41.4	53.1	81.8	106.0	121.1	1950	115	1950	3	1950	82	1925	27	1914	5267	1640	1950	0	1970	6.25	3.08	1940	0	1955	1.91	1957	12.7	26.0	1916	7.1	1954	12.1	1960	1960	1960	1960	1960	1960

EXTREME AVERAGES OR TOTALS
AND YEAR OR SEASON OF OCCURRENCE

1912-1970 TEMPERATURE AVERAGES (°F)

HIGHEST ANNUAL	56.2	1958+
LOWEST ANNUAL	50.2	1929
HIGHEST WINTER (10-J-F)	41.1	1933-34
LOWEST WINTER	24.2	1948-49
HIGHEST SPRING (M-A-M)	58.2	1947
LOWEST SPRING	48.0	1955
HIGHEST SUMMER (J-J-A)	78.2	1958
LOWEST SUMMER	70.3	1954
HIGHEST FALL (S-O-N)	56.6	1963
LOWEST FALL	49.6	1946

1912-1970 PRECIPITATION TOTALS (IN.)

GREATEST ANNUAL	11.45	1950
LEAST ANNUAL	3.26	1967
SNOW, ICE PELLETS (SLEET)		
GREATEST SEASONAL	43.6	1915-16
LEAST SEASONAL	0.3	1957-58

1945-1970 WIND SPEED AVERAGE (mph)

HIGHEST ANNUAL	8.3	1968+
LOWEST ANNUAL	6.3	1957

1946-1970 RELATIVE HUMIDITY AVERAGE (%)

HIGHEST ANNUAL	57.9	1950+
LOWEST ANNUAL	49.4	1967

1946-1970 SKY COVER AVERAGES
(SUNRISE TO SUNSET, SCALE 0-10)

HIGHEST ANNUAL	6.4	1966
LOWEST ANNUAL	5.1	1949

1953-1970 SOLAR RADIATION
AVERAGE DAILY TOTAL (LANGLEYS)

HIGHEST ANNUAL	385	1957
LOWEST ANNUAL	357	1967

	WIND (mph)						RELATIVE HUMIDITY (%)												SKY COVER (SCALE 0-10)				SOLAR RADIATION (LANGLEYS)*									
	1945-1970 AVERAGES						PEAK GUST						1946-1970 AVERAGES						1946-1970 EXTREMES		1946-1970 AVERAGES (SUNRISE TO SUNSET)				1953-1970 AVG. DAILY TOTALS				1953-1970 EXTREME DAILY TOTALS			
	PREVAILING DIRECTION	MEAN MONTHLY SPEED	HIGHEST MONTHLY	YEAR	LOWEST MONTHLY	YEAR	SPEED	DIRECTION	YEAR	MEAN	HIGHEST MONTHLY	YEAR	LOWEST MONTHLY	YEAR	HIGHEST	LOWEST	YEAR	MONTHLY	HIGHEST MONTHLY	YEAR	LOWEST MONTHLY	YEAR	MONTHLY	HIGHEST MONTHLY	YEAR	LOWEST MONTHLY	YEAR	HIGHEST MONTHLY	YEAR	LOWEST MONTHLY	YEAR	
Jan.	NW	6.3	9.6	1953	3.1	1955	65	S	1967	75.7	88.8	1960	60.0	1963	100	1970+	13	1963	7.8	9.0	1969	4.3	1949	118	135	1962	88	1955	277	1969	16	1970+
Feb.	NW	7.0	9.4	1961	4.6	1963	63	SW	1965	69.9	86.9	1963	54.0	1967	100	1970+	14	1962	7.4	8.9	1961	5.9	1964	200	238	1960	164	1954	422	1958	37	1970+
Mar.	WNW	8.4	10.7	1964	5.9	1958	70	SW	1956	55.8	65.9	1940	44.0	1965	100	1970+	12	1965+	6.7	7.9	1950	4.9	1965	340	388	1965	305	1961	542	1968	71	1963
Apr.	WNW	9.0	11.1	1959	7.4	1958	60	WSW	1969	46.7	64.5	1963	36.9	1966	100	1963+	9	1954	6.4	8.1	1963	3.7	1951	470	526	1959+	374	1963	691	1958	115	1970
May	WNW	8.8	10.5	1965+	5.8	1957	71	SSW	1948	42.2	62.4	1948	31.2	1966	100	1969+	7	1953	5.8	7.7	1960	4.5	1949	571	634	1970	511	1962	782	1959	67	1962
June	WNW	9.2	10.7	1949	7.7	1950+	72	SW	1957	39.6	53.5	1950	30.0	1949	100	1967+	10	1964+	5.2	7.0	1950	2.8	1961	626	696	1960	563	1953	809	1957	112	1965
July	WNW	8.6	9.6	1963	6.8	1955	55	WSW	1968	31.8	40.5	1955	21.9	1959	97	1963	6	1951	2.7	4.5	1955	0.9 <td>1953</td> <td>659</td> <td>700</td> <td>1964+</td> <td>588</td> <td>1955</td> <td>789</td> <td>1969</td> <td>150</td> <td>1955</td>	1953	659	700	1964+	588	1955	789	1969	150	1955
Aug.	WNW	8.0	9.1	1946	6.0	1956	66	SW	1961	34.8	43.8	1968	24.5	1967	100	1959	7	1951	3.3	5.9	1968	0.6	1955	551	613	1955	475	1968	721	1957	107	1959
Sept.	WNW	7.5	9.2	1961	5.4	1957	65	SSW	1963	40.6	55.1	1959	33.9	1952	100	1962+	10	1962+	4.1	6.1	1959	2.5	1950	418	457	1961	354	1959	591	1970	61	1957
Oct.	WNW	6.7	9.1	1946	4.4	1952	63	SSW	1950	57.8	74.2	1962	42.5	1952	100	1969+	10	1962+	5.9	7.7	1950	3.9	1952	262	299	1958	227	1956	428	1958	38	1962
Nov.	NW	6.2	7.9	1945	2.9	1956	64	SSW	1949	72.9	80.5	1956	64.1	1959	100	1970+	16	1959	7.5	9.0	1965	6.2	1967	135	180	1967	67	1942	283	1957	14	1969
Dec.	NW	6.0	8.3	1968	3.9	1963+	71	SW	1955	80.4	89.9	1963	69.0	1968	100	1970+	28	1968+	8.1	9.2	1962	0.8	1954	91	116	1970	57	1969	185	1960	14	1969+
Year	WNW	7.6	11.1	1959	2.9	1956	72	SW	1957	54.0	89.9	1963	21.9	1959	100	1970+	6	1951	5.9	9.2	1962	0.6	1955	370	700	1964+	57	1969	809	1957	14	1969+

TABLE II.3-5 (Continued)

NUMBER OF DAYS (1945-1970)**																															
CLEAR					PTLY CLOUDY	CLOUDY					THUNDERSTORMS					HEAVY FOG VIS. 1/4 MI. OR LESS				PRECIP. 0.10 INCH OR MORE				SNOW 1.0 INCH OR MORE							
	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR	MEAN	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR	MEAN	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR
Jan.	4	13	1949	0	1955+	7	20	27	1969+	6	1949	0	0	1962	0	1970+	6	14	1965	0	1949	3	8	1970	0	1962+	2	10	1950	0	1967+
Feb.	5	9	1968+	1	1969+	6	17	26	1958	10	1951+	0	0	1962	0	1970+	3	11	1963	0	1967+	2	5	1961	0	1967+	1	4	1959+	0	1970+
Mar.	5	12	1965+	2	1961+	9	15	22	1968	7	1948	0	0	1969+	0	1970+	4	5	1951	0	1968+	2	8	1957	0	1968+	0	0	1957+	0	1970+
Apr.	7	18	1951	1	1963	11	12	21	1963	3	1949	1	3	1948	0	1970+	0	1	1950	0	1970+	2	5	1948	0	1968+	0	0	0	0	0
May	8	14	1953	2	1960	12	11	19	1960	3	1949	2	7	1956	0	1965+	0	1	1958	0	1970+	2	4	1967+	0	1968+	0	0	0	0	0
June	11	21	1961	3	1966	10	9	15	1957	0	1949	3	8	1948	0	1963+	0	0	0	0	1970+	2	5	1950	0	1962+	0	0	0	0	0
July	21	27	1953	14	1955	7	3	8	1955	0	1967+	2	5	1958+	0	1969+	0	0	0	0	1970+	1	3	1955	0	1970+	0	0	0	0	0
Aug.	19	30	1955	11	1968	8	4	13	1968	0	1969+	2	8	1953	0	1969+	0	1	1959	0	1970+	1	3	1953	0	1970+	0	0	0	0	0
Sept.	15	21	1967	8	1968	8	7	13	1969	2	1952+	1	4	1959	0	1970+	0	1	1957	0	1970+	1	3	1959	0	1970+	0	0	0	0	0
Oct.	10	16	1953	3	1950+	9	12	18	1956+	3	1946	0	0	1968+	0	1970+	0	2	1962	0	1970+	2	8	1950	0	1969+	0	0	0	0	0
Nov.	5	10	1957	1	1965+	6	19	24	1965+	12	1948	0	0	0	0	0	5	13	1965	0	1960	3	7	1960+	0	1967	0	0	1955	0	1970+
Dec.	3	7	1954	0	1947	7	21	28	1962	14	1946	0	0	0	0	0	8	17	1950	2	1968+	3	9	1964	0	1969+	2	6	1964	0	1966+
Year	115	30	1955	0	1955+	100	150	28	1962	0	1969+	11	8	1953+	0	0	24	17	1950	0	0	24	9	1964	0	0	5	10	1950	0	0

	NUMBER OF DAYS (1945-1970)												NUMBER OF DAYS (1912-1970)																			
	3" OR MORE SNOW ON GND.				PEAK GUST 40 MPH OR GREATER				MAX. TEMP. 90 OR ABOVE				MAX. TEMP. 100 OR ABOVE				MAX. TEMP. 32 OR BELOW				MIN. TEMP. 32 OR BELOW				MIN. TEMP. 0 OR BELOW							
	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY				
Jan.	5	23	1969	0	1967+	3	9	1953	0	1957+	0	0	0	0	0	0	11	29	1937	0	1967+	28	31	1960+	9	1953	2	14	1950	0	1970+	
Feb.	3	16	1950	0	1970+	2	6	1961+	0	1970+	0	0	0	0	0	0	3	19	1936	0	1970+	22	28	1944+	5	1958	1	9	1929	0	1970+	
Mar.	0	0	0	0	0	3	9	1956	1	1965+	0	0	0	0	0	0	0	2	1960	0	1970+	16	25	1944+	6	1968+	0	0	0	0	0	
Apr.	0	0	0	0	0	3	6	1959	0	1967+	0	0	1926	0	1970+	0	0	0	0	0	0	5	15	1935	0	1962+	0	0	0	0	0	
May	0	0	0	0	0	2	6	1951	0	1963+	3	21	1924	0	1965+	0	0	1	1966+	0	1970+	0	0	0	0	3	1938	0	1969+	0	0	
June	0	0	0	0	0	2	4	1970+	0	1967+	9	20	1940+	0	1953	2	9	1970	0	1968+	0	0	0	0	0	0	0	0	0	0	0	
July	0	0	0	0	0	1	4	1962+	0	1969+	21	29	1941	8	1963	7	16	1960+	0	1963+	0	0	0	0	0	0	0	0	0	0	0	
Aug.	0	0	0	0	0	1	5	1951	0	1970+	18	29	1915	7	1948	4	16	1942	0	1964+	0	0	0	0	0	0	0	0	0	0	0	
Sept.	0	0	0	0	0	2	4	1951	0	1970+	5	16	1938	0	1970+	0	2	1955+	0	1970+	0	0	0	0	0	0	0	0	0	0	0	
Oct.	0	0	0	0	0	2	8	1967	0	1957+	0	1	1933	0	1970+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Nov.	1	10	1955	0	1970+	2	5	1961+	0	1969+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Dec.	2	14	1955	0	1969+	3	8	1957+	0	1969+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Year	11	23	1969	0	0	26	9	1953	0	0	56	29	1941+	0	0	13	16	1960+	0	0	24	29	1937	0	0	119	31	1963+	0	0	0	0

REFERENCE NOTES

- * CALORIES/cm²
 ** SKY COVER AND PRECIPITATION OBSERVATIONS NOT BEGUN UNTIL 1946
 # LESS THAN 1/2
 + ALSO ON EARLIER YEARS

LOCATION AND HISTORY

PRESENT LOCATION 25 MILES NW OF RICHLAND, WASHINGTON
 LATITUDE 46°34' N; LONGITUDE 119°36' W ELEVATION 733 FEET
 OBSERVATIONS FROM 1912 TO 1944 WERE BY UNITED STATES WEATHER BUREAU COOPERATIVE OBSERVERS AT A SITE ABOUT 10 MILES ENE OF PRESENT LOCATION. SINCE 1944 OBSERVATIONS HAVE BEEN MAINTAINED ON A 24 HOUR-A-DAY BASIS BY THREE DIFFERENT AEC CONTRACTORS.

NUMBER OF DAYS

CLEAR 10.3 TENTHS SKY COVER, SR TO SSI

GREATEST ANNUAL (1946-70) 141 1951
 LEAST ANNUAL (1946-70) 85 1966

CLOUDY (8-10 TENTHS SKY COVER, SR TO SSI)

GREATEST ANNUAL (1946-70) 181 1969+
 LEAST ANNUAL (1946-70) 84 1949

THUNDERSTORMS

GREATEST ANNUAL (1945-70) 23 1948
 LEAST ANNUAL (1945-70) 3 1949

HEAVY FOG (VIS. 1/4 MILE OR LESS)

GREATEST SEASONAL (1945-70) 42 1950-51
 LEAST SEASONAL (1945-70) 9 1948-49

PRECIPITATION 0.10 INCH OR MORE

GREATEST ANNUAL (1946-70) 39 1950
 LEAST ANNUAL (1946-70) 10 1965

SNOW 1.0 INCH OR MORE

GREATEST SEASONAL (1946-70) 15 1955-56
 LEAST SEASONAL (1946-70) 0 1957-58

3 IN. OR MORE SNOW ON GROUND

GREATEST SEASONAL (1946-70) 40 1964-65
 LEAST SEASONAL (1946-70) 0 1960-61+

PEAK GUST 40 MPH OR GREATER

GREATEST ANNUAL (1945-70) 41 1961
 LEAST ANNUAL (1945-70) 13 1958

MAX. TEMPERATURE 90 OR ABOVE

GREATEST ANNUAL (1912-70) 85 1940+
 LEAST ANNUAL (1912-70) 37 1954

MAX. TEMPERATURE 100 OR ABOVE

GREATEST ANNUAL (1912-70) 32 1942
 LEAST ANNUAL (1912-70) 1 1954

MAX. TEMPERATURE 32 OR BELOW

GREATEST SEASONAL (1912-70) 53 1955-56
 LEAST SEASONAL (1912-70) 1 1937-38

MIN. TEMPERATURE 32 OR BELOW

GREATEST SEASONAL (1912-70) 141 1916-17
 LEAST SEASONAL (1912-70) 75 1957-58

MIN. TEMPERATURE 0 OR BELOW

GREATEST SEASONAL (1912-70) 18 1949-50
 LEAST SEASONAL (1912-70) 0 1969-70+

extremes are included in this table. (Reference 57 contains this and much of the following data.)

The average maximum temperatures in July and January are 91.8°F and 36.7°F. The average minimum temperatures for the same months are 61.0°F and 22.1°F. The average relative humidity varies from a low of 31.8% in July to a high of 80.4% in December. The minimum diurnal temperature in winter seasons ranges from -27°F to 22°F, compared to diurnal maximum temperatures in summer seasons which vary from 100°F to 115°F.

Average annual precipitation is 6.25 in. November, December, and January contribute 42% of the total, whereas July, August, and September contribute only 10%. A slight secondary maximum in precipitation occurs in early summer. About 45% of all precipitation during the months of December through February is in the form of snow.

Mean monthly wind speeds range from about 9 mph in the summer to 6 mph in the winter. July hourly average wind speeds vary from a low of about 5 mph in midmorning to a high of 13 mph in the late evening. The corresponding speeds in January have the same trend, but have less than a 1 mph difference. The prevailing wind directions at the HMS are from the NNW through NW. The strongest winds tend to be from the SW. The highest observed peak wind gust at HMS was 72 mph from the SW. Winds with a peak gust of 40 mph or greater have been observed on the average of at least once in every month of the year, although the winter months tend to have a higher frequency of high wind periods.

The preceding description of climatology based on the observations at the HMS can be taken as representative of the Hanford site, although some local variations in climate may be expected as a result of the size of the site coupled with local topographical effects.

No apparent climatological temperature differences exist among the low-level sites, although observations show that simultaneous differences up to 10°F and 15°F can occur. In studies on the slopes of the ALE Reserve on the northeastern slope of the Hanford site, average variations in temperature with change in elevation were found to closely follow the adiabatic lapse rate. This pattern is modified at higher elevations near the crest of the Rattlesnake Hills where the isotherms of minimum temperatures indicate a well-defined nocturnal temperature inversion reaching to 600 to 1000 feet above the valley floor. The inversion varies with season, intensifying in the spring and fall and diminishing in winter and summer.

Tornadoes are relatively rare in this region and tend to be small, with little damage when they do occur. A single small tornado was observed onsite during 29 years of observation. No damage from this tornado was reported. Fourteen tornadoes have been confirmed within 100 miles of the Hanford area between 1916 and the present. Data has been analyzed to determine the probability of a tornado hitting a particular facility onsite.^{58,59} During any year, it was estimated that the probability is six chances in a million.

II.3.9.2 Diffusion Climatology

Drainage winds play an important role in local air circulation. The Cascade Mountains to the west of the project exert considerable influence on the winds by serving as a source of cold air drainage. Differences in surface winds on the site can usually be attributed to differences in air flow associated with local topographical features (such as Rattlesnake Mountain and Wahluke Slope).

Joint wind speed, direction, and stability data are available from two locations onsite. The longest periods of data are from the HMS tower, which has been in continuous operation since the mid-forties. Wind roses for each stability and for all stabilities combined, based on 15 years of HMS data, are given in Figure II.3-24. Included in these are groupings of the persistences by wind speeds for each direction. Figure II.3-25 presents wind rose summaries based on one year of data from the meteorology tower at the N Reactor site. These two locations cover the winds in the northern and central sections of the Hanford site. The definition of stability used in Figures II.3-24 and II.3-25, as well as in the Hanford diffusion model, is given in Table II.3-6.

FIGURE II.3-24

WIND ROSES AS A FUNCTION OF STABILITY AND WIND SPEED AT HMS BASED ON WINDS AT 200 FT AND AIR TEMPERATURE STABILITY DEFINED BETWEEN 3 FT AND 200 FT FOR THE PERIOD OF 1955 THROUGH 1970 (the points of the rose represent the directions from which the winds come)

FIGURE II.3-25 WIND ROSES AS A FUNCTION OF STABILITY AT N AREA BASED ON WINDS AT 200 FT AND AIR TEMPERATURES BETWEEN 3 FT AND 200 FT FOR THE PERIOD OF JANUARY 29, 1970 TO JANUARY 28, 1971 (the points of the rose represent the directions from which the winds come)

TABLE II.3.6

HANFORD ATMOSPHERIC DISPERSION MODEL
DEFINITION OF STABILITIES

<u>Class</u>	<u>$\Delta T/200$ ft in $^{\circ}F$</u>
Very Stable	Greater than or equal to 3.5
Moderately Stable	-0.4 to 3.4
Neutral	-1.4 to -0.5
Unstable	Less than or equal to -1.5

Toward the southeastern section of the Hanford site, 16 point surface wind data summaries are available for the FFTF site and WNP-2 site. Annual wind roses for these sites are given in Figures II.3-26 and II.3-27. A tendency to greater north-south flow on this section of the Hanford site is evident.

Surface wind rose data based on an 8-point compass were compiled from a telemetered network of meteorology stations. A summary of these wind roses plotted on a map of the Hanford site is given in Figure II.3-28. These sensors were placed in locations to define local topographical effects on surface winds as well as to define the general surface flow of winds.

A comparison of the telemetered data from the 300 Area with the FFTF data revealed only minor differences in the annual summaries. This suggests that the more detailed FFTF data may reasonably be considered representative of the 300 Area.

Winds over the site have been studied. Ground released balloon (Pibal) observations from the HMS show that at higher levels winds tend to exhibit stronger westerly components than are observed in the surface wind observations.

FFTF Site at 13 ft
January 1, 1971
through July 1, 1973

FIGURE II.3-26 WIND ROSE FOR THE
FFTF SITE

WNP-2 at 23 ft
 April 1972
 through
 March 1973

FIGURE II.3-27 WIND ROSE FOR THE
 WNP-2 SITE

FIGURE II.3-28 SURFACE WIND ROSES FOR VARIOUS LOCATIONS ON AND SURROUNDING THE HANFORD SITE (the points of the rose represent the direction from which the winds come)

II.3.10 Aquatic Ecology^(a)

II.3.10.1 The Columbia River

The basic physical and chemical characteristics of the Columbia River were presented in previous sections of this report. References 60, 61 and 62 present additional data as well as the three most comprehensive evaluations of the ecological characteristics of the river, mainly in the Hanford to McNary Dam section.

Studies of the various aquatic organisms in the Columbia River, relating mainly to influence of the reactor operation, were conducted for over 25 years; a bibliography with abstracts of these investigations was recently published.⁶³ The following paragraphs summarize the essential ecological characteristics of the major communities. Figure II.3-29 is a simplified diagram of the food-web relationships in selected Columbia River biota and represents the probable major energy pathways.

II.3.10.1.1 Phytoplankton

Diatoms are the dominant algae in the Columbia River, usually representing over 90% of the population. The main genera include Fragilaria, Asterionella, Melosira, Tabellaria, and Synedra. Lentic forms that originate in the impoundments behind the upstream dams are dominant in the Hanford section of the river. Peak biomass of net phytoplankton amounted to about 2.0 g dry wt/m³ and winter numbers were less than 0.1 g dry wt/m³.⁶⁴ A spring increase, with a second pulse in late summer and autumn, has been observed in other studies in the Columbia River.^{65, 66} Green algae and blue-green algae occur mainly in the warmer months, but in substantially fewer numbers than the diatoms.

(a) A more detailed description of the Aquatic Ecology of the Hanford Reservation is given in Appendix II.3-F.

II.3-67

FIGURE II.3-29 FOOD WEB IN THE COLUMBIA RIVER

II.3.10.1.2 Periphyton

Periphytic communities develop on suitable solid substrates wherever sufficient light occurs for photosynthesis. Dominant diatom genera include Melosira and Gomphonema; in spring and summer luxuriant growths of the filamentous green algae Stigeoclonium and Ulothrix occurs. Net Production Rate (NPR), as measured from 14 day colonization of artificial substrates, varied from 0.07 mg dry wt/cm²/day in August to less than 0.01 mg dry wt/cm²/day in December and January.⁶⁷

II.3.10.1.3 Macrophytes

Emergent macrophytic vegetation is extremely sparse and is usually found in slack-water areas. Some rushes and sedges occur in flooded areas.

II.3.10.1.4 Zooplankton

In the Hanford stretch of the Columbia River zooplankton populations are generally sparse. They are associated with benthic deposits in slack water areas near the edge of the river with cladocerans being more abundant than copepods.⁶⁸ Twenty-four species of Cladocera and Copepoda have been identified in McNary Reservoir.⁶⁹ This reservoir receives water from the Yakima, Snake and Walla Walla Rivers as well as from the Columbia, all of which may contribute to the zooplankton population.

II.3.10.1.5 Benthos

Benthic biota consist of organisms which are either attached or closely associated with the substrate. Dominant organisms presently found in the free-flowing Columbia include insect larvae, sponges, molluscs, flatworms, leeches, crayfish, and oligochaetes. The daily fluctuating water levels caused by the manipulation of flow by an upstream hydroelectric dam have destroyed a part of this fauna in the littoral zone. Near the old Hanford townsite, midge larvae (Chironomidae) and caddis fly larvae (Trichoptera) are the most numerous benthic organisms, averaging 121 and 208 organisms/ft², respectively.⁶⁰ Caddis fly larva and molluscs (Mollusca) are predominant in terms of biomass, averaging 2.24 and

1.23 g wet wt/ft², respectively. Total benthic organisms averaged 375/ft² and 3.59 g wet wt/ft² during 1951-52. These figures are approximations of these populations, due to the difficulty in sampling the entire bottom in a large river such as the Columbia. Sampling was restricted to the shallow shoreline and even there, variations between replicate samples were sometimes greater than seasonal variations.

II.3.10.1.6 Fish

Of the many species of fish in the Columbia River, the anadromous salmon and steelhead trout are of greatest economic importance. Even though the construction of dams and other interferences by man decreased this resource, the Columbia and its tributaries are still major producers of a salmon and trout fishery. An estimate of the local population of these species is difficult to obtain. For the period 1962-1971, the estimated average annual steelhead population in the section of the Columbia River from McNary Dam to Priest Rapids Dam was 16,700.⁷⁰ An estimated 10,000 steelhead spawn annually in the Hanford reach of the Columbia. The average annual fall chinook spawning population in the Hanford reach is about 9,500 fish for the years 1947 to 1972.^{71,72}

Whitefish and steelhead are the species most fished for by sportsmen in the Columbia River in the vicinity of Hanford. From a creel census and household follow-up conducted from 1963 to 1968 in the section from Ringold just downstream of the plant boundary to the mouth of the Snake River, the Washington State Game Department calculated that the average annual catch of steelhead in this area was about 2700 fish. The whitefish are resident in the Hanford section of the river and support a winter sport fishery.

Population estimates of resident coarse fishes, such as suckers and minnows, have not been made. The problems in effectively sampling a river the size of the Columbia preclude definitive measurements. The above-mentioned species constitute a large portion of the resident popu-

lation; other common species include sculpin, dace, sturgeon, sticklebacks, and bass. Thirty-nine species of fish have been identified in the Hanford area of the Columbia River.

II.3.10.2 100-N Overflow Trench

Liquid waste from the N Reactor flows into a crib from which the overflow goes into a 1600-ft long dispersal trench. Water seeping from the trench passes through about 2000 feet of soil before reaching the Columbia River.

No ecological studies have been performed on this dispersal trench, although periphytic algae and associated microscopic organisms are probably present as well as possibly some insect larvae. The trench was occasionally used by waterfowl until it was partly screened and back-filled to prevent their access.

II.3.10.3 200-Area Ponds and Ditches

A number of ponds and ditches in the vicinity of the 200 East and 200 West Areas have received low-level aqueous waste since the project's inception. Ecological studies have not been performed on the majority of the sites because they occur within controlled access areas and present no known radiological problems involving the biota. The ditches generally have sand substrates with a rapid rate of infiltration. Vegetation grows abundantly along the shores.

Ecological studies have been in progress since June 1972 on Gable Mountain Pond and since July 1973 on U Pond. The shoreline vegetation around Gable Mountain Pond is predominately cattails and rushes. Open sections are present near the inlet and at the northwest end where the overflow passes through a culvert in a dike. Figure II.3-30 represents the basic food web present in Gable Mountain Pond and U Pond. The biota is rich in terms of species diversity but additional work is needed to quantify the various populations. Quantitative sampling is in progress on the 22-acre U Pond. The daily thermal regime of the pond depends

FIGURE II.3-30 FOOD WEB IN GABLE MOUNTAIN POND AND U POND

primarily upon the incoming water and secondarily on atmospheric and solar heat; however, the range within which the pond fluctuates is influenced by seasonal changes in solar and atmospheric heat. Primary productivity is closely related to seasonal changes in insolation and temperature, and striking pulses occur during the warmer months when wind and cloud cover are minimal. The pond supports a simple food web based mainly on detritus and sedimented organic matter. Primary producers are mainly phytoplanktonic green algae (*Chlorococcales*) and several emergent vascular plants. Benthic detritivores and scavengers include chironomid larvae, oligochaetes, amphipods, and mayfly and beetle larvae. Goldfish, a recent accidental introduction and the only nektonic form, also scavenge the bottom. Dragonfly larvae constitute the only known carnivores in the pond.

II.3.10.4 300 Area Waste Ponds

The two ponds, totalling about 12 acres, receive low-level liquid waste generated in the 300 Area laboratories and reactor fuel canning complex. The south pond is presently dry but could receive water again. Since copper and uranium are usually present in the waste, a layer of copper hydroxide is on the bottom.

No ecological studies have been conducted on these ponds. Vascular plants grow down to the water's edge, but the pond proper is unsuitable for aquatic life. A few ducks frequent the ponds and the sanitary waste leach trenches alongside.

II.3.10.5 Rattlesnake Springs

Rattlesnake Springs, located on the Arid Land Ecology (ALE) Reserve, is a permanent spring which begins from groundwater seepage and is subsequently fed by small groundwater springs along its course. It flows for approximately 2 miles, starting at about 0.4 cfs and disappearing into the ground. The stream bottom is composed of sand and gravel, with rubble in some areas. The biotic communities in the stream are subjected to periodic flash floods in winter, depending upon weather conditions. Despite these floods the stream supports a diverse flora and fauna.

II.3.10.5.1 Phytoplankton and Periphyton

Some 90 species of algae in Rattlesnake Springs were collected and identified. Slightly over half of the species are diatoms; in summer green algae such as Spirogyra and Cladophora are the second most numerous group and are dominant in terms of biomass.

II.3.10.5.2 Macrophytes

Cattails and sedges occur along the stream, especially where it is not shaded, but the overwhelmingly dominant macrophyte is watercress, Rorippa nasturtium-aquatica. This seasonal plant occupies from 2 to 85% of the total stream area.⁷³

II.3.10.5.3 Invertebrates

Several groups of invertebrates occupy the stream, although the species diversity is highly dependent upon the size of the winter floods, if any, and the resulting physiognomy of the stream. No exhaustive taxonomic study has been made of the invertebrates; dominant forms present include midge larvae, blackfly larvae, and molluscs.

II.3.10.6 Other Springs on the ALE Site

Approximately 14 other permanent and intermittent springs occur on the ALE site. No ecological studies have been made on these springs, but qualitative collections were made for certain organisms. Algae was collected at a few sites, and the crayfish, Pacifasticus leniculatus, was collected for laboratory experiments.

II.3.11 Terrestrial Ecology^(a)

II.3.11.1 Climatic Influences

A term frequently chosen to describe the Hanford region is "steppe", referring to its general resemblance to the steppeland of central Asia. The region is called a shrub-steppe⁷⁴ to differentiate it from true steppes having more grasses and fewer shrubs. Steppes have some characteristics in common: 1) little precipitation and 2) wide daily and annual temperature ranges. Aridity arises at Hanford from its geographical location in the rainshadow of the Cascade Mountains. Lying in the path of frequent winter storm tracks, the Hanford region is visited by many winter storms that bring clouds but little water. However, precipitation is relatively high during all winter months (about 2 or 3 cm per month). Although June exhibits a secondary maximum, the June precipitation is too little and too late to be of substantial importance to the vegetation, because the rains usually wet the soil only to a depth of 20 cm or less, well within the reach of evaporation by the high

(a) A more detailed description of the Terrestrial Ecology of the Hanford Reservation is given in Appendix II.3-G.

insolation intensities and warm soil temperatures of that season.^{75,76} Consequently, the precipitation of importance to vegetation is that which is stored as soil water during the cool season.⁷⁷

II.3.11.2 Vegetation

The vegetation mosaic of the Hanford Reservation (Figure II.3-31) consists of eight major kinds of shrub-steppe communities identified by the most conspicuous or most abundant plant species:

- Sagebrush/bluebunch wheatgrass (Figure II.3-32 and Figure II.3-33)
- Sagebrush/cheatgrass or sagebrush/sandberg bluegrass (Figure II.3-34 and Figure II.3-35)
- Sagebrush-bitterbrush/cheatgrass (Figure II.3-36)
- Greasewood/cheatgrass-saltgrass (Figure II.3-37)
- Winterfat/sandberg bluegrass (Figure II.3-38)
- Thyme buckwheat/sandberg bluegrass (Figure II.3-39)
- Cheatgrass-tumble mustard (Figure II.3-40)
- Willow (Figure II.3-41)

Figure II.3-42 shows the location and direction of view for each of the preceding photographs.

On the Hanford Reservation, the sagebrush/bluebunch wheatgrass vegetation-type occupies extensive acreage in the Rattlesnake Hills and is mostly confined to the ALE Reserve. Bluebunch wheatgrass is the most important livestock forage plant here. The most broadly distributed vegetation-type on the Reservation is the sagebrush/cheatgrass-bluegrass association. This vegetation-type occurs as a broad zone between the sagebrush/bluebunch wheatgrass type and the sagebrush-bitterbrush/cheatgrass type. Spiny hopsage and rabbitbrush may be intermingled with sagebrush shrubs. The general paucity of herbaceous cover tends to favor invasion by tumbleweed, with or without fire.

FIGURE II.3-31 DISTRIBUTION OF VEGETATION TYPES
ON THE HANFORD RESERVATION

FIGURE II.3-32 SAGEBRUSH/BLUEBUNCH WHEATGRASS COMMUNITY. (The shrub is big sagebrush and the large bunchgrass is bluebunch wheatgrass.)

FIGURE II.3-33 SAGEBRUSH/BLUEBUNCH WHEATGRASS COMMUNITY. (Burned in 1957. The shrub in the foreground is rabbitbrush, a shrub that can sprout following fire damage; sagebrush is usually killed by fire.)

FIGURE II.3-34 SAGEBRUSH/CHEATGRASS COMMUNITY. (The shrub is big sagebrush, the dense grass understory is mostly cheatgrass, an alien weed introduced into the Pacific Northwest with the advent of livestock grazing and agriculture. These growths are prevalent on the low-elevations of the Hanford Reservation.)

FIGURE II.3-35 : SAGEBRUSH/SANDBERG'S BLUEGRASS COMMUNITY. (The shrub is big sagebrush and the sparse understory grass is Sandberg's bluegrass.)

FIGURE II.3-36 SAGEBRUSH-BITTERBRUSH/CHEATGRASS COMMUNITY. (The light colored shrub is sagebrush and the dark colored shrub is bitterbrush. The understory is mostly cheatgrass.)

FIGURE II.3-37 GREASEWOOD/CHEATGRASS-SALTGRASS COMMUNITY. (The shrub clump in the foreground is greasewood, the understory grasses are a mixture of cheatgrass and saltgrass.)

FIGURE II.3-38 WINTERFAT/SANDBERG'S BLUEGRASS COMMUNITY.. (The short-statured shrub in the foreground is winterfat..)

FIGURE II.3-39 THYME BUCKWHEAT/SANDBERG'S BLUEGRASS COMMUNITY.
(Appearing at high elevations on the ALE Reserve, the low-growing cushion-like plants are thyme buckwheat.)

FIGURE II.3-40 CHEATGRASS-TUMBLE MUSTARD COMMUNITY. (This occupies a 30-year old abandoned wheatfield at midelevation on the ALE Reserve.)

FIGURE II.3-41 WILLOW COMMUNITY. (Located at Rattlesnake Springs on the ALE Reserve.)

FIGURE II.3-42 LOCATION AND DIRECTION OF VIEW FOR PLANT COMMUNITY PHOTOGRAPHS

The sagebrush-bitterbrush/cheatgrass vegetation-type occupies the low elevations in the southeastern sector of the Hanford Reservation. Snow eriogonum, a small shrub, is often locally abundant. The sagebrush-bitterbrush/cheatgrass vegetation-type occupies the sandiest soil short of dunes. The colonization of sandy soils in an arid environment is a slow process, especially if large areas are affected--by fire, for example--and seed sources severely reduced (Figure II.3-33). The most efficient early invader of burned areas in the sagebrush-bitterbrush/cheatgrass vegetation-type is tumbleweed. Bitterbrush is an important forage plant for mule deer, especially in fall and winter.

The greasewood/cheatgrass-saltgrass vegetation-type is restricted to a small area of about 100 acres in the vicinity of Rattlesnake Springs.⁷⁸ This vegetation-type is important because the geographic distribution of greasewood is determined by the presence of a relatively shallow water table.

The winterfat/sandberg bluegrass vegetation-type occupies several thousand acres along the gentle lower slopes of the Rattlesnake Hills. For the most part, the geographic distribution of winterfat in the Pacific Northwest is restricted to the ALE Reserve.

The thyme buckwheat/sandberg bluegrass vegetation-type occupies thin, stony soils along ridge crests in the Rattlesnake Hills and Gable Mountain areas. These communities have no potential for agricultural use and provide limited forage for livestock and wildlife, but they possess great aesthetic value because of the presence of many species with showy flowers.

The cheatgrass-tumble mustard vegetation-type occupies abandoned agricultural fields, especially in the 100 Areas and at Benson Ranch and Snively Range on the ALE Reserve. This vegetation-type consists mostly of alien annual plants, i.e., cheatgrass and annual mustards; it has, over the past 30 years, resisted invasion by native perennial grasses and shrubs and colonization by tumbleweed. Cheatgrass-tumble mustard

communities in the absence of livestock grazing are effective in binding soil against wind and water erosion and have practical value in revegetation of highly disturbed soils.

Willow vegetation occurs along the banks of the Columbia River, waste ponds in the 200 Areas, abandoned agricultural irrigation ditches in the 100 Areas and along permanent spring courses in the Rattlesnake Hills. Although the amount of acreage occupied by willow communities is small, their value to wildlife is large. Willows and associated deciduous trees, shrubs and herbaceous plants provide food and nest sites for game and song birds, summer forage, and cover for mule deer.

Miscellaneous vegetation-types occur throughout the Hanford Reservation. Of particular importance are deciduous trees around waste ponds,⁷⁹ abandoned homesteads and abandoned military installations that provide nesting and resting sites for raptorial birds of prey. Appendix II.3-G presents a current floristic list for the Hanford Reservation.

The historical pattern of plant succession in the steppe region of Washington was altered during the past century by the introduction of annual weeds from the steppes of Eurasia. One of the most aggressive of these plants is cheatgrass. Cheatgrass is well adapted to the fall-winter precipitation regime of the area, its seeds are highly viable, and seedling growth is more competitive than that of native perennial grasses.⁸⁰ Agricultural fields abandoned for 30 years continue to be dominated by cheatgrass; apparently the competition for soil water and available essential mineral nutrients is sufficient to exclude other kinds of plants for long periods of time.

Tumbleweed, another exotic plant, has an effective method of seed dispersal. Tumbleweed is not as competitive as cheatgrass in most habitats, but it is the most successful colonizer of habitats where cheatgrass is suppressed by mechanical means or herbicides or in soils with heterogeneous texture. In the absence of physical disturbance, cheatgrass and

tumbleweed are not effective in invading pristine steppe communities. Nevertheless, cheatgrass and tumbleweed will tend to become more important on the Hanford Reservation as more soil is disturbed by construction and waste burial sites.

II.3.11.3 Mammals

The mule deer is the only big game mammal found on the Hanford Reservation. Most of the mule deer on the Hanford Reservation live along the Columbia River, with smaller concentrations near Gable Mountain and the 200 Area, at Rattlesnake Springs, and on the Snively Ranch area in the Rattlesnake Hills.

The cottontail rabbit is the most abundant small game mammal, with small populations scattered throughout the Reservation area. The raccoon is probably the most abundant furbearing mammal on the Hanford Reservation, mostly confined to shoreline areas of the Columbia River and waste ponds in the 200 Areas. Beaver and muskrats occur in backwater areas of the Columbia River; muskrats are found also in waste ponds and ditches in the 200 Areas. Mink occur along the Columbia River while weasels are scattered throughout the Hanford area. The coyote is abundant on the Hanford Reservation as compared to adjacent land areas, although no accurate estimate of population density has been made. The bobcat and badger are present on the Reservation, but in low numbers.

The jackrabbit is widely distributed on the Hanford Reservation; however, it is less abundant in the sagebrush/bluebunch wheatgrass vegetation than in the sagebrush/cheatgrass and sagebrush-bitterbrush/cheatgrass vegetation-types. The jackrabbit is an important food item for coyotes and raptors.

The porcupine is widely distributed over the Reservation area but is especially abundant along the Columbia River. Porcupines occur in the 200 Areas and in the canyons and valleys of the Rattlesnake Hills.

Small mammals are abundant on the Hanford Reservation, particularly the Great Basin pocket mouse. Deer mice and ground squirrels are locally

abundant, as is the pocket gopher. The kangaroo rat is not found on the Hanford Reservation although it is common in the steppe region of Oregon.

Appendix II.3-G presents a species list of the mammals (and other vertebrates) that occur on the Reservation.

II.3.11.4 Birds

The chukar partridge is the most important upland game bird on the Hanford Reservation. Most of the population is concentrated on the ALE Reserve, especially the Rattlesnake Hills, but there are local populations in the Gable Mountain area. Chinese ring-necked pheasants are present on the Hanford Reservation but in small numbers, and California quail are present as scattered local populations along the Columbia River. Mourning doves are migratory birds that nest throughout the Hanford Reservation area during the spring months.

Sage grouse are present in small numbers. In recent years, sightings generally occurred in the Rattlesnake Hills on the ALE Reserve. Over the years the sage grouse population has declined in southeastern Washington as pristine habitat was converted to dryland wheat and irrigated agricultural fields. The most abundant birds in steppe vegetation are the western meadowlark and the horned lark.⁸¹

The Canada goose is the most important of the nesting waterfowl on the Hanford Reservation; the nesting habitat is confined to islands in the free-flowing reach of the Columbia River.⁸² The Columbia River also provides a resting sanctuary for migratory flocks of ducks and Canada geese. At peak migratory periods, 70,000 birds--mostly mallards--occupy the Hanford reach of the Columbia River.

Raptorial birds use the Hanford Reservation as a refugium from human intrusions, especially during the nesting season.

Trees around abandoned farms in the 100 Areas and around abandoned military installations provide nesting habitat for red-tailed hawks, Swainson's hawks, and great horned owls. Prairie falcon nests are

located on Gable Butte and along Umtanum Ridge.⁸³ The sparrow hawk is the most abundant of the raptorial birds. The marsh hawk nests on the Hanford Reservation (as does the burrowing owl), but the osprey is only an occasional visitor along the Columbia River. The golden eagle and the bald eagle are both winter visitors. The raptorial birds are of particular interest because their ancestral ranges are being steadily reduced by human encroachment. Relatively large areas of uninhabited land, such as the Hanford Reservation, provide a nesting and foraging ground for raptorial birds.

II.3.11.5 Snakes and Lizards

As compared to southwestern United States desert areas, the herpetofauna of south-central Washington is sparse. The most abundant reptile in low elevation steppe vegetation is the sideblotched lizard. The horned lizard is not common and the sagebrush lizard is scarce. The most abundant snake is the gopher snake, but the yellow-bellied racer and the Pacific rattlesnake are common. The coachwhip snake and the desert night snake are seldom observed. Snakes are an important food item for the Swainson's hawk.

II.3.11.6 Insects

A preliminary list of insect species known to inhabit this area is given in Appendix II.3-G. This list will probably continue to be updated for several years as additional specimens are found. It is probably safe to assume that the species which contribute significantly to insect abundance are contained in this list.

Leafhoppers (Cicadellidae), aphids (Aphididae) and plant hoppers (Fulgoroidea) are all present, but members of the superfamily Coccidea are the most abundant. The Coccidea are primarily mealybugs (Pseudococcidae), most of which occur in association with bluebunch wheatgrass. Cicadas may periodically be conspicuously present in this area, primarily due to the buzzing "song" produced by the males.

The order Orthoptera contains the well known family Acrididae (grasshoppers) which are frequently very destructive members of grassland communities. The grasshopper possessing the greatest potential for outbreak in this area is the migratory grasshopper (Melanoplus sanguinipes). Localized concentrations have occurred at Hanford in the past⁶⁴ and will probably continue to do so in the future. These concentrations appear to occur only in the cheatgrass-tumble mustard vegetation.

The order Coleoptera (beetles) constitutes the largest insect order and contains nearly 50% of all known insect species. They are a very diverse group, inhabiting nearly all conceivable types of habitat. Some important predacious beetle families in this area are the ground beetles (Carabidae) tiger beetles (Cicindelidae), checkered beetles (Cleridae) and ladybird beetles (Coccinellidae). The weevils (Curculionidae) are probably the most important group of plant eaters in this order. Sixteen species of darkling beetles are known to occur in this area. Two species, Philolithus densicollis and Stenomorpha puncticollis, can be particularly abundant. Philolithus is very much more abundant in native grasslands than in cheatgrass swards, while Stenomorpha, somewhat less abundant than Philolithus, is less sensitive to vegetation type, but Stenomorpha does not occur at low elevations.

The order Hymenoptera (ants, wasps, bees) contains a great number of species that are either predators or parasites, as well as the plant pollinators essential for ensuring fertilization of many flowering plant species. The ants (Formicidae) can be an important component of natural systems, but they are not abundant on the Reservation. Ants apparently occur in all vegetation types. Members of the family Sphecidae are solitary wasps. The Ichneumonidae, another important Hymenopteran family, also attack a great variety of insect hosts. However, unlike the Sphecids (who paralyze and drag their prey to a burrow), the Ichneumonids are mostly internal parasites of immature stages of the host. Wasps are very mobile and occur in all vegetation types.

The collembola (springtails) play a dual role, some members feeding on decomposing plant material, others feeding directly on living plant tissue. Collembola are very common in any mulch layer but are frequently overlooked, due to their tiny size. The most abundant collembola species belongs to the family Sminthuridae, sometimes called the globular springtails.

In Appendix II.3-G is a distribution list of the abundant plants and animals in the several vegetation types, arranged in order of decreasing elevation. This listing demonstrates clearly that animals are more ubiquitous than plants.

II.3.11.7 Rare or Threatened Species

Allium robinsonii, a wild onion restricted to Columbia River gravel bars between Wenatchee and John Day, may occur on the Hanford Reservation, the last stretch of free-running river. The rocky soils on the ridge crests of the Rattlesnake Hills hold an endemic species of Balsamroot, Balsamorhiza rosea, but this species is locally abundant and not endangered at this time.

The Hanford Reservation provides a refugium for several rare, threatened or indeterminate species, all raptors.⁸⁵ The prairie falcon (Falco mexicanus) nests in several regions on the Reservation, with the number of nesting pairs probably in the dozens.⁸³ The American peregrine falcon (Falco peregrinatus anatum) apparently does not nest on the Reservation but does in neighboring regions, probably in small numbers. Species lacking specific data to attest to their status but considered to be possibly in some danger⁸⁵ include the ferruginous hawk (Buteo regalis), which nests in several sites on the Reservation but in small numbers; the American osprey (Pandion haliaetus carolinensis), only a visitor; and the northern long-billed curlew (Numenius americanus parvus) and the western burrowing owl (Speotyto cunicularia hypugaea), both of which nest on the Reservation in small but significant numbers.

II.3.11.8 Primary Productivity (Plants)

Arid and semiarid lands are not as biologically productive as humid or wet lands which can produce 2 or 3 kg/m² annually. In contrast, deserts produce about 70 g of herbage/m². Cheatgrass-tumble mustard communities on the ALE Reserve over the last 5 years produced herbage yields ranging between 110 and 330 g/m².⁷⁷ However, cheatgrass communities produce more herbage than sagebrush-grass communities. The annual productivity of pristine stands of sagebrush-bunchgrass was determined⁷⁴ to be about 100 g/m². On the ALE Reserve, annual production of herbage has been about 120 g/m² in a sagebrush-grass community.

There are pronounced differences in species diversity between cheatgrass communities and the sagebrush-grass communities: nine species of plants, eight of which are annuals, contribute to the herbage yield of cheatgrass communities. About 20 species contribute to plant biomass in the sagebrush-grass community, and most of these are perennials of several different life forms.

Although herbage production is the visible output of plant growth, a root system is also produced each year. Less than 25% of the root biomass in the cheatgrass community penetrates deeper than 20 cm, compared to 50% for the sagebrush-grass community. The total root biomass is also greater in the sagebrush-grass community compared to the cheatgrass community, 1200 versus 800 g/m².

II.3.11.9 Mineral Uptake and Cycling

Herbage provides a source of energy, protein and essential minerals for herbivorous animals, but the amount of energy available to consumers is quite variable. The average heat of combustion (total heat release, or caloric content) varies from 3.8 kcal/g for cheatgrass leaves to 6.1 kcal/g for mustard leaves. Sagebrush leaves and native grasses fall in between. Although a crude measure of energy such as this does not measure usable energy, the relative contribution of the various species to digestible energy is probably similar.

Plants extract minerals from the soil solution for their own functioning, making these minerals available for consumer organisms. The amount of stable mineral elements that plants obtain from the soil in which they grow is important to radiation ecology, because some plants, such as greasewood,⁸⁶ accumulate mineral elements to significant concentrations.

Continuous maintenance of life requires that mineral nutrients currently bound up in plant and animal life eventually be returned to a common nutrient pool for use by succeeding generations. The rate of return is mostly governed by the activity of microflora and microfauna, organisms of decay which live on or in dead biotic material. The metabolic activity of these microbiota (measured by CO₂ evolution from the soil) is rather closely attuned to environmental conditions of temperature and moisture.⁸⁷ High levels of both temperature and water induce high levels of soil CO₂ evolution, but the climate of the Hanford Reservation precludes such coincidence in general. Consequently, soil CO₂ evolution is usually low, implying relatively little microbiotic activity compared to, say, a humid climate.

Measurements of loss from litter bags over a 2-yr period indicated that cheatgrass litter disappearance can be accurately thought of as an exponential process with a half-time of 6 ± 1 year, much slower than the 1 or 2 year half-time noted for bluebunch wheatgrass.

Sagebrush casts about 90% of its leaf biomass in early summer, presumably a period of relatively slow decomposition, but weight losses⁸⁸ from litter bags imply a half-time of about one year, very much faster than cheatgrass leaves and stems. However, leaf and inflorescence litter--the annual portion of sagebrush biomass--represent only about half of 1% of the total standing crop. No detectable weight losses of bark, branches, and buried roots occurred even after 2 1/2 years,⁸⁸ indicating that minerals in these portions of the sagebrush community remain unavailable for a relatively very long time.

II.3.11.10 Animal Populations

Most of the animals on the Hanford Reservation are nongame species having no direct link to man through the food he eats. However, these animals provide food for predators. Some of the most abundant animals on the Hanford Reservation in terms of biomass per unit area are darkling beetles, which have attained an estimated peak biomass of 2 g/m^2 (20 lb/acre) in cheatgrass communities.⁸⁹ These beetles can provide an important food supply for some predators in autumn when adult beetles are active on the soil surface for a few weeks.⁹⁰

Coyotes are wide-ranging animals that have the potential for wandering on and off the Hanford Reservation boundaries in search of food. Coyotes have disrupted the nesting of Canada geese on Columbia River islands.⁸² No studies have been made on the Hanford Reservation to determine the population densities or movements of the coyote, but an aerial patrol maintained for the ALE Reserve keeps casual coyote sightings recorded; the number of sightings doubled in recent years compared to 1969-1970.

The relative freedom from "people use" makes the Hanford Reservation an attractive nesting refugium for large raptors. A scarcity of suitable places to build nests is one of the reasons for low density nesting populations of Swainson's and red-tailed hawks.⁸³ Marsh hawks, sparrow hawks, prairie falcons, burrowing owls and great-horned owls are known to nest on the Hanford Reservation. The golden eagle, bald eagle and osprey frequent the Hanford Reservation in winter as a foraging ground.

The mule deer and the Canada goose are the most important game species that use the Hanford Reservation as a breeding ground. Both rely heavily upon the relative security of the islands in the Columbia River as a sanctuary for rearing young. Over the past four years 180 mule deer fawns were tagged near the Columbia River and released; 17 tags were returned from legal kills and road kills, etc., some from more than 40 miles from the tagging site.⁹¹ A 21-yr history of Canada goose nesting on the islands was summarized recently.⁸³ A recent decline in numbers was attributed to coyote predation during nesting. Over the study period, Hanford's nesting geese had 97.4% fertility, equal to or better than other nesting areas.

II.3.11.11 Food Webs

The dynamic interplay of the many organisms in an ecosystem can best be grasped by considering the rates and routes of energy transfers between species--the "fate and effects" of food in the ecosystem. The following is a synthesis of ecological transfers on the Hanford Reservation, based on a few representative organisms and interactions, beginning with potential transfers to man, then considering a non-anthropocentric ecosystem.

II.3.11.11.1 Transfers to Man

Historically, the unmodified steppe ecosystem of southern Washington provided relatively little food to man. Indian tribes relied mostly upon the Columbia River fishes as a food base. Apparently, steppe vegetation did not support bison nor antelope herds.

Livestock grazing is not widely practiced; mule deer forage to some extent upon steppe vegetation but rely mostly upon riparian vegetation for food and cover. Since deer are mobile animals, some animals that are born on the Reservation are harvested off the Reservation by hunters. The chukar partridge is the most abundant game bird that can subsist on the food and cover provided by unmodified steppe vegetation. Although chukar partridges are not hunted on the Reservation, hunting is common in the Rattlesnake Hills, Yakima Ridge and the Saddle Mountains.

Ducks and geese are the important biota with the potential of contributing to the food chain to man. Hunting is not permitted on the Reservation, which serves as a refugium for ducks and geese during the hunting season. During the peak week of use in 1972, 1,100 ducks and geese were on ponds,⁹² and 70,000 were on the Hanford reach of the Columbia River.

II.3.11.11.2 Food Webs in a Steppe Ecosystem

Figure II.3-43 shows a web of energy and nutrient transfers centering on cheatgrass. Although inadvertently introduced to the region, this grass is well adapted to the Hanford climate; physiologically, it is geared for growth under the cool conditions concurrent with Hanford's wet season. Consequently, green cheatgrass appears (as seedlings) when few perennials are growing, making it desirable forage for a wide variety of animals, including mule deer, coyotes, and chukars. Mature cheatgrass seeds form important food sources for pocket mice and birds. The dead leaves and stems support a large number of microbiota, including mites, insects, nematodes and fungi. Figure II.3-43 demonstrates the motivation for discussing food webs rather than chains, because typically a consideration of "who eats whom" will result in many linked transfers rather than a simple linear cascade of matter and energy through the ecosystem. Similar webs could be constructed around each plant species on the Reservation.

The edges of all food webs involve the same top carnivores--coyotes, eagles, owls, and so on--and all webs have a transfer into the microbiota, indicated by the transfer to fungi and bacteria. Microbiota are critical for continuous functioning of an ecosystem, but generally they are difficult to discuss with the same degree of concreteness as the larger organisms, because they are numerous, small, transient, hard to identify, and difficult to observe in action.

II.3.11.12 Ecological Research Results and Availability

The preceding pages summarized some aspects of the ecological systems of the Hanford Reservations; more could be written based on the many

FIGURE II.3-43 FOOD WEB CENTERED ON CHEATGRASS

years of research at Hanford. A current and complete bibliography of journal articles, annual reports, Battelle documents and other writings by the staff of the Ecosystems Department is available.⁹³ Many of the references in that bibliography devolve directly from ecological research on the Hanford Reservation.

Good bibliographies of (world-wide) publications concerning ecological aspects of radioactive waste management are available, both for radioactive waste in general⁹⁴ and for transuranics⁹⁵ specifically.

II.3.12 Natural Radiation Background and Fallout Radioactivity

The natural radiation background has three components:

- naturally-occurring long-lived radionuclides, predominately ^{40}K , uranium, and thorium, and their radioactive daughters
- direct radiation from cosmic radiation and its secondaries
- nuclides formed by interaction of stable elements with high-energy radiation.

The latter occurs to a significant degree only with the lighter elements in the outer layers of the earth's atmosphere, but large scale atmospheric movements transport the radioactive species to the earth's surface. Tritium and ^{14}C are well-known products, but other nuclides such as ^7Be and ^{22}Na can readily be measured in ambient air. Superimposed on the natural radioactivity is residual fallout from atmospheric weapons testing, mostly tritium and fission products with half-lives of a year or more, (e.g., ^{90}Sr , ^{106}Ru , ^{137}Cs , U, and ^{239}Pu .)

All of these radionuclides are undoubtedly present in all surface environmental media, but even unusually good radioanalyses will show measurable concentrations of only a few of the many possible. Direct radiation at the earth's surface also reflects the combined inventory from all the given sources.

Measurements of background radioactivity in air tend to be quite variable in space and time. Major factors affecting these measurements include:

- distance from soil or ore bodies containing uranium and thorium
- altitude (or depth)
- seasonal movements of large air masses
- occurrence of precipitation
- persistence of atmospheric stability.

Such variability is indicated in Table II.3-7 where ranges of measurements are given.

The Hanford site, at approximately 45° N. Latitude and with elevations from about 300 to 700 feet above MSL, shows less than average (for the U.S.) cosmic radiation. Some indications of small, naturally-occurring uranium and thorium sources are present, mainly as elevated concentrations of radon and thoron daughters during atmospheric inversions. The arid climate tends to minimize the amount of fallout nuclides accumulated in local soils.

II.3.12.1 Direct Radiation

For the last several years the contribution of fallout to the direct radiation has decreased to the point where it constitutes on the average less than 7%⁹⁶ of the total terrestrial exposure. The total-body external dose in the vicinity of Hanford was estimated recently⁹⁸ as 75 to 92 mrem per year.

II.3.12.2 Air

A particulate air sample collected in eastern Washington and counted immediately upon collection would yield predominately radon daughters; RaA, RaB, RaC, and RaC'. If allowed to decay for one week, the radon daughters go through several half-lives and are much less dominant. Shown in Figure II.3-44 is the range of radionuclides measured in airborne particulates with a high-volume sample at Richland, Washington from 1962 through 1972. This chart also shows the timing of atmospheric tests of nuclear weapons in relation to the measured air concentrations

TABLE II.3-7

CONCENTRATIONS OF RADIONUCLIDES IN SURFACE AIR
 AT RICHLAND, WASHINGTON, 1972
 (Background, Fallout and Hanford Contributions)

<u>Isotope</u>	<u>(10^{-3} pCi/m³)</u>	<u>Isotope</u>	<u>(10^{-3} pCi/m³)</u>
⁷ Be	45-90	^{110m} Ag	0.002-0.05
²² Na	0.005-0.03	¹²⁴ Sb	0.005-0.05
⁴⁰ K	0.23-1.8	¹²⁵ Sb	0.4-2
⁴⁶ Sc	0.0005-0.01	¹²⁹ I	3.8×10^{-5} - 38×10^{-5}
⁵⁴ Mn	0.04-0.22	¹³⁴ Cs	0.03-2
⁵⁷ Co	0.01-0.1	¹³⁷ Cs	2-9
⁵⁸ Co	0.005-0.5	¹⁴⁰ Ba	0.05-9
⁶⁰ Co	0.005-0.1	¹⁴⁴ Ce	2-30
⁶⁵ Zn	0.005-0.1	¹⁵⁵ Eu	0.0005-0.005
⁸⁸ Y	0.005-0.04	²²⁶ Ra	0.004-0.03
⁹⁰ Sr	0.5-5	²³² Th	0.01-0.2
⁹⁵ Zr	1.4-45	²³⁸ Pu	0.01-0.2
¹⁰³ Ru	0.5-32	²³⁹ Pu	0.01-0.2
¹⁰⁶ Ru	2.2-14

FIGURE II.3-44a RADIONUCLIDE CONCENTRATION IN SURFACE AIR AT RICHLAND, WASHINGTON. (Background, Fallout and Hanford Contributions)

FIGURE II.3-44b RADIONUCLIDE CONCENTRATION IN SURFACE AIR AT RICHLAND, WASHINGTON. (Background, Fallout and Hanford Contributions)

at Richland, as well as the weapon yield in megatons. ^{238}Pu and $^{238}\text{Pu}/^{239}\text{Pu}$ ratios show the influence of a ^{238}Pu source contained in a space vehicle which burned in the atmosphere in 1967.

II.3.12.3 Columbia River

Table II.3-8 shows the background and fallout nuclides found³⁸ in the Columbia River upstream from Hanford at Priest Rapids Dam in 1972. Uranium concentrations in the river, for which the alpha activity concentrations are an approximation, may have been affected over the long term by such human activities as mining, dam construction, and irrigation, but the local record does not so indicate.

TABLE II.3-8

CONCENTRATIONS OF RADIONUCLIDES IN COLUMBIA RIVER
WATER UPSTREAM FROM HANFORD, 1972
(10^{-9} $\mu\text{Ci/ml}$)

Radionuclide	Analy. Limit	Vernita		
		Max.	Min.	Avg.
Alpha	0.3	0.74	0.30	0.54
^3H	220.	1400	(a)	110.
^{46}Sc	25	(a)	(a)	(a)
^{51}Cr	20	20	(a)	(a)
^{60}Co	15	0.30	(a)	(a)
^{65}Zn	2	2.0	(a)	(a)
^{90}Sr	0.5	2.8	(a)	0.50
^{131}I	1.0	5.2	(a)	1.2
$^{137}\text{Cs}-^{137m}\text{Ba}$	3.0	(a)	(a)	(a)
^{239}Pu	0.01	0.03	(a)	0.008

(a) Less than the analytical limit shown

II.3.12.4 Groundwater

Naturally occurring radionuclides noted in wells in the Hanford region are ^{40}K and members of the uranium and thorium series, all of which are of natural origin. Tritium in the groundwater can be detected near areas of surface recharge occurring since 1955, but in older groundwater, concentrations are less than 10 pCi/liter.

II.3.12.5 Vegetation

For the purpose of this report the vegetation is split into two categories:

- in food chains leading to man
- in natural vegetation not normally eaten by local livestock.

Table II.3-9 gives the values for nuclides found in both categories during 1972 in the general Hanford area.³⁸

II.3.12.6 Sediments

Isotopic concentrations are given in Table II.3-10 for samples collected near or on the Hanford site during 1972. The Columbia River sediment samples for which dates are given were collected behind Priest Rapids Dam upstream from the Hanford site.

II.3.12.7 Miscellaneous Foodstuffs

Miscellaneous foodstuff items³⁸ are collected locally and should be representative of the Hanford area. Radioactivity in gamebirds and food animals collected near Hanford in 1972 is given in Table II.3-11. Radioactivity for 1972 in milk and eggs, collected from both commercial sources as well as local irrigated farms, is shown in Table II.3-12; measurable radioactivity is attributed to non-Hanford sources.

II.3.13 Radiological Status of the Hanford Site and Environment

Radiological surveillance of the Hanford environment began with the first reactor startup in 1944 and has played a significant role, not only in evaluating the adequacy of plant waste management, but also in providing

significant scientific data not otherwise available. Although the relative emphasis has shifted through the years and there has been significant interaction, these two purposes have largely been met by a separate operational surveillance program and a series of special scientific studies. The latter have generally been published in the open literature⁶⁴ as well as in topical reports⁷¹ or in annual reports to sponsoring AEC Divisions.⁷³ In recent years, the routine surveillance program results have been documented and published in a series of annual reports of radiological conditions in the plant environment³⁸ and of the radiological status of the Hanford site;⁹⁷ the status of the groundwater beneath the Hanford site has been documented separately in semiannual reports.⁵² The following sections include extracts from the most recent of all these reports with the exception of the groundwater discussed earlier.

Although the emphasis here is on 1972 measurements, it must be remembered that these data reflect the residual accumulated effects of almost 30 years of plant operation.

II.3.13.1 Columbia River

N Reactor, the only production reactor remaining in operation at Hanford during 1972, uses recirculating, demineralized water as a primary coolant. Waste water containing some radioactive material is discharged to the ground in the 1301-N Crib. Many of the radionuclides are short-lived and disappear quickly due to radioactive decay before reaching the river; others are largely absorbed in soil particles and retained in the soil.

Some residual long-lived activity from previous single-pass reactor operation is still measurable where sediments are accumulated. Scouring by high river flows of these sediments, including those deposited in reservoirs behind each downstream dam, causes seasonal fluctuations in transport rates of those longer-lived nuclides associated with the sediments.

TABLE II.3-9

RADIOACTIVITY CONCENTRATIONS IN VEGETATION NEAR HANFORD - 1972
(pCi/gm - dry weight)

<u>Element</u>	<u>Leafy Green Composite</u>	<u>Natural Vegetation</u>	<u>Grass</u>
^{40}K	24-5.0	2.7-21	1.6-19
^{54}Mn	NA	NA	<0.009-0.12
^{60}Co	NA	<0.04-0.09	<0.001-0.02
^{65}Zn	<0.08	NA	<0.03
^{88}Y	NA	NA	<0.008-0.02
^{89}Sr	0.004-0.008	NA	NA
^{90}Sr	0.008-0.003	0.02-2.1	NA
$^{95}\text{ZrNb}$	0.04-0.14	0.14-2.1	<0.1-4.3
^{106}Ru	<0.08-1.0	<0.4-5.7	<0.06-4.9
^{125}Sb	NA	NA	<0.04-0.71
^{137}Cs	<0.04-0.09	<0.24-5.8	0.14-4.7
^{144}Ce	<0.35	<0.4-4.4	<0.4-7.7
^{155}Eu	NA	NA	<0.01
^{226}Ra	NA	NA	0.1-0.5
^{232}Th	NA	NA	0.02-0.8
^{239}Pu	NA	0.001-0.010	NA
U_{nat}	NA	0.01-0.23	NA

NA - Not Analyzed

TABLE II.3-10

RADIOACTIVITY IN THE COLUMBIA RIVER
SEDIMENT UPSTREAM FROM HANFORD - 1972
(pCi/gm - dry weight)

<u>Element</u>	<u>Sediment</u>
^{40}K	23. 1-29.5
^{54}Mn	1
^{60}Co	1
^{65}Zn	1
^{137}Cs	1-5.6

TABLE II.3-11

RADIOACTIVITY IN GAMEBIRDS AND FOOD ANIMALS NEAR HANFORD, 1972
(pCi/gm - wet weight)

Animal	^{32}P	^{40}K	^{60}Co	^{90}Sr	^{137}Cs	^{239}Pu
Whitefish	<1-1.8	26-4.9	<0.15-0.18	<0.002-0.003	<0.10-0.22	<0.003-0.008
Ducks	NA	<2.4-4.9	<0.15-0.24	<0.002-0.009	<0.10-1.2	<0.003-0.008
Geese	NA	2.4-4.7	<0.15	<0.002-0.017	<0.10-0.97	
Pheasant	NA	<1.8-3.2	<0.15	<0.002-0.006	<0.10-0.15	NA
Chicken	<1	2.0-2.8	NA	<0.002-0.004	<0.03-0.04	
Beef	NA	1.5-2.8	<0.15	<0.002-0.006	<0.02-0.08	NA

NA - Not Analyzed

TABLE II.3-12

RADIOACTIVITY IN LOCAL MILK AND EGGS, 1972³⁸
(pCi/liter - milk; pCi/gm - eggs)

Item	^{40}K	^{89}Sr	^{90}Sr	^{131}I	^{137}Cs
Milk	0.74-1.9	<0.002-0.002	<0.002-0.005	<0.002	<0.03-0.05
Eggs	0.8-1.4	NA	0.002-0.03	NA	<0.03-0.04

NA - Not Analyzed

Table II.3-13 shows the maximum, minimum, and annual average radionuclide concentration in Columbia River water upstream of the plant at Vernita and downstream at Richland for 1972.³⁸ The average radionuclide concentrations were less than 1% of the Concentration Guides (CG) for water for all the radioisotopes in Table II.3-13, except the 2.2% of the CG for an unknown mixture of alpha-emitters. Table II.3-14 shows river transport rates for 1972 of five radionuclides at Richland and at Bonneville Dam, approximately 490 km (240 miles) below the N Reactor. This is the farthest downstream location where river water is routinely sampled as part of the Hanford Environmental Surveillance Program; measurements at this location approximate the annual transport of specific nuclides into the Pacific Ocean. More sensitive high volume measurements for several radionuclides were made at McNary Dam, the first dam downstream from the plant, as part of a special study of the changing inventories of radionuclide content and transport in river sediments following the shutdown of the old single-pass, water-cooled reactors. This data is tabulated in Table II.3-15.

An inventory of radionuclides from Hanford reactors present in the Columbia River and Pacific Ocean was estimated for the year 1970, before the last of the direct-cooled plutonium production reactors was shut down and at a period when shorter-lived activation products (^{24}Na , ^{32}P , ^{46}Sc , ^{51}Cr , ^{56}Mn , ^{65}Zn , ^{76}As) were prevalent in the reactor effluents. This estimate⁹⁸ was based on extrapolation backward from river transport data at Richland.⁴⁰ By the end of 1972, virtually all of the shorter-lived nuclides had disappeared, although a residual of about 1000 Ci of ^{65}Zn (half-life of 8 months) remained. In addition, some 4000 Ci of ^{60}Co and 2000 Ci of ^{152}Eu is estimated to still have been present in the aquatic environment, along with about 30,000 Ci of tritium and 10,000 Ci of ^{99}Tc , and less than 1000 Ci of all other nuclides. Of special interest is the estimated inventory of one to two Ci of ^{239}Pu from the decay of short-lived ^{239}Np in the reactor effluents. Virtually all of the tritium and most of the other radioactivity was transported

TABLE II.3-13

CONCENTRATIONS OF RADIONUCLIDES IN COLUMBIA RIVER WATER FOR 1972

(10⁻⁹ μ Ci/ml)

Radionuclide	VERNITA						RICHLAND						C.G.
	Analy. Limit	No. of Samples	Max.	Min.	Avg.	Percent of C.G.	Analy. Limit	No. of Samples	Max.	Min.	Avg.	Percent of C.G.	
Alpha	0.3	12	0.74	0.30	0.54	1.8	0.3	12	0.92	0.48	0.67	2.2	30
³ H	220	12	1400	*	110	0.003	220	12	1300	*	110	0.003	3,000,000
³² P	6.						6.	11	*	*	*	<0.02	20,000
⁴⁶ Sc	25.	5	*	*	*	<0.01	25.	53	*	*	*	<0.01	40,000
⁵¹ Cr	20.	5	20.	*	*	<0.01	300	53	700	*	94.	0.005	2,000,000
⁶⁰ Co	15.	5	0.30	*	*	<0.01	15.	53	42.	*	*	<0.02	17,000
⁶⁵ Zn	2.	5	2.0	*	*	<0.01	2.0	4	2.0	*	*	<0.01	100,000
⁹⁰ Sr	0.5	12	2.8	*	0.50	0.17	0.5	13	0.55	0.12	0.35	0.12	300
¹³¹ I	1.0	5	5.2	*	1.2	0.67	6.0	26	6.4	*	*	<0.03	300
¹³⁷ Cs- ^{137m} Ba	3.0	8	*	*	*	<0.01	3.0	7	*	*	*	<0.01	20,000
²³⁹ Pu	0.01	4	0.03	*	0.008	0.0005	0.01	4	0.06	*	0.02	0.001	1,700

* Less than the analytical limit shown.

No entry indicates no specific analysis was made.

TABLE II.3-14

ANNUAL AVERAGE TRANSPORT RATES OF SELECTED RADIONUCLIDES
IN THE COLUMBIA RIVER AT RICHLAND AND AT BONNEVILLE DAM, 1972

(Ci/day)

	Richland			Bonneville Dam
	Max.	Min.	Avg.	
⁴⁶ Sc	<15.	0	<1.7	<0.1
⁵¹ Cr	340	0	<36	--
⁶⁰ Co	42	0	<3.9	--
⁶⁵ Zn	28	0	<3.1	<1
¹³¹ I	1.7	<0.04	<0.35	--

TABLE II.3-15

ANNUAL AVERAGE RADIONUCLIDE CONCENTRATIONS
IN COLUMBIA RIVER AT McNARY DAM--1972

(10⁻¹² μ Ci/ml)

	⁶⁰ Co	⁶⁵ Zn	¹³⁷ Cs	⁵⁴ Mn
Filterable	180	190	132	39
Non-Filterable	18	24	16	22
Total	198	214	148	61

via the river and was distributed over thousands of square miles of ocean. Estimates of the environmental inventory from Hanford operations are currently being reviewed and the quantities given here are subject to change; however, these estimates are believed to provide upper limits.

AEC-sponsored research studies at the University of Washington and Oregon State University have, among many other objectives, been addressed to the distribution, fate, and significance of radionuclides of Hanford origin in the Columbia River estuary and the Pacific Ocean and its connecting bodies of water. The results of these studies were published in a number of graduate theses and scientific papers ^{99,100} as well as a series of annual progress reports to the Atomic Energy Commission. Perhaps the best summary of this work through 1971 is given in a collection of articles in Reference 101. Several contributors to this volume noted the usefulness of the low concentration of radioactivity in the river water as radioactive tracers for their investigations. Documentation is provided for 1) the seasonal changes in distribution of Columbia River water and associated sediments in the ocean, with prevailing northward drift in the winter and southeastward in the summer, 2) the dominance of ⁵¹Cr and ⁶⁵Zn in the measurable radioactivity during the years of direct-cooled reactor operation, and 3) some data on concentration factors for these and other nuclides in shellfish and other marine biota.

As a result of these studies, shellfish from the Willapa Bay location were identified as the critical exposure pathway for Hanford effluents reaching the estuary and sampling of these were incorporated in the Hanford Environmental Surveillance program. As reported in annual surveillance reports, radioactivity in these shellfish has decreased since 1970 at approximately the rate indicated by the radioactive half-life.

II.3.13.1.1 Columbia River Bed--Contamination Studies

The radionuclide discharges in the cooling-water effluent of the original single-pass reactors on the Hanford project were formed by neutron activation of 1) impurities in the Columbia River water used to cool the reactors, 2) corrosion products from reactor components, and 3) chemicals used in the water treatment process. In the river, the radionuclides associated with sediment and biota or remained in solution and subsequently were distributed downstream throughout the river system and the Columbia River estuary to the Pacific Ocean. The most abundant radionuclides found in the sediments are ^{54}Mn , ^{60}Co , ^{65}Zn , ^{137}Cs , and ^{152}Eu and ^{154}Eu , although at one time ^{46}Sc and ^{51}Cr were major components. Studies³² show that radionuclide concentrations are somewhat related to particle sizes of the sediments.

II.3.13.1.2 Radioactivity in Drinking Water

The city of Richland, about 75 km (45 miles) downstream from N Reactor, is the first community below the project that uses the Columbia River as a source of drinking water. Pasco and Kennewick, a few miles further downstream, also use the Columbia River as a source of drinking water. The Richland and Pasco water plants use a modern flocculation-filtration treatment method; water for Kennewick is pumped from Raney Well collectors (infiltration pipes) laid in the riverbed.

During 1972, cumulative and grab drinking water samples were collected at the Richland water plant and were analyzed for selected individual radionuclides and gross beta activity (Table II.3-16).³⁸ Average radionuclide concentrations in Richland drinking water samples, except for total alpha were much less than 1% of the CG. The estimated annual GI tract dose for the average Richland resident from the consumption of drinking water derived from the Columbia River was <0.1 mrem. Radionuclide concentrations in drinking water at 100-H were also measured in 1972 during occupancy by non-AEC contractor personnel; the calculated GI tract dose from this source was estimated as 3.2 mrem.

II.3.13.2 Ditches and Ponds

Radionuclide concentrations in samples collected from open waters on the Hanford project during 1972 were well below the plant working limit of 5×10^{-5} $\mu\text{Ci/ml}$. Table II.3-17 shows average 1972 concentrations for open ponds on the Hanford site as determined by routine samples.

II.3.13.3 Airborne Radioactivity

Tables II.3-18 through 21 give a summary of 1972 data for radioactivity in air at and near the Hanford site. Concentrations of ^{131}I in the atmosphere, measured in charcoal samples, were below 2×10^{-14} $\mu\text{Ci/ml}$.

At most locations, both onsite and offsite, the average total beta particulate activity was similar to that of recent years, except that no pronounced summer peaking was observed. The maximum measured beta

TABLE II.3-16

CONCENTRATIONS OF SEVERAL RADIONUCLIDES IN RICHLAND DRINKING WATER - 1972
(10^{-9} $\mu\text{Ci/ml}$)

Radionuclide	Analytical Limit	# of Samples	Concentration			% of Concentration Guide
			Max.	Min.	Avg.	
Alpha	0.67 ^(a)	53	3.9	*	0.71	2.4 ^(a)
Beta ^(b)	0.220	53	0.360	*	*	<0.01
⁴⁶ Sc	23.	53	37.	*	*	<0.01
⁵¹ Cr	300.	53	420.	*	*	<0.01
⁶⁰ Co	20.	53	39.	*	*	<0.01
⁶⁵ Zn	35.	53	84.	*	*	<0.01
⁹⁰ Sr	0.4	12	0.38	*	0.22	<0.7
¹³⁷ Cs- ^{137m} Ba	0.6	53	49.	*	*	<0.01

(a) Concentration Guide for an unknown mixture not including plutonium.

(b) Concentration Guide 2,000,000.

* Less than the analytical limit.

TABLE II.3-17

GAMMA ACTIVITY IN WASTE WATER SAMPLES - 1972
(10^{-9} $\mu\text{Ci/ml}$)

Location	Date	^{46}Sc	^{51}Cr	^{60}Co	^{65}Zn	$^{95}\text{ZrNb}$	$^{106}\text{RuRh}$	^{137}Cs	$^{140}\text{BaLa}$	$^{144}\text{CePr}$
West Lake	6/2	*	*	*	*	*	*	*	*	*
	10/13	*	*	*	*	*	*	*	*	*
Gable Pond	1/14	*	*	*	*	*	*	9.4	*	*
	4/7	*	*	*	*	*	*	37.	*	*
	7/7	*	*	*	*	*	*	90.	*	*
	10/13	*	*	*	*	*	*	32.	*	*
B Pond	1/14	*	*	*	*	59.	*	*	*	*
	4/7	*	*	*	*	*	*	*	*	*
	7/7	*	*	*	*	*	*	*	*	*
	10/13	*	*	*	*	*	*	*	*	*
T Pond	1/14	*	*	*	*	*	*	35.	*	*
	4/7	*	*	*	*	*	*	*	*	*
	7/7	*	*	*	*	*	*	*	*	*
S Pond	1/14	*	*	*	*	*	*	62.	*	*
	4/7	*	*	*	*	*	*	40.	*	*
	7/7	*	*	*	*	*	*	170.	*	*
	10/13	*	*	*	*	*	*	*	*	*
U Pond	1/14	*	*	*	*	*	*	*	*	*
	4/7	*	*	*	*	*	*	*	*	*
	7/7	*	*	*	*	*	*	220.	*	*
	10/13	*	*	*	*	*	*	*	*	*
Redox Pond	1/14	*	*	*	*	*	*	*	*	*
	4/7	*	*	*	*	*	*	*	330.	*
	7/7	*	*	*	*	*	*	*	*	*
216 B 63 Ditch	1/14	*	*	*	*	*	*	*	*	*
	4/7	*	*	*	*	*	*	*	*	*
	7/7	*	*	*	*	*	*	*	*	*
	10/13	*	*	*	*	*	*	*	*	*
331 Pond	1/11	*	*	*	*	*	*	*	*	*
	4/4	*	*	*	*	*	*	*	*	*
	7/11	*	440.	*	*	*	*	*	*	*
	10/10	*	*	*	*	*	*	*	*	*

*Less than analytical limit.

TABLE II.3-18

RADIOACTIVITY IN AIR AT HANFORD ONSITE LOCATIONS - 1972
(10⁻¹² μ Ci/ml)

Analytical Limit	Beta			I-131			Alpha		
	0.02			0.02			0.001		
Location	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.
200 ENC	30.	0.19	4.6	*	*	*	0.060	*	0.004
200 ESE	0.56	0.014	0.294	0.062	*	*	0.012	*	0.002
200 WEC	0.69	0.029	0.228	*	*	*	0.053	*	0.003
Redox	0.58	0.043	0.220	0.043	*	*	0.005	*	0.002
300 Area	0.70	0.016	0.138	0.112	*	*	0.008	*	0.002
ACRMS	1.2	*	0.124	*	*	*			
100-K	0.48	*	0.147						
100-N	0.40	0.023	0.130	0.073	*	*	0.007	*	0.002
100-D	0.46	0.018	0.128						
100-H	0.53	*	0.144				0.008	*	0.002
100-F	0.51	0.022	0.124						
Hanford	1.7	0.015	0.212				0.010	0.001	0.002
Wye Barricade	0.55	0.089	0.243	*	*	*	0.005	*	0.002
Rattlesnake	0.66	0.062	0.187						
ERC	0.41	0.046	0.163						
Yakima Barricade	0.62	0.069	0.189	*	*	*	0.005	0.001	0.002
Vernita	0.36	0.013	0.158						
Wahluke #2	0.43	0.016	0.165						

*Less than the analytical limit.

No entry indicates no analysis was performed.

TABLE II.3-19

ANNUAL AVERAGE CONCENTRATIONS OF SELECTED RADIONUCLIDES IN
AIR HANFORD ONSITE LOCATIONS - 1972
(10^{-12} $\mu\text{Ci/ml}$)

	<u>^{90}Sr</u>	<u>$^{95}\text{ZrNb}$</u>	<u>$^{106}\text{RuRh}$</u>	<u>^{134}Cs</u>	<u>$^{137}\text{Cs}-^{137m}\text{Ba}$</u>	<u>$^{140}\text{BaLa}$</u>	<u>$^{144}\text{CePr}$</u>	<u>Total Pu</u>
<u>Concentration Guides</u>	200	1000	200	400	500	1000	200	1
<u>Active Areas</u>								
Active Area #1	0.021	0.68	*0.80	0.06	3.1	0.61	*	0.00004
Active Area #2	0.003							0.0002
Active Area #3	0.003	0.044	0.16	*0.003	0.049	0.053	0.035	0.0001
Active Area #4	0.001	0.024	0.20	*0.002	0.004	0.047	0.042	0.000004
Active Area #5		0.027	0.24	0.007	0.01	0.13	0.055	
<u>Inner Ring</u>								
Inner SW Quadrant	0.002	0.032	0.26	*0.002	*0.002	*	0.038	0.00003
Inner NW Quadrant	0.001	0.030	0.22	*0.001	0.005	*	0.032	0.000009
Inner East Quadrant	0.001	0.036	0.27	*	0.012	*	0.042	0.00006
Inner NE Quadrant	*0.0008	0.035	0.24	*	*0.0007	*	0.037	0.00002
Inner SE Quadrant	0.001	0.027	0.26	*0.0009	*0.001	*	0.044	0.00002

TABLE II.3-20

RADIOACTIVITY IN AIR AT HANFORD OFFSITE LOCATIONS - 1972
(10^{-12} $\mu\text{Ci/ml}$)

Analytical Limit Concentration Guide	Gross Alpha				Gross Beta				Iodine-131			
	0.001 0.03				0.02 100				0.07 100			
Eastern Quad.	Max.	Min.	Avg.	% CG	Max.	Min.	Avg.	% CG	Max.	Min.	Avg.	% C.G.
Othello	.006	*	.002	6.6	.44	.03	.18	.18	*	*	*	<1
Wahluke W.M.					.50	.01	.14	.14	*	*	*	<1
Connell					.58	.01	.16	.16	*	*	*	<1
New Moon		*			.46	.03	.16	.16	.043	*	*	<1
Eltopia					.40	.04	.15	.15				
Pasco	.005	*	.002	6.6	.35	.03	.17	.17	*	*	*	<1
Kennewick					.44	.03	.16	.16				
Richland	.005	.001	.002	6.6	.43	.04	.17	.17	*	*	*	<1
Berg Ranch	.006	*	.002	6.6	.92	.03	.22	.22	.056	*	*	<1
Ringold	.006	.001	.002	6.6	.57	.03	.18	.18	*	*	*	<1
Byers Landing	.006	.001	.002	6.6	.45	.05	.16	.16	.071	*	*	<1
<u>Perimeter Communities</u>												
Sunnyside					.37	.01	.12	.12				
Ellensburg					.20	.02	.10	.10				
Moses Lake					.35	.03	.14	.14				
Washtucna					.42	.06	.16	.16				
Walla Walla	.004	*	.001	3.3	.45	.02	.15	.15				
McNary Dam	.006	.001	.002	6.6	3.6	.04	.29	.29				
<u>Western Quad.</u>												
Yakima Barr.	.005	.001	.002	6.6	.62	.07	.19	.19	*	*	*	<1
Vernita					.36	.01	.16	.16				
Wahluke #2					.43	.02	.16	.16				
ERC					.41	.05	.16	.16				
Rattlesnake Spr.					.66	.06	.19	.19				
Benton City	.005	*	.002	6.6	.41	.04	.17	.17	*	*	*	<1

* Less than the analytical limit.
No entry indicates no analysis was made.

TABLE II.3-21

AVERAGE CONCENTRATIONS OF SELECTED
RADIONUCLIDES IN AIR, QUARTERLY AVERAGES - 1972
(10^{-12} $\mu\text{Ci/ml}$)

	<u>Average Gross Beta</u>	<u>^{90}Sr</u>	<u>% C.G.</u>	<u>Average Total Alpha</u>	<u>Pu Alpha</u>	<u>% C.G.</u>
Concentration Guide	100	10		.03	.02	
<u>Eastern Quad.</u>						
Jan-March	.115	.001	.01	.002	.000005	.025
April-June	.281	.001	.01	.001	.000015	.075
July-Sept.	.181	.002	.02	.001	.000045	.225
Oct.-Dec.	.092	.0001	.001	.003	.000006	.03
<u>Perimeter Communities</u>						
Jan-March	.109	.001	.01	.002	.000006	.03
April-June	.309	.001	.01	.002	.00002	.1
July-Sept.	.146	.002	.02	.001	.00003	.15
Oct.-Dec.	.059	.001	.01	.002	.000025	.125

particulate activity, 3×10^{-11} $\mu\text{Ci/ml}$, occurred in October at a 200 East Area fence-line location. Annual average beta particulate activity ranged between 1 and 2×10^{-13} $\mu\text{Ci/ml}$ and 2 to 3×10^{-13} $\mu\text{Ci/ml}$ in the 100 and 200 Areas, respectively. Offsite beta activity ranged from 1×10^{-13} to 3×10^{-13} $\mu\text{Ci/ml}$ and averaged about 2×10^{-13} $\mu\text{Ci/ml}$. Total alpha concentrations in air during 1972 averaged about 2×10^{-15} $\mu\text{Ci/ml}$ at most locations. Analyses of composite samples all showed less than 10^{-16} $\mu\text{Ci/ml}$ plutonium. Table II.3 21 shows seasonal variations.

II.3.13.4 Soil and Vegetation

Plutonium concentrations in soil and vegetation at perimeter sampling locations in 1972 were typical of current general levels for the arid western states (Tables II.3-22 and 23). ^{137}Cs was present in several onsite vegetation samples from near the 200 Areas at higher concentrations than at perimeter sites. Concentrations of gamma-emitting radionuclides and ^{90}Sr at perimeter sites are believed to be the result of regional fallout.

TABLE II.3-22
CONCENTRATIONS OF RADIONUCLIDES IN SOIL SAMPLES--1972
(10^{-6} $\mu\text{Ci/g}$)

Location	On-Site													
	^{40}K		^{58}Co		^{60}Co		^{65}Zn		^{90}Sr		$^{95}\text{ZrNb}$		^{106}Ru	
	1 in.	2 in.	1 in.	2 in.	1 in.	2 in.	1 in.	2 in.	1 in.	2 in.	1 in.	2 in.	1 in.	2 in.
W. of 100-N	16.	16.	.03	.11	.08	*	•	*	.04	.05	.29	.31	*	.89
331	16.	16.	•	.04	.11	•	•	*	.05	.06	.20	*	*	.84
FFTF	14.	14.	.07	.04	•	.11	.19	•	.05	.02	.29	.21	.51	.43
Wye Barricade	15.	17.	.03	*	*	*	*	*	.28	.18	.21	*	*	.60
Hanford	13.	14.	.06	*	.10	.10	*	*	.33	.26	*	.14	1.4	.49
100-F	11.	14.	.02	.03	*	*	*	*	.28	.10	•	*	1.2	1.2
200 Fire Station	14.	16.	.03	.03	*	*	*	*	.22	.11	.40	.20	.73	1.4
200-E Hill	15.	11.	*	*	•	*	*	*	.71	.30	*	.42	.53	*
Rt. 4x11A	16.	16.	*	*	*	*	*	*	.21	.05	*	*	.98	.59
Army Loop Road	12.	13.	*	*	*	*	*	*	.39	.05	.33	.38	1.4	.43
Average On-Site	14.	15.	.03	.03	.03	.03	.05	*	.26	.12	.22	.21	.73	.72
Location	Perimeter													
	^{40}K		^{58}Co		^{60}Co		^{65}Zn		^{90}Sr		$^{95}\text{ZrNb}$		^{106}Ru	
	1 in.	2 in.	1 in.	2 in.	1 in.	2 in.	1 in.	2 in.	1 in.	2 in.	1 in.	2 in.	1 in.	2 in.
Benton City	14.	14.	•	*	•	*	*	*	.38	.27	.27	*	*	1.6
ERC	16.	15.	*	*	.07	*	.18	*	.10	.03	*	*	1.5	.72
Rt. 240 CP54	14.	15.	*	*	.04	*	*	*	.20	.09	*	*	.81	*
Rattlesnake Springs	12.	14.	*	*	.10	*	*	*	.01	.03	*	*	.55	*
Yakima Barricade	13.	12.	*	•	*	*	*	*	.12	.11	.24	.04	*	*
Vernita	16.	16.	*	.041	*	.06	.10	*	.10	.04	.25	*	.57	.91
Wahluke #2	12.	14.	*	*	.04	*	*	*	.30	.13	*	.36	.48	*
Berg Ranch	12.	13.	*	.05	*	*	*	*	.20	.07	.25	.30	*	*
Ringold	16.	14.	.11	*	•	*	*	*	.12	.08	.54	*	1.3	*
Byers P.H.	20.	18.	•	*	*	*	*	*	.08	.09	1.2	.28	*	*
Byers Landing	18.	13.	*	*	*	*	*	*	.13	.18	.34	.13	*	*
Riverview	14.	13.	*	*	.15	*	*	*	.23	.17	*	*	.84	.70
North Richland	16.	14.	*	•	*	*	*	*	.32	.18	.23	*	2.2	*
Average Perimeter	15.	14.	.01	.01	.04	*	.02	*	.18	.11	.28	.12	.64	.36

*Less than the analytical limit.

TABLE II.3-22 (Continued)

Location	On-Site													
	¹³⁴ Cs		¹³⁷ Cs		¹⁴⁴ CePr		²²⁴ Ra		²²⁶ Ra		²³⁸ Pu		²³⁹ Pu	
	1 in.	2 in.	1 in.	2 in.	1 in.	2 in.	1 in.	2 in.	1 in.	2 in.	1 in.	2 in.	1 in.	2 in.
W. of 100-N	*	.27	.65	.48	1.2	.76	2.1	1.6	*	.61	*	.006	.015	.022
331	*	*	.15	.25	.41	*	1.7	.88	.59	.62	*	.012	.003	.003
FFTF	.05	*	.13	.06	.39	*	1.0	1.2	*	.47	.004	.006	.005	.011
Wye Barricade	*	*	.76	.42	.79	1.3	1.5	2.4	.50	.79	.003	.005	.014	.016
Hanford	.18	.09	1.2	.31	.53	.89	.54	1.8	*	.56	.005	*	.024	.004
100-F	*	.06	.65	.41	.97	.74	1.6	1.3	*	.44	*	*	.009	.005
200 Fire Station	*	.06	.24	.29	.55	.80	1.2	2.4	.62	.64	*	*	.017	.012
200-E Hill	.08	.04	1.8	.14	.81	.75	.88	1.6	.59	.51	*	*	.023	.008
Rt. 4x11A	*	.07	.49	.30	.40	.51	2.1	2.4	.80	.59	*	*	.009	.009
Army Loop Road	*	*	1.4	.31	*	.84	1.3	3.2	.56	.88	*	.006	.021	.009
Average On-Site	.04	.06	.75	.30	.60	.68	1.4	1.9	.50	.61	.002	.004	.014	.010
Location	Perimeter													
	¹³⁴ Cs		¹³⁷ Cs		¹⁴⁴ CePr		²²⁴ Ra		²²⁶ Ra		²³⁸ Pu		²³⁹ Pu	
	1 in.	2 in.	1 in.	2 in.	1 in.	2 in.	1 in.	2 in.	1 in.	2 in.	1 in.	2 in.	1 in.	2 in.
Benton City	*	.10	1.1	.84	1.3	1.4	1.6	1.8	.61	.55	*	*	.023	.011
ERC	*	.06	.04	*	.68	1.1	2.7	2.2	.69	.47	*	.011	.001	.013
Rt. 240 CP54	.04	.01	.51	.19	1.2	.32	1.9	2.3	.84	.77	.003	.004	.006	.004
Rattlesnake Springs	*	.13	1.5	.35	1.4	*	1.9	1.6	1.3	.86	*	*	.011	.006
Yakima Barricade	*	.07	.26	.36	.52	.93	1.6	1.6	.72	.56	.003	*	.005	.005
Vernita	*	.01	.26	.17	.73	*	.93	2.1	*	*	.008	*	.003	.001
Wahluke #2	*	.14	.72	.16	1.1	1.0	1.3	1.3	*	.81	*	.006	.010	.003
Berg Ranch	*	.12	.23	*	1.1	.65	1.4	1.2	.57	.66	*	.016	.007	.002
Ringold	*	*	.40	.048	.92	.49	1.8	1.8	.48	.94	.005	.016	.008	.022
Byers P.H.	.04	.08	.42	.59	1.8	1.2	1.4	2.6	.78	.88	*	*	.003	.003
Byers Landing	.05	*	.84	.88	1.5	.57	2.6	2.4	.56	.79	*	.003	.006	.013
Riverview	.05	*	.55	.45	.66	.52	1.4	1.6	*	.65	*	*	.008	.009
North Richland	*	*	.75	.36	*	.52	1.3	2.2	.52	.48	.012	.010	.009	.006
Average Perimeter	.01	.06	.58	.34	.99	.67	1.7	1.9	.62	.67	.003	.005	.008	.008

*Less than the analytical limit.

TABLE II.3-23

CONCENTRATIONS OF RADIONUCLIDES IN VEGETATION-1972
(10^{-6} μ Ci/g)

Location	On-Site									
	^{40}K	^{60}Co	^{65}Zn	^{90}Sr	$^{95}\text{ZrNb}$	^{106}Ru	^{137}Cs	$^{144}\text{CePr}$	^{238}Pu	^{239}Pu
										U ($\mu\text{gm/gm}$)
W of 100-N	12.	*	-	.05	.44	3.0	1.2	*	*	.001
331	12.	*	-	.05	.91	3.0	.14	.88	*	.22
FFTF	4.7	.16	-	.08	.79	2.5	1.9	*	*	.004
Wye Barricade	6.9	.12	.46	.17	3.2	*	16.	*	*	.004
Hanford	6.5	*	-	.04	1.7	5.0	4.2	*	.005	.003
100-F	5.8	.15	-	.13	2.6	7.2	7.0	.88	*	.002
Rt 4 x 11A	11.	*	-	.04	.73	1.7	1.6	*	*	*
Redox P.S.	26.	.13	5.5	.34	18.	*	120.	*	*	.007
200 Fire Station	8.9	.11	.44	.13	2.7	*	12.	*	*	.006
200 E. Hill	14.	.11	2.5	.03	8.7	*	55.	*	*	.008
Average On-Site	11.	.09	.89	.10	4.0	*	22.	*	.001	.004
										.07
	Perimeter									
	^{40}K	^{60}Co	^{65}Zn	^{90}Sr	$^{95}\text{ZrNb}$	^{106}Ru	^{137}Cs	$^{144}\text{CePr}$	^{238}Pu	^{239}Pu
Benton City	5.2	*	*	.08	.96	5.2	.73	1.2	.003	.002
ERC	2.7	*	*	.11	2.1	5.7	1.9	4.4	.003	.007
Rt 240 CP54	3.8	*	*	.12	1.5	5.2	2.7	*	*	.002
Rattlesnake Spring	9.7	*	*	.03	1.0	2.9	.97	1.2	*	.010
Yakima Barricade	10.	*	*	.07	1.1	4.6	1.7	*	*	.001
Vernita	7.1	*	*	.11	2.0	3.8	5.8	*	*	.005
Wahluke #2	9.8	*	*	.06	.66	5.7	.71	*	*	.006
Berg Ranch	11.	.09	*	.10	1.4	1.9	1.2	*	*	.004
Ringold	4.2	*	*	.05	.59	2.4	.56	*	.005	*
Byers P.H.	11.	*	*	.05	.84	2.5	3.8	*	.003	.003
Byers Landing	21.	*	*	.07	.34	2.1	1.0	*	.007	.010
Riverview	15.	*	*	.85	.14	*	.24	*	*	.001
North Richland	7.9	*	*	.04	.70	2.4	.79	.82	*	.001
Average Perimeter	9.1	*	*	.13	1.0	3.5	1.7	.30	.003	.004
										.06

*Less than the analytical limit.

II.3.13.5 Biota

Routine sampling of waterfowl and small mammals was attempted at all Hanford waste ponds during 1972, although success of collection was highly variable with the site. Tables II.3-24 and 25 give the results of the radioanalyses of the specimens. The only significant levels of radioactivity were found in mice collected at the 100-N trench. This trench receives the overflow from the 1301-N crib; it is screened to prevent access by birds or large mammals, but mice can penetrate the wire mesh.

Waterfowl and pheasants are collected along the river during hunting season near public hunting areas. Several deer are also collected. Tables II.3-26 and 27 show the radioanalyses for the 1972 samples. Also shown in Table II.3-27 are radioactivity concentrations in Columbia River fish and shellfish from near the mouth of the Columbia. The coyote was a road kill analyzed for reference data. In all river-associated biota, concentrations of Hanford radionuclides showed a significant decline with shutdown of the single-pass reactors.

II.3.13.6 Foodstuffs

Milk, meat, eggs, and produce are all purchased in season from nearby farms, including several irrigated with Columbia River water taken downstream from the reactors, as well as commercial sources for comparison. Table II.3-28 gives the results of this sampling for 1972. Although slight indications of Hanford-originating nuclides exist, by far the greatest part of the radioactivity present is from residual world-wide fallout from nuclear weapons testing.

II.3.13.7 Direct Radiation

The maximum annual average exposure rate measured during 1972 with ground dosimetry was 1.8 mR/day at the fence of the 200 East Chemical Separations and Waste Management Area. The range of exposure rates measured both on and off the Hanford Reservation is given in Table II.3-29.

TABLE II.3-24
CONCENTRATIONS OF SEVERAL RADIONUCLIDES IN SMALL ANIMALS
(10^{-6} μ Ci/g in muscle)

<u>Date</u>	<u>Location</u>	<u>^{24}Na</u>	<u>^{40}K</u>	<u>^{54}Mn</u>	<u>^{58}Co</u>	<u>^{59}Fe</u>	<u>^{60}Co</u>	<u>^{65}Zn</u>	<u>^{90}Sr</u>	<u>$^{95}\text{ZrNb}$</u>
<u>Mice</u>										
2/16	300 Pond	*	*	*	*	*	*	*	0.065	*
2/24	100-N Trench	*	*	*	650.	*	820.	110.	7.9	*
	(Special Diode Count)	*	81.	*	850.	*	*	170.	*	*
2/24	200-E Chem. Ditch	*	*	*	*	*	*	*	0.92	*
4/25	100-N Trench	*	270.	*	640.	*	850.	350.	16.	*
6/14	100-N Trench	*	100.	210.	*	*	210.	55.	30.	*
6/15	U Pond	*	*	*	*	*	*	*	9.9	*
7/20	100-F	*	*	*	*	*	*	*	52.	*
11/29	100-N Trench	*	5.7	5400.	*	7100.	11,000	*	31.	2900.
11/29	300 Pond	*	*	*	*	*	*	*	0.33	*
11/30	200 West	*	*	*	*	*	*	*	0.018	*
<u>Rabbit</u>										
3/15	222 S Pond	*	*	*	*	*	*	*	0.066	*
5/25	300 Pond	*	4.7	*	*	*	*	*	0.010	*
7/31	200-E Area	*	3.2	*	*	*	*	0.14	0.020	*
11/20	100-N Area	*	2.4	*	*	*	*	*	0.004	*

*Less than the analytical limit.

TABLE II.3-24 (Continued)

Date	Location	^{103}Ru	^{106}Ru	^{131}I	^{134}Cs	^{137}Cs	$^{140}\text{BaLa}$	^{141}Ce	$^{144}\text{CePr}$	U	^{239}Pu
<u>Mice</u>											
2/16	300 Pond	*	*	*	*	*	*	*	*	0.099	0.0002
2/24	100-N Trench	*	*	*	*	58.	*	*	*		0.15
	(Special Diode Count)	*	*	*	*	26.	*	*	*		
2/24	200-E Chem. Ditch	*	*	*	*	3.4	*	*	*		0.006
4/25	100-N Trench	*	*	*	*	180.	*	*	*		
6/14	100-N Trench	*	*	*	*	50.	*	*	27.		0.051
6/15	U Pond	*	*	*	*	21.	*	*	*	0.34	0.037
7/20	100-F	*	*	*	*	*	*	*	*		0.002
11/29	100-N Trench	350.	2400.	1500.	140.	120.	140.	510.	3800.		
11/29	300 Pond	*	*	*	*	*	*	*	*	0.006	0.010
11/30	200 West	*	*	*	*	1.0	*	*	*		0.0006
<u>Rabbit</u>											
3/15	222 S Pond	*	*	*	*	9.8	*	*	*		0.004(a)
5/25	300 Pond	*	*	*	*	*	*	*	*	0.021(a)	*
7/31	200-E Area	*	*	*	*	1.3	*	*	*		0.0003(a)
11/20	100-N Area	*	*	*	*	0.13	*	*	*		*

(a) Concentration in liver tissue.

*Less than the analytical limit.

No entry indicates no analysis was performed.

TABLE II.3-25

AVERAGE RADIONUCLIDE CONCENTRATIONS IN MUSCLE OF GAMEBIRDS - 1972

Units of 10^{-6} $\mu\text{Ci/gm}$ (wet weight)

<u>Location</u>	<u>Species</u>	<u>No. of Samples</u>	<u>^{58}Co</u>	<u>^{60}Co</u>	<u>^{65}Zn</u>	<u>^{90}Sr</u>	<u>^{137}Cs</u>	<u>^{141}Ce</u>
Analytical Limit			0.15	0.15	0.20	0.002	0.1	
U Pond	Ducks	2	*	*	*	0.006	27.	*
Redox Pond	Ducks	2	*	*	*	0.054	3.1	*
Gable Pond	Ducks	4	*	*	*	0.003	26.	*
B Pond	Ducks	4	*	*	0.11	0.003	3.3	*
300 Pond	Ducks	5	*	*	*	*	*	*
100-F Trench	Ducks	3	*	*	0.14	0.11	0.14	*
T Pond	Ducks	1	*	0.20	0.40	0.003	70.	*
West Lake	Ducks	1	*	*	*	*	4.2	*
Columbia River	Ducks	71	*	*	0.096	0.003	0.070	*
Columbia River	Geese	32	*	*	0.079	0.003	0.11	*
100 Areas	Pheasants	24	*	*	.073	0.003	0.084	*

*Less than the analytical limit.

TABLE II.3-26

CONCENTRATION OF SEVERAL RADIONUCLIDES
HANFORD DEER AND COYOTE--1972 ^a

Units of 10^{-6} $\mu\text{Ci/gm}$ (wet weight)						
<u>Location</u>	<u>Date</u>	<u>Tissue</u>	<u>^{65}Zn</u>	<u>^{90}Sr</u>	<u>^{137}Cs</u>	<u>^{239}Pu</u>
<u>Deer</u>						
Rt. 11A, Mi. 1.5	1/20	Muscle	*	*	0.048	
Rt. 11A, Mi. 1.5	1/20	Bone	*	0.48	*	0.009
Rt. 11A, Mi. 1.5	1/20	Liver				0.00008
300 Area	9/28	Muscle	0.081	*	0.071	
300 Area	9/28	Liver				0.00005
Rt. 4S, Mi. 13	11/7	Muscle	0.054	*	0.24	
Rt. 4S, Mi. 13	11/7	Liver				*
<u>Coyote</u>						
Rt. 4S, Mi. 20	1/20	Muscle	*	*	0.18	
Rt. 4S, Mi. 20	1/20	Liver	0.28	0.009	0.11	0.0001

*Less than the analytical limit.

No entry indicates no analysis was performed.

- a) Measurements of Cs^{137} in the muscle tissue of mule deer in the Ft. Collins Colorado area for the winter of 1972-1973 range from $0.04\text{--}0.1 \times 10^{-6}$ $\mu\text{Ci/gm}$ and averaged 0.065×10^{-6} $\mu\text{Ci/gm}$.¹⁰² Similar measurements for antelope in eastern Idaho during the autumn of 1972 range from $0.038\text{--}0.060 \times 10^{-6}$ $\mu\text{Ci/gm}$ and averaged 0.048×10^{-6} $\mu\text{Ci/gm}$.¹⁰³

The data for Cs-137 in the Hanford deer population is about the same as that due to fallout in similar species in the Western United States.

TABLE II.3-27
AVERAGE RADIONUCLIDE CONCENTRATIONS IN MUSCLE
GAMEBIRDS, FISH, AND SHELLFISH--1972
(10^{-6} μ Ci/g)

Analytical Limit	^{32}P				^{60}Co				^{65}Zn				^{90}Sr				^{137}Cs			
	No. Sample	Max.	Min.	Avg.	No. Sample	Max.	Min.	Avg.	No. Samples	Max.	Min.	Avg.	No. Samples	Max.	Min.	Avg.	No. Samples	Max.	Min.	Avg.
		1.0				0.15				0.2				0.002				0.1		
Species																				
Geese (river)(a)	1	*	*	*	32	0.12	*	*	32	0.37	*	0.079	10	0.017	*	0.003	32	0.97	*	0.10
Duck (river)(a)	1	*	*	*	71	0.24	*	*	71	0.77	*	0.096	58	0.014	*	0.003	71	1.2	*	0.070
Pheasant(b)					24	*	*	*	24	0.29	*	0.073	20	0.008	*	0.002	24	0.24	*	0.084
Whitefish	20	1.8	*	0.62	21	0.18	*	*	21	0.92	*	0.40	7	0.003	*	0.002	21	0.31	*	0.17
Oysters	9				9	*	*	*	9	2.5	1.0	1.7					9	*	*	*

(a) Collected in January 1972 on the Columbia River within the Hanford boundary.

(b) Collected in November and December 1972 within 5 km (3 miles) of the Columbia River and within the Hanford boundary.

* Less than the analytical detection limit.

No entry indicates no analysis was made.

TABLE II.3-28

RADIONUCLIDE CONCENTRATIONS IN LOCALLY PURCHASED MILK AND FOOD--1972

A. Milk (10^{-6} $\mu\text{Ci/ml}$)

		<u>^{65}Zn</u>			<u>^{90}Sr</u>			<u>^{131}I</u>			<u>^{137}Cs</u>		
Concentration Guide (Water)		100			0.3			0.3			20		
Analytical Limit		.050			0.002			0.002			.030		
Sample	# Samples	Max.	Avg.	% CG	Max.	Avg.	% CG	Max.	Avg.	% CG	Max.	Avg.	% CG
Riverview	21	.092	.016	.02	.004	.003	1.0	*	*	.33	.049	.014	.07
Benton City & West Richland Composite	26	*	*					.004	.001	.33	.029	.009	.05
Col. Basin Composite	52	.067	*		.002	.002	.67	.005	.001	.33	.033	.012	.06
Commercial	37	.062	.016	.02	.007	.004	1.3	*	*	.33	.035	.016	.08

B. Foodstuffs (10^{-6} $\mu\text{Ci/gm}$)

		<u>^{65}Zn</u>		<u>^{90}Sr</u>		<u>$^{95}\text{ZrNb}$</u>		<u>^{106}Ru</u>		<u>^{131}I</u>		<u>^{137}Cs</u>		<u>$^{144}\text{CePr}$</u>	
Analytical Limit		.030		.002		.020		.370		.070		.040		.350	
Sample	# Samples	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.
Commercial Meat	12	.064	.016	.006	.001	*	*	*	*	*	*	.084	.034	*	*
Poultry	4	.13	.06	.004	.003	*	*	*	*	*	*	.035	.01	*	*
Eggs	10	.088	.038	.026	.013	*	*	*	*	*	*	.040	.009	*	*
Local Produce	3	*	*	.03	.03	.14	.095	*	*	*	*	.090	.043	*	*
Commercial Produce	5	*	*	.010	.009	.12	.034	1.0	.38	*	*	*	*	*	*

NOTE: Minimum concentrations reported were all below the analytical limit and therefore not listed in this Table.

* Less than the analytical limit.

TABLE II.3-29

AVERAGE EXTERNAL GAMMA EXPOSURE RATES

(units of mR/day)

<u>Location</u>	<u>1971 Jan-June</u>	<u>1971 July-Dec</u>	<u>1972 Jan-June</u>	<u>1972 July-Dec</u>
<u>100 Areas</u>				
Vernita	0.22	0.20	0.24	0.26
Midway				
100-B				
100-K	0.21	0.21	0.31	0.28
100-N				
100-N (WPPSS)	0.20	0.20	0.28	0.30
100-D	0.16	0.25	0.22	0.20
100-F	0.22	0.15	0.23	0.23
Hanford	0.16	0.16	0.21	0.21
100-H			0.24	0.23
<u>200-West Area</u>				
Redox	0.31	0.23	0.25	0.27
West-Center	0.22	0.23	0.30	0.31
East-Center	0.16	0.16	0.22	0.21
West-Northeast	0.18	0.19	0.24	0.26
<u>200-East Area</u>				
North-Center	0.36	0.36	0.56	0.78
West-Center	0.45	0.29	0.21	0.21
Southeast	0.22	0.22	0.28	0.27
East-Center	0.80	0.22	0.34	0.24
<u>Wahluke Slope</u>				
C.P. 17	0.20	0.24	0.25	0.25
C.P. 18	0.20	0.20	0.26	0.25
C.P. 19	0.19	0.19	0.24	0.23
C.P. 20	0.20	0.20	0.24	0.25
C.P. 21	0.19	0.18	0.27	0.24
C.P. 22	0.20	0.18	0.24	0.25
C.P. 23	0.19	0.19	0.24	0.24
C.P. 24	0.20	0.20	0.25	0.25
C.P. 46	0.19	0.19	0.24	0.25
<u>Other On-Site</u>				
Yakima Barricade	0.18	0.20	0.28	0.25
Rattlesnake Springs	0.20	0.16	0.20	0.22
Emergency Relocation Center	0.21	0.21	0.24	0.26
FFTF Site	0.20	0.18	0.23	0.23
WYE Barricade	0.16	0.15	0.19	0.20
Rt. 10 Mile 1.6	0.18	0.17	0.26	0.25
300 Area (3705 Bldg)	0.22	0.21	0.26	0.24
300 Area (320 Bldg)	0.20	0.16	0.26	0.25
300 Area (331 Bldg)	0.23	0.17	0.22	0.23
300 Pond	0.26	0.22	0.40	0.25
ACRMS	0.18	0.16	0.24	0.24

No entry indicates no measurement was performed.

On the basis of exposure rate measurements offsite and at 100-N, the annual total-body dose of WPPSS personnel from Hanford sources of external radiation at 100-N during 1972 was estimated to be 5 mrem.

Measurements of immersion exposure rates in the Columbia River and of exposure rates above the surface of the river downstream from N Reactor were not statistically different from upstream measurements (Tables II.3-30 and 31). Shoreline dose-rates were slightly higher within the site boundary especially when N Reactor was operating.

TABLE II.3-30

DOSE RATES^(a) FROM MONTHLY SHORELINE SURVEYS FOR 1972
(μ R/hr)

A. COLUMBIA RIVER PLANT SHORE

	382.5 P ^(b)	331.5 P	379.4 P	379.0 P	369.7 P	368.3 P	362.0 P	350.4 P	343.3 P	340.5 P
Date	Above 181-KW	Below 181-KE	100-N Trench	Below 100-N	White Bluff Ferry	100-F Pond	Hanford	Power- line Cross.	Port of Benton	Richland
1/20	12	13	25	18	13	10	15	15		12
2/23	12	12	15	12	11	12	12	13		12
3/16	10	8	15	10	8	9	8	7		10
4/26	8	12	14	12	14	15	17	22		12
5/23	12	12	18	15	14	14	12	13		12
6/21	12	10	20	10	10	11	11	11		12
7/24	13	10	22	10	8		12	13		7
8/18	15	15	15	22	15	15	15	15		15
9/25	10	12	22	11	10	15	15	11	10	12
10/20	12	20	23	14	16	18	15	17	11	12
11/16	9	9	20	12	11	12	11	11	10	10
12/19	10	11	28	11	13	12	14	12	13	12

- (a) Measurements reported in μ R/hr are taken 1 meter above the ground and 1 meter back from the water's edge. Measurements reported in () are the maximum c/m found with a GM in the immediate vicinity of the water's edge.
- (b) River miles measured from the mouth of the Columbia. Plant shore, far shore, and island are designated by P, F, and I, respectively.
- (c) Point open to the general public during the entire year.
- (d) Point only open to the general public on Wednesdays, Saturdays, and Sundays, during the hunting season. No entry indicates no measurement was performed.

TABLE II.3-30 (Continued)

B. COLUMBIA RIVER - ISLAND LOCATION

	377.4 I	375.8 IF	373.4 IP	371.1 IP	367.0 IF	355.7 I ^(d)
Date	D Island	E Island	Locke Island	Locke Island	100-F Pond	Near Ringold
1/20	20	12	9	12	13	
2/23	13	10	10	10	13	10
3/16	10	7	9	7	12	8
4/26	17	11	13	12	17	14
5/23	10	12		11	10	10
6/21	12	10		11	15	10
7/24	13	12	13	12	10	13
8/18	20	12	12	14	18	15
9/25	15	12	13	12	12	12
10/20	15	15	13	13	12	14
11/16	9	10	9	10	11	10
12/19	15	13	17	11	14	13

C. COLUMBIA RIVER - FAR SHORE

	381.0 F	378.4 F	369.8 F	362.0 F ^(d)	359.1 F	354.7 F ^(c)	350.4 F	345.2 F
Date	100-K Trench	Above 181-D	White Bluffs Ferry	Hanford	Savage Island	Ringold	Powerline Cross.	Byers Landing
1/20	8	10	14	15	10	10	13	25
2/23	9	8	13	15	10	9	12	12
3/16	10	8	7	8	10	8	9	7
4/26	10	10	11	19	10	13	13	21
5/23	11	12	12	10	10	10	12	10
6/21	10	10	10	10	11	10	20	14
7/24	13	10	10	12	11	10	10	13
8/18	15	15	12	15	15	15	15	12
9/25	10	12	10	12	12	12	12	14
10/20	20	13	11	18	13	16	16	17
11/16	8	8	9	12	11	10	11	13
12/19	12	15	12	16	8	13	15	15

TABLE II.3-31

AVERAGE EXPOSURE RATES BELOW THE SURFACE OF
THE COLUMBIA RIVER--1972

(mR/day)

	<u>Jan-June</u>	<u>June-Dec</u>
100-K Barge	0.14	0.18
Below 100-N	0.16 ^(a)	0.19
Above 100-D	0.15 ^(a)	0.18
D Island	0.20	0.19
100-F Area	0.23 ^(a)	0.17
S. Wooded Island	0.18	0.19 ^(c)
Richland Pumphouse	0.14 ^(b)	0.13

(a) March-June

(b) January-April

(c) September, November, December

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III ENVIRONMENTAL IMPACT

III.1 ENVIRONMENTAL EFFECTS OF ROUTINE OPERATION OF PLANT FACILITIES

This section considers the effects of existing Hanford facilities and the associated released waste during routine operation. The waste considered includes radioactive, chemical and thermal waste that is released to 1) the atmosphere, 2) the Columbia River, and 3) the ground. Amounts of radioactivity that reach the environment as a result of 1972 operations are considered the routine releases that are to be expected during normal operation of the facilities in later years for impact calculations, although the actual release of waste to the environment will be less, due to the installation of pollution abatement facilities, the small increase in waste volume (10%) expected in the future, and the less mobile form of the waste. The detailed models and computer codes used for evaluating the environmental radiation doses are given in Appendix III-A.

III.1.1 Radiological Impact on Man

III.1.1.1 Pathways of Exposure

During the operation of the Hanford project, radioactive materials are released to the atmosphere, the Columbia River and the ground. (The radionuclides released to the environment during CY-1972 are tabulated in Section II of this report.) Studies have been conducted of the exposure pathways in the environment of Hanford.¹ These studies, combined with results of the environmental radiation monitoring and evaluation program, have facilitated the construction of a hypothetical person whose dietary and recreation habits maximize the potential radiation doses he might receive. Such a hypothetical person is called the maximum individual. The habits and diet of the maximum individual include the maximum reported values for each exposure mode in spite of the fact that the maximum values are not all attributable to the same one person. In addition, these studies permitted delineation of an average member of the population, the average individual. Similar studies identified the

total harvest of such important dietary items as Columbia River fish, game birds, and locally irrigated produce. The potential pathways of exposure to man are summarized in Table III.1-1.

Historically, the principal pathways of exposure involve only the direct releases to the atmosphere and to the Columbia River. Radioactive effluents released to the atmosphere are diluted and dispersed during their travel to areas of public access and can lead to 1) external exposure of the skin and total body, and 2) internal dose (principally to the thyroid from radioiodine) from inhalation or from ingestion of foods contaminated via deposition of airborne materials. External exposure from ground contamination via deposition is characteristically insignificant (several orders of magnitude less than) compared to exposure via the other air pathways.

Release of radioactive materials in liquid effluents that reach the Columbia River can lead to public exposure through several pathways. Direct external exposure can result from swimming in or boating and water skiing upon the Columbia River and from hunting, fishing or picnicking on the shoreline of the river. Ingesting of water or foods derived from the river or from river-irrigated farms can lead to radiation doses to the total body and internal organs. Such foods include Columbia River fish and waterfowl, irrigated produce, and milk, eggs and meat produced by animals ingesting river water or river-irrigated feeds.

Irrigation of farm land with Columbia River water drawn from immediately downstream of the Hanford project is limited to two areas: Ringold and Riverview. At Ringold, a small number of family farms use Columbia River water for irrigation of orchards, their own gardens and to a limited extent pasture grass. At Riverview, a total of 3300 acres, occupied by about 3000 people, is irrigated from the river.² About 75% of the acreage used for growing crops is in pasture and hay. Most have kitchen gardens, but only a very limited number are large enough to provide produce for market.

TABLE III.1-1

POTENTIAL PATHWAYS OF RADIATION EXPOSURE TO MAN FROM OPERATION
OF THE NUCLEAR FACILITIES AT HANFORD

- A. Gaseous Effluents Released to the Atmosphere
 - Air submersion
 - Inhalation
 - Ingestion of foods contaminated via deposition
 - Exposure of ground contaminated via deposition
- B. Liquid Effluents Released to the Columbia River
 - Water immersion (swimming)
 - Exposure to water surface (boating)
 - Exposure to contaminated shoreline (hunting, fishing, picnicking)
 - Ingestion of aquatic foods (fish and waterfowl)
 - Ingestion of irrigated foods (produce, milk, eggs, meat)
- C. Liquid Effluents Discharged to the Ground
 - Ingestion of waterfowl which had access to surface ponds
 - Use of well water drawn from contaminated groundwater for drinking or irrigation
 - Migration of contaminated groundwater to the Columbia River (pathways under B above)
- D. Solid Waste Buried in the Ground
 - Leaching of radionuclides from burial sites close to the Columbia River during flood
- E. Transportation of Radioactive Materials on Public Highways
 - External exposure to persons in the proximity of the shipment

Liquid effluents released to the ground have only a small potential for public exposure through the several different pathways listed. At the present time there is no public access to the groundwater beneath the project and the second item under C in Table III.1-1 is listed only as a potential future pathway.

Studies of the waterfowl inhabiting open ponds and trenches led to measures to prevent their access to contaminated surface waters in the 100 Areas. Contamination of the waterfowl via the slightly radioactive surface waters in the 200 Areas is a minor contribution to the radiation exposures of the general public.

Another pathway by which radioactive liquid effluents disposed to ground can reach man is via migration to the Columbia River. At the present time, radionuclides in liquid effluents sent to ground in the 200 Area (fuels processing areas), with the possible exception of tritium, are not entering the Columbia River via groundwater migration. Such small amounts of tritium, which could be entering the river from 200 Area sources in 1972 are less than the tritium present in the river as a result of fallout of tritium from past weapons testing and natural sources. The quantities of tritium entering the river will increase in the future as a result of the slow migration of groundwater from the 200 Areas' disposal sites. The forecast peak rate of entry of tritium from the transport model simulation should be reached in the early 1980's, at which time about 2×10^{-7} Ci/day of tritium and 2×10^{-10} Ci/day of gross beta activity would be entering the Columbia River. This rate of discharge would probably continue for about 6 years after which it would decrease. The radiation doses from the entry of tritium and gross beta into the Columbia River during the peak years would be

extremely small (less than 10^{-6} mrem/yr to the maximum individual and less than 0.1 man-rem/yr to the local population).

The 100-N Reactor has a disposal trench and crib (1301-N) for liquid effluents which are not directly discharged to the Columbia River. Some of the radionuclides disposed to these facilities reach the river with the groundwater at seepage springs along the riverbank. The radionuclide content of the spring water has been reduced below that in the original liquid effluent by soil retention of some radionuclides and by radioactive decay during the travel time (3 to 5 days minimum) between the crib and trench and the river. Similar ground disposal techniques were employed in years past at the older reactors and seepage springs existed at some of those reactor areas also.

As of August 1974 the radioactivity in the riverbank seepage contributes the major fraction of total radioactivity entering the Columbia River. The major portion of the radionuclides reaching the Columbia River do so via the groundwater from the 1301-N crib disposal site.

In addition to the radionuclides reaching the Columbia River in 1972, some residual long-lived contamination is present in river sediments from past effluent disposal. During the annual spring runoff some of these deposits are scoured by the increased river flow rates and transported downstream. As a result, occasionally small concentrations of certain radionuclides are measured in river water and biota samples even though no measureable quantities of the nuclides were being released. These small concentrations in turn can lead to radiation doses to local residents from many of the potential pathways outlined above for liquid effluent releases to the river.

Radioactive solid waste placed in burial grounds has no further impact on the general public. The potential effects of accidents and floods are discussed in Section III.2.

III.1.1.2.1 Impact of Liquid Releases

The radiation doses to the hypothetical maximum individual and to the general population during 1972 were calculated from releases of liquid effluents at Hanford listed in Tables III.1-2 through III.1-4 and from bio-accumulation factors listed in Table III.1-5.

Several distinct sources of liquid effluents are released to the Columbia River:

- the 102-in. cooling water pipeline and the crib and trench at 100-N
- animal farm waste at 100-F and 300 Areas
- uranium from the 300 Area North Pond
- tritium migrating to the river with the groundwater from the 200 Areas' disposal sites.

The latter source did not contribute any measurable tritium during 1972. At 100-F and 300 Areas, the amount of radioactive material disposed to shoreline trenches and ponds in 1972 were measured rather than the actual amount entering the river.

Experience gained with the behavior of the liquid effluents at 100-N was used to determine the fraction of the gross alpha and gross beta activity reaching the river from disposal of animal farm waste. If the gross alpha is ^{239}Pu , less than 0.1% of that put in the trench would eventually reach the river, while 4.5% of the gross beta (as ^{90}Sr) would do so. Measurements of shoreline springs and river water at 100-F and 300 Areas have not indicated any detectable ^{239}Pu reaching the river from the leaching trenches.

TABLE III.1-2

RADIONUCLIDES RELEASED TO THE COLUMBIA RIVER WITH LIQUID
EFFLUENTS AT 100-N IN 1972(a)

<u>Nuclide</u>	<u>Ci/Yr</u>	<u>Nuclide</u>	<u>Ci/Yr</u>
^3H	7000	^{95}Nb	4
^{24}Na	500	^{99}Mo	21.1
^{32}P	160 ^(b)	^{103}Ru	0.4
^{51}Cr	25.3	^{106}Ru	4.
^{54}Mn	40	^{124}Sb	0.8
^{56}Mn	600	^{131}I	41.9
^{59}Fe	10	^{133}Xe	10.
^{58}Co	2	^{134}Cs	0.5
^{60}Co	20	^{137}Cs	5.05
^{65}Zn	440 ^(b)	^{140}Ba	5.25
^{89}Sr	0.05	^{140}La	5.25
^{90}Sr	0.95	^{239}Np	90
^{95}Zr	4.		

(a) Includes both the discharge from the 102-inch pipeline and riverbank seepage from disposal to the 1301-N crib. The annual discharges have been reduced to <500 Ci/yr tritium and <10 Ci/yr of all other radionuclides after CY-1973.

(b) Estimated from concentration measured in whitefish in 1972 and historical data relating water concentrations to fish concentrations.

TABLE III.1-3

RADIONUCLIDES RELEASED TO THE COLUMBIA RIVER WITH LIQUID
EFFLUENTS AT 100-F IN 1972

<u>Released to Leaching Trench</u>		<u>Reaching River</u>	
<u>Nuclide</u>	<u>Ci/Yr</u>	<u>Nuclide</u>	<u>Ci/Yr^(a)</u>
Gross Beta (as ⁹⁰ Sr)	6.6×10^{-2}	⁹⁰ Sr	1.5×10^{-3}
		⁹⁰ Y	1.5×10^{-3}
Gross Alpha (as Pu)	1.14×10^{-3}	²³⁹ Pu	$<1.1 \times 10^{-6}$

- (a) Experience at the 1301-N crib site in 1972 indicates that about 4.5% of the ⁹⁰Sr and <0.1% of the ²³⁹Pu reaches the river from trench disposal. In addition, the gross beta is assumed to be an equilibrium mixture of ⁹⁰Sr and ⁹⁰Y.

TABLE III.1-4

RADIONUCLIDES RELEASED TO THE COLUMBIA RIVER WITH LIQUID
EFFLUENTS AT 300 AREA IN 1972

<u>Released to Pond or Trench</u>		<u>Reaching River</u>	
<u>Nuclide</u>	<u>Ci/Yr</u>	<u>Nuclide</u>	<u>Ci/Yr</u>
Gross Beta (as ^{90}Sr)	1.44×10^{-4}	^{90}Sr	3.25×10^{-6} (a)
		^{90}Y	3.25×10^{-6} (a)
Gross Alpha (as Pu)	2.6×10^{-5}	^{239}Pu	$<2.6 \times 10^{-8}$ (a)
^{234}U	0.24	^{234}U	0.24 (b)
^{235}U	0.011	^{235}U	0.011 (b)
^{238}U	0.17	^{238}U	0.17 (b)

- (a) Experience at the 1301-N crib site in 1972 indicates that about 4.5% of the ^{90}Sr and <0.1% of the ^{239}Pu reaches the river. In addition, the gross beta measurement is assumed to be an equilibrium mixture of ^{90}Sr and ^{90}Y .
- (b) Measurements in the Columbia River near the 300 Area³ indicate that a large, but unknown, fraction of the uranium disposed of to the 300 Area ponds reaches the river.

TABLE III.1-5

BIOACCUMULATION FACTORS FOR RADIONUCLIDES IN FRESH WATER ORGANISMS
(pCi/kg Organism/pCi/liter Water)

Radionuclide	Fish	Invertebrates	Plants
^3H	1	1	1
^{24}Na	100 ^(a)	200	500
^{32}P	170 ^(a)	100,000	100,000
^{51}Cr	20	2,000	4,000
^{54}Mn	400	90,000	10,000
^{56}Mn	400	90,000	10,000
^{59}Fe	100	3,200	1,000
^{58}Co	50	200	200
^{60}Co	50	200	200
^{65}Zn	64 ^(a)	10,000	20,000
^{89}Sr	30	100	500
^{90}Sr	30	100	500
^{95}Zr	330	7	1,000
^{95}Nb	30,000	100	800
^{99}Mo	10	10	1,000
^{103}Ru	10	300	2,000
^{106}Ru	10	300	2,000
^{124}Sb	1	10	1,500
^{131}I	15	5	40
^{134}Cs	2,000	100	500
^{137}Cs	2,000	100	500
^{140}Ba	4	200	500
^{140}La	25	1,000	5,000
^{239}Np	10	400	300

(a) Based on actual measurements in the Columbia River for panfish

A study of the behavior of uranium discharged to the 300 Area North Pond was conducted in 1957.³ This study indicated that a large fraction of the uranium eventually reached the Columbia River where it was rapidly dispersed in the water and mixed with the much higher concentrations of natural background uranium already present in the river water.

In addition to the radionuclides reported as released to the Columbia River in 1972, certain other radionuclides were detected in water and/or biota samples.⁴ Principal among these were ^{32}P in whitefish and ^{65}Zn in river water and fish and chickens and eggs from local farms adjacent to the river. The ^{65}Zn was undoubtedly scoured from the river sediments during the spring runoff and can also be accumulated to some extent on irrigated farm land and in shoreline insects eaten by the chickens. The ^{32}P was present in low concentrations in the 100-N liquid effluents discharged to the Columbia River through the 102-inch pipeline. Table III.1-2 includes the estimated quantities of ^{32}P and ^{65}Zn released from 100-N.

The population within 50 miles of the project utilizing Columbia River water for sanitary purposes includes the cities of Pasco (1970 population was 19,500), and Richland (1970 population was 28,500). The city of Kennewick utilizes groundwater drawn from collectors placed along the Columbia River. Historically, the Kennewick city water has contained significantly lower concentrations of radionuclides than the water in the Pasco municipal system immediately across the river.

The city of Richland supplements its water supply with well water (recharged with Yakima River water) to a varying degree depending upon seasonal demand. At most, about 20% of the Richland residents receive well water all year around. In addition, during the hottest summer days, up to a maximum of another 20% of the residents may receive well water depending upon demand. For purposes of radiation dose calculations,

the simplifying and conservative assumption can be made that all Richland residents use Columbia River water and no Kennewick residents use Columbia River water.

Extensive data available on the removal efficiencies for specific radionuclides in the municipal water treatment plants⁵ were employed when calculating radiation doses from drinking water. These removal factors are tabulated in Table III.1-6. For nuclides not directly measured at the water treatment plant, factors for chemically similar elements were employed.

The results of these dose calculations are summarized in Tables III.1-7 and III.1-12. Assuming a consumption rate of 2.0 liters/day of water, an average individual living in Richland or Pasco would receive a total-body dose of 0.015 mrem/yr from this source. The total population of consumers (~50,000) drinking an average of 1.2 liters/day would receive an integrated total-body dose of 0.45 man-rem/yr; tritium, ³²P and ⁶⁵Zn contribute about 70% of these doses. The radiation dose to the individual adult thyroid from consumption of 2.0 liter/day of drinking water was estimated to be 0.3 mrem/yr, primarily from ¹³¹I with a small contribution from tritium.

Because fish will concentrate radionuclides from the water they inhabit, the potential radiation dose from consumption of Columbia River fish was estimated for both the individual and the population within 50 miles of the plant.

TABLE III.1-6⁵

REMOVAL OF RADIONUCLIDES BY WATER TREATMENT
SYSTEMS AT RICHLAND AND PASCO, WASHINGTON

<u>Nuclide</u>	<u>Concentration Ratio (Treated Water/Raw Water)</u>
RE + Y ^(a)	0.16
⁶⁴ Cu	0.28 (0.6) ^(b)
⁴⁶ Sc	0.32
⁷⁶ As	0.37 (0.5) ^(b)
³² P	0.38
⁶⁵ Zn	0.39
²⁴ Na	0.62 (0.9) ^(b)
²³⁹ Np	0.67
¹²² Sb	0.77
¹³¹ I	0.83
⁵¹ Cr	0.87

(a) Rare Earths plus Yttrium.

(b) () indicates ratios estimated for elements
by correcting for radioactive decay within
the water plant.

TABLE III.1-7

ESTIMATED MAXIMUM DOSE TO AN INDIVIDUAL FROM THE EFFLUENTS RELEASED AT THE
HANFORD PROJECT IN 1972(a)
(mrem/year)

Pathway	Annual Exposure	Skin	Total Body	GI-LLI	Thyroid	Bone
<u>Gaseous Effluents</u>						
Air Submersion	8766 hr	0.088	0.011	(0.011) (d)	(0.011)	(0.011)
Tritium-Inhalation & Transpiration	8766 hr	2×10^{-4}	2×10^{-4}	2×10^{-4}	2×10^{-4}	----
Radioiodine-Inhalation	7300 m ³ air	--	--	--	0.0019	--
Milk	274 liters(b)	--	--	--	0.056	--
Vegetables	30 kg(c)	--	--	--	0.042	--
Total Air Pathways		0.088	0.011	0.011	0.11	0.011
<u>Liquid Effluents(e)</u>						
Drinking Water	730 liters	--	0.015	0.036	0.30	0.066
Fish Consumption	40 kg	--	0.30	1.02	0.31	1.63
Irrigated Foods	710 kg	--	0.16	0.25	0.33	0.33
Shoreline	500 hr	0.10	0.090	(0.090)	(0.090)	(0.090)
Swimming	100 hr	0.0032	0.0026	(0.0026)	(0.0026)	(0.0026)
Boating	100 hr	0.0016	0.0013	(0.00013)	(0.0013)	(0.0013)
Total Water Pathways		0.10	0.57	1.4	1.0	2.1
Total (Adult)		0.19	0.58	1.4	1.1(f)	2.1
<u>Infant Thyroid Dose</u>						
Airborne Tritium	8766 hr				0.0001	
Air Submersion	8766 hr				(0.011)	
Inhalation	2045 m ³				0.002	
Milk	274 liters(b)				0.46	
Drinking Water	292 liters				0.95	
Total					1.4(f)	

(a) Using releases tabulated in Tables III.1-2, 3, 4, 8, 9 and 10.

(b) One liter/day for a 9-month grazing season.

(c) 200 g/d for a 5-month produce season.

(d) () indicates internal dose from external exposure.

(e) Essentially all from 100-N effluents.

(f) Does not include contribution from ¹²⁹I in the environment from previous years' operations estimated to be ~0.4 millirem/yr to both the maximum individual adult and infant.⁶

The following assumptions were used:

- For population dose calculations, it was assumed that the fish were caught from water containing radionuclides at concentrations calculated by diluting the radionuclide release rates in the 1972 annual average Columbia River flow (160,000 cfs).
- There was a minimum of 24 hour delay between harvest and consumption.
- There were no losses in preparation of the fish (cooking or long-term freezer storage).
- An individual consumes as much as 40 kg of fish per year.⁷
- The total edible weight of sport fish harvested from the Columbia River between the Ringold area and Boardman, Oregon, is not over 1.5×10^4 kg/yr.⁷

Based on these assumptions, the dose to the individual fisherman would be 0.3 mrem/yr to his total body. Integrated dose to the population would be 0.1 man-rem/yr from fish consumption. The doses for an avid waterfowl hunter from consumption of 40 kg/yr of waterfowl from the Hanford environment would be somewhat less than the doses to the avid fisherman reported here, while the integrated dose to the population would be <0.1 man-rem/yr.

Aquatic recreation is a popular pastime in the stretch of the Columbia River below the plant site. Swimming, boating, water skiing and picnicking along the shore or on islands could result in small incremental doses to the local population. Assuming an individual spent 100 hr/yr swimming, 100 hr/yr water skiing or boating, and 500 hr/yr along the shoreline, all near the site his total-body dose from external exposure would total only 0.09 mrem/yr. This dose and others potentially received by such an ardent water sports fan are summarized in Table III.1-7.

The population dose received during water recreation activities can be estimated on the basis of the following assumptions:

- The average number of hours spent in various water sports by the population are:⁸

10 hr/yr swimming (immersion)

5 hr/yr boating and water skiing (surface)

17 hr/yr on rivershore

- The population within 50 miles of the site in the sectors between the NE and SSW directions, inclusive, are the persons who travel to the Columbia River for their aquatic recreation. This population totaled approximately 120,000 persons in 1972.
- The dilution offered by the Snake River below Pasco and the decay during river travel time to southwest Benton County can be ignored. The majority (over 50%) of the exposed population resides in the vicinity of the Tri-Cities (Pasco, Kennewick and Richland).

Under these conservative^(a) assumptions, the integrated population dose from water sports would be 0.4 man-rem/yr.

Even though a limited amount of fruit, vegetables, eggs and meat are produced on farms irrigated with water drawn from the Columbia River downstream of the Hanford project, the hypothetical maximum individual could possibly eat local irrigated foods during the entire growing season. In addition, certain products such as root vegetables, fruit, eggs, and meat are assumed to be available year-round either because they can be produced any month or because they can be stored for several months after harvest.

The uptake and concentration of radionuclides in irrigated produce from the water applied was calculated using local data on season and irrigation rates and the uptake equation and factors given in the reports on the "Year 2000 Studies."^{9,10}

(a) The word "conservative" implies the use of assumptions which would tend to overestimate rather than underestimate the dose to man.

For conservatism, only relatively short decay times were used between harvest and consumption, (1 day for most foods, 10 days for potatoes and orchard fruit and 15 days for beef and pork). The total dose to the maximum individual for all irrigated products was 0.2 mrem/yr to the total body and 0.3 mrem/yr to the thyroid (Table III.1-7).

For the population dose from irrigated products, it was conservatively assumed that 2000 persons each consumed about one-half as much irrigated foods as did the maximum individual. On that basis, the population doses from irrigated products would be 0.2 man-rem/yr to the total body and 0.3 man-thyroid-rem/yr to thyroids (Table III.1-12).

The radiation dose from all liquid pathways combined listed in Table III.1-7 for the maximum individual adult is 0.6 mrem/yr to the total body and 1 mrem/yr to the thyroid. The infant thyroid dose from the liquid pathways is about 1 mrem/yr, entirely from drinking water, and the total infant thyroid dose is 1.4 mrem/yr. The combined total-body dose to the population from liquid pathways was estimated to be about 1 man-rem/yr, while the combined population thyroid dose from the liquid pathways is ~10 man-thyroid-rem/yr (Table III.1-12).

III.1.1.2.2 Impact of Gaseous Releases

The radionuclides released to the atmosphere from the several Hanford facilities were discussed in Section II.1.1. The various releases were grouped into five categories for purposes of dose calculation. Table III.1-8 lists the releases from the 200-ft stack at the 100-N Reactor area. Table III.1-9 summarizes all of the releases to the atmosphere in the 200 East and 200 West areas into two categories: roof vent releases and stack releases. For purposes of offsite dose calculations, all of these releases were assumed to occur at one location between 200 East and 200 West areas close to the Hanford Meteorology Tower.

Table III.1-10 summarizes the release data from all of the facilities in 300 Area into two categories: roof vent and 200-ft stack. Many of the stack release measurements in the 300 Area were below detection

TABLE III.1-8

RADIONUCLIDES RELEASED WITH GASEOUS EFFLUENTS AT 100-N AREA
IN 1972(a)

Nuclide	Ci/Yr
^3H	27
^{41}Ar	1×10^5
^{131}I	0.013
^{133}I	0.5

(a) Released from the 200-ft stack.

TABLE III.1-9

RADIONUCLIDES RELEASED WITH GASEOUS EFFLUENTS AT THE 200 AREAS IN 1972

Nuclide	Curies/Year Released	
	Roof Vents (a)	Stacks (b)
^3H	----	1.0×10^3
^{85}Kr	----	4.0×10^5
^{90}Sr	2.28×10^{-1}	8.03×10^{-1}
^{131}I	4.71×10^{-3}	2.06×10^{-1}
^{133}Xe	----	2.0×10^2
^{239}Pu	1.53×10^{-3}	3.78×10^{-3}

(a) Assumed to be a ground release for purposes of dose calculations.

(b) Released from the 200-ft stacks.

TABLE III.1-10

RADIONUCLIDES RELEASED WITH GASEOUS EFFLUENTS AT 300 AREA IN 1972

Nuclide	Curies/Year Released	
	Roof Vents ^(a)	Stacks ^(b)
Gross Alpha	$<3.6 \times 10^{-5}$ ^(c)	$<2.4 \times 10^{-5}$ ^(d)
Gross Beta ^(e)	2.9×10^{-3}	$<1.6 \times 10^{-4}$
^{131}I	1.3×10^{-2}	$<1.6 \times 10^{-3}$

- (a) For purposes of dose calculations, a ground level release was assumed.
- (b) All measurements were below detection limits; however, for purposes of dose calculations, the values were assumed to be positive and a release height of 200 feet was used. The dose contributions of the stack releases so calculated were a small fraction of the total dose from 300 Area releases.
- (c) Measured as gross alpha, assumed to be plutonium with a composition like that processed in 327 building during 1972 (viz, 0.035 wt% ^{238}Pu , 86.3 wt% ^{239}Pu , 11.8 wt% ^{240}Pu , 1.7 wt% ^{241}Pu and 0.15 wt% ^{242}Pu).
- (d) Assumed to be all ^{239}Pu for purposes of dose calculations.
- (e) Reported variously as gross beta, ^{90}Sr and mixed fission products (MFP). Assumed to be all ^{90}Sr for purposes of dose calculations.

level in 1972. Nevertheless, the values in Table III.1-10 were assumed to be positive measurements for purposes of dose calculation.

In order to maximize the total dose from all gaseous pathways, the hypothetical maximum individual adult and child were assumed to be located directly across the river from the 300 Area. This is the location of the highest concentrations of radioiodine in the air, on vegetation and in milk, but is not the location of highest dose rate (mrem/hr to a radiation detector) from airborne radionuclides from all sources. Since the major contributors to the air submersion dose rate are the releases from the 100-N stack, the highest external dose rate would be directly across the river from 100-N. However, there are no

permanent residences in the near vicinity of the 100-N site and the annual external doses to nonresident farmers and hunters should not be as great as the combined dose to the permanent residents on farms near the 300 Area. The mathematical model used to calculate air dispersion of the radionuclide releases is that given in Reference 11; the computer calculation scheme is given in detail in Reference 12 (excerpts included in part 1 of Appendix III-A).

The meteorological data bases employed in the calculations were as follows:

- Data collected at the Hanford Meteorological Station (HMS) (over a 15-year period) were used for the 200-Area releases.
- Data collected (over a 1-year period) at 100-N were used for the 100-N releases.
- A combination of wind velocity data collected (over a 2.5-year period) at the FFTF site and long-term stability data from HMS were used for the 300-Area releases.
- Correction for height of release and plume rise were included.
- Changes in elevation of the receptor location were not included.
- Releases from building vents were treated as though they were at ground level.
- No building wake factors were included. This results in conservative (higher) values for the atmospheric dilution factor ($\bar{\chi}/Q$) and dose to man.

The "maximum individual" across the river from the 300 Area is in a location where the annual average atmospheric dilution is

- $3.2 \times 10^{-7} \text{ sec/m}^3$ ^(a) from 300 Area vent releases
- $6.0 \times 10^{-8} \text{ sec/m}^3$ from 300 Area stack releases

(a) Ci/m^3 divided by Ci/sec .

- 2.3×10^{-9} sec/m³ from 100-N stack releases
- 4.0×10^{-9} sec/m³ from 200 Area stack releases
- 2.1×10^{-8} sec/m³ from 200 Area vent releases.

The doses to the maximum individual resulting from these various sources depends also upon the rate of release of the several radionuclides with the gaseous effluent. The external radiation doses to the maximum individual adult and child from air submersion and the internal doses from radioiodine are summarized in Table III.1-7.

Inhalation and transpiration of tritium through the skin contribute a very small increment (2×10^{-4} mrem/yr) to the internal dose received by all organs listed in the table except for the mineral bone which does not accumulate tritium. The release of ⁸⁵Kr from the 291-A stack contributes 82% of the external dose to the skin but only 8% of the external dose to the total body of the maximum individual. Approximately 80% of the internal thyroid dose from airborne radionuclides results from the release of ¹³¹I from the 300 Area. The total dose to the maximum individual from air pathways is given in the table as 0.023 mrem/yr to the skin, 0.011 mrem/yr to the total body, GI tract and bone (principally from external exposure) and 0.11 mrem/yr to the thyroid principally from ingestion of radioiodine.

The total-body dose due to air submersion is tabulated versus distance from the project center (Hanford Meteorology Station) in Table III.1-11. The integrated dose from this source is 1.3 man-rem/yr in 1972. The contributions from releases at the 200 Areas (9×10^{-3} man-rem/yr) and the 300 Area (4×10^{-6} man-rem/yr) are a negligibly small fraction of the total air submersion dose.

The population dose from all gaseous pathways is listed in Table III.1-12. A small increment population dose (0.02 man-rem/yr) results from releases of tritium to the atmosphere from the 100-N and the 200 Areas stacks.

The total population dose to the thyroids of local residents was estimated by two methods. A tabulation of all dairy cows in Benton and

TABLE III.1-11

ESTIMATED CUMULATIVE POPULATION, CUMULATIVE ANNUAL DOSE
AND AVERAGE ANNUAL DOSE IN CIRCULAR AREAS AROUND THE
HANFORD METEOROLOGY STATION FROM GASEOUS EFFLUENTS RELEASED
FROM ALL FACILITIES IN 1972

<u>Radius (miles)</u>	<u>Cumulative Population (1973)</u>	<u>Cumulative Dose man-rem/year</u>	<u>Average Annual Dose mrem/year per person</u>
10	0	0	0
20	5,885	0.097	0.017
30	71,438	0.74	0.010
40	135,944	1.1	0.0081
50	248,644	1.3 ^(a)	0.0052

(a) Contributions from 100-N, 200 Areas and 300 Area are 1.3,
9 x 10⁻³, and 4 x 10⁻⁶ man-rem/year, respectively.

TABLE III.1-12

SUMMARY OF ESTIMATED POPULATION DOSES
RECEIVED AS A RESULT OF THE HANFORD
OPERATIONS IN 1972

<u>Pathway</u>	<u>Total Body Dose man-rem/yr</u>	<u>Thyroid Dose man-thyroid rem/yr</u>
<u>Gaseous Effluents</u>		
Air Submersion	1.3	(1.3) ^(a)
Tritium (Inhalation & Transpiration)	0.02	0.02
Radiiodine (Inhalation, Milk, Vegetables)	--	0.6
<u>Liquid Effluents</u>		
Drinking Water	0.45	8.9
Fish Consumption	0.11	0.12
Aquatic Recreation	0.40	(0.40)
Irrigated Foods (Produce, Eggs, Meat)	<u>0.16</u>	<u>0.33</u>
Total	2.4	12. (a)(b)

(a) () indicates internal dose from external exposure.

(b) Not including the contribution from ¹²⁹I in the Hanford environment presumably as a result of previous years of operation. This contribution can be estimated to be an additional 4 man-thyroid-rem/yr.^{6, 13}

Franklin counties was available from the bi-county health department. From these data, it was estimated that 41,200 lb of milk were produced each day for delivery to commercial milk plants in eastern Washington and to a limited extent Portland, Oregon, and Seattle, Washington. In addition, about 10,500 lb/day of milk were produced by nonshippers in Benton and Franklin counties. At an average population consumption of 0.35 liters of milk/day, this quantity of milk would provide for about 74,000 consumers if it were all used as fresh milk.

Concentrations of radioiodine in this milk from all plant sources were estimated using the mathematical models previously discussed, and the resultant population thyroid dose to all the milk consumers was calculated to be 0.5 man-thyroid-rem/yr. Inhalation and consumption of fresh leafy vegetables was estimated to add another 0.1 man-thyroid-rem to this total. These results are listed in Table III.1-12.

Another estimate was made of the maximum potential thyroid dose by assuming that sufficient milk and leafy vegetables were produced locally to supply all of the needs of the population within 50 miles. The dairy cows and gardens were distributed the same way that the population was (not necessarily implying each family had their own cow and garden). On this basis, the total integrated thyroid dose was estimated from a modification of the air submersion dose computer code to have an upper limit of 0.9 man-thyroid rem/yr from inhalation, milk and leafy vegetables combined, in reasonable agreement with the value of 0.6 calculated by the first method.

An additional source of thyroid exposure in the Hanford environments is the ^{129}I present from past releases. Measurements of this radionuclide have recently been reported.^{6,13,14} From these data,¹³ the thyroid doses to individuals in the vicinity of Hanford from all potential pathways were calculated.⁶ The dose to the maximum individual adult and infant thyroids were both estimated to be about 0.4 mrem/yr. In a manner similar to that employed for calculating the population doses from ^{131}I and ^{133}I

for 1972, the contribution from ^{129}I was estimated to be about 4 man-thyroid-rem/yr. These ^{129}I contributions were not included in the thyroid doses tabulated in Tables III.1-7 and III.1-12.

III.1.1.2.2.1 Inhalation of Plutonium

The estimated dose to the lung and to the bone of individuals in the Hanford environment due to plutonium releases to the atmosphere can be calculated by the methods detailed in Appendix III-B. These calculations have been made for both soluble and insoluble plutonium compounds for 1 year of chronic exposure at the release rates for 1972 as given in Table III.1-9. The first year and the 50 year dose commitments were calculated. The resultant doses depend on the individual's location relative to the 200 Areas. The doses calculated at the distance of closest approach to the plant boundary in the prevailing downwind direction (east southeast to southeast) are summarized in Table III.1-13. (These small radiation doses were not included in Table III.1-7.)

TABLE III.1-13
MAXIMUM RADIATION DOSE TO AN INDIVIDUAL FROM
INHALATION OF PLUTONIUM RELEASED AT THE 200 AREAS IN 1972^a

	<u>Soluble</u>		<u>Insoluble</u>	
	<u>1st Year (rem)</u>	<u>50 Year Dose Commitment (rem)</u>	<u>1st Year (rem)</u>	<u>50 Year Dose Commitment (rem)</u>
Lung	2.2×10^{-7}	2.7×10^{-7}	2.2×10^{-6}	1.0×10^{-5}
Bone	1.1×10^{-6}	1.0×10^{-4}	5.9×10^{-8}	3.9×10^{-5}

An analysis of plutonium air sample data showed no significant difference between nearby areas in the prevailing downwind direction from the chemical processing areas and similar data for more distant perimeter communities in both the upwind and downwind direction. In 1972, the plutonium concentrations averaged 1.9×10^{-5} pCi/m³ at nearby

a. Results based on ICRP Task Group Lung Model. See Appendix III-B.

downwind locations and 1.8×10^{-5} pCi/m³ at the more distant perimeter communities. Since these are actual air concentration measurements, they include any contribution from resuspension of any previously deposited plutonium. The lung dose due to these concentrations, which are believed to be due to worldwide plutonium fallout, is about 2.2×10^{-4} rem/year. The 50-year lung dose commitment is about 10^{-3} rem. These lung dose values were calculated from the measured average plutonium air concentrations at perimeter communities using the concentration to dose conversion factor of (12 rem/yr)/(pCi/m³) as given in EPA report number EPA-520/4-73-003.¹⁵

III.1.1.2.2.2 Plutonium Analysis of Human Tissue Samples at Autopsy

In 1949 a program of tissue sampling at autopsy was initiated¹⁶ on former Hanford employees, residents of the Hanford regions and persons from distant places who had died locally. The objective of this program is to obtain tissue samples for analysis for plutonium and other radionuclides to form a basis for assessing the radiological impact of the Hanford plutonium facilities on workers and local residents and to form a basis for evaluation of the long-term effectiveness of safety practices associated with operation of Hanford facilities. This study supplements two other AEC sponsored studies relating to the health of Hanford workers and residents in the U.S. Transuranium Registry and the AEC Health and Mortality Study. Both studies have issued periodic reports.

The number of cases analyzed between 1949 and 1970 amounted to about one-third of those coming to autopsy at the local hospital.¹⁷ Samples of lung, liver, bone and the tracheobronchial lymph nodes, when prominent, were taken from noncontagious disease cases as selected by the pathologist. At various times other samples such as blood, pancreas, prostate, seminal vesicles and spleen have been taken. Because of the infrequency of measurable plutonium in these samples, tissues are no

longer sampled on a routine basis. In cases where measurable plutonium was anticipated because of known occupational exposure the sampling of tissues has been more extensive.

The measurement capability for plutonium in autopsy tissue samples varies with amount and type of sample and with analytical chemistry parameters. For practical purposes, the detectable amount in a sample may be taken for the cases reported here as about 20 fCi Pu (total plutonium alpha) per sample. The detectable concentration then depends on the sample size. For example, using the above, the detectable concentration of plutonium in a one gram tracheobronchial lymph node would amount to 20 fCi Pu/g whereas if 1000 grams of lung had been processed, the detectable concentration would amount to 0.02 fCi Pu/g of lung.

Results of sample analyses completed through 1970¹⁷ were published in 1972. At that time, 160 cases had been analyzed for individuals who had worked at Hanford. Another 147 cases were reported for individuals who had lived in the Hanford area for at least three years but who had not worked at Hanford and another 50 cases for individuals coming to autopsy locally but who had not resided locally.

Of the individuals residing locally, the largest positive measurements were 2.6 fCi Pu/g of lung and 2.3 fCi/g of liver. About one-half of the results for each of these tissues were less than 0.5 fCi Pu/g. Of those individuals not residing locally, the measured concentration of plutonium in lung and liver did not exceed 5 fCi Pu/g except for one liver specimen in which a measured concentration of 6.5 fCi/g was obtained in 1950. Again, about one-half of these results were less than 0.5 fCi Pu/g. The largest positive measurements obtained since 1950 were 1.8 fCi Pu/g of lung and 1.1 fCi Pu/g of liver.

Measurement of plutonium in tracheobronchial lymph nodes was initiated in late 1959 and results have been obtained on 76 cases of local residents and 31 cases of nonlocal residents. Among local residents, the highest concentration found was 140 fCi Pu/g. Ninety-seven percent of the results were less than 20 fCi Pu/g and over one-half of the results were less than 5 fCi Pu/g. Among nonlocal cases, the highest concentration measured was 68 fCi Pu/g and again about 97 percent of the results were less than 20 fCi Pu/g and over one-half of the concentrations were less than 5 fCi Pu/g.

Except for one individual residing locally, the concentration of plutonium in bone was less than 20 fCi Pu/g for all individuals of either environmental category. A plutonium concentration of 49 fCi/g of bone was determined for one individual in 1967. More than three-fourths of the results of measurements of plutonium in bone indicated concentrations of less than 5 fCi Pu/g.

The amount of fallout plutonium that might be expected in local lung tissue samples is estimated to be on the order of 0.5 fCi Pu/g.^{16,17} This result as well as the Hanford measurement results for both categories of environmental residents are in substantial agreement with analytical results obtained elsewhere for the general population in New Mexico, Colorado, Georgia, South Carolina, Tennessee and New York.¹⁸ As a consequence, the Hanford data are considered to suggest preclusion of past Hanford operations as an important contribution to the presence of plutonium in local residents.

III.1.1.2.3 Direct Radiation

Because of the isolation of the major nuclear facilities within the Hanford project, there is no direct radiation exposure of the public from these sources. Potential direct radiation exposure from a severe accident will be discussed later.

III.1.1.2.4 Transportation of Radioactive Materials

During 1972 the radioactive materials transported to or from the Hanford site did not result in any measurable population exposure. The quantities shipped were either small or consisted of alpha emitting radionuclides (uranium and plutonium), which had extremely low external radiation potential.

Prior to 1972, shipments of 100-N irradiated fuel were made to West Valley, New York for processing. The population dose potential received from such shipments was estimated using the shipping data and the calculation methods published by the USAEC in WASH-1238.¹⁹ The population density along the shipping route was taken to be 110 persons per square mile in the western half of the route and 330 persons per square mile in the eastern half. Thus, for 12 shipments made per year at 3000 miles each, the general population dose would be ~ 0.01 man-rem. However, a few individuals would receive additional radiation exposure from closer approach to the vehicles. If a person were to spend about 3 minutes at 3 feet from the shipment, where the dose rate was 3 mR/hr, he would receive a total-body dose of 0.15 mrem. Assuming 10 such persons/shipment and 12 shipments/yr, the total-body dose to all such persons would be 0.018 man-rem/yr. The dose to the transportation workers can also be estimated to be about 0.15 mrem/person/shipment; with the same total of 10 workers/shipment and 12 shipments/yr, the total dose to the workers becomes 0.018 man-rem/yr.

Thus, the total population dose for all three categories combined is estimated to be ~ 0.04 man-rem/yr. Since this dose was not incurred in 1972, it was not included in Tables III.1-7 and III.1-12. But it is a potential dose if the alternative of offsite shipment instead of local processing were selected for the 100-N irradiated fuels.

III.1.1.2.5 Dose to Population from All Sources

The total doses to the total body and the thyroids of the population living within 50 miles of the Hanford project from the several pathways

are summarized in Table III.1-12. The total-body population dose rate from all sources is 2.4 man-rem/yr. The average per-capita annual dose rate is 9.6×10^{-3} mrem/yr. When N Reactor is shut down, the current release of ^{41}Ar and some tritium and ^{131}I as well as other activation and fission products with N Reactor effluents will cease. At that time, the air submersion dose to the population will be reduced to about 0.01 man-rem/yr and the dose attributable to the liquid effluents will be reduced as the radioactive materials already in the river sediments decay. The radionuclides reaching the Columbia River from the groundwater system, (mostly tritium and $^{106}\text{Ru-Rh}$) will, at their maximum rate of discharge, contribute less than 0.1 man-rem/yr to the local population dose. The population total-body dose in the first year after N Reactor is shut down is not expected to exceed 0.5 man-rem/yr and will then continue to decrease as the river inventory decays.

The 50-year population lung dose commitment due to the Hanford Waste Management Operation 1972 release of ^{239}Pu (all assumed to be insoluble) was 0.03 man-rem. The corresponding 50-year population lung dose commitment due to worldwide fallout plutonium (all assumed to be insoluble ^{239}Pu) was about 250 man-rem. The 50-year lung dose commitment from fallout plutonium was nearly 9,000 times the calculated 50-year lung dose commitment from Hanford 1972 emissions.

Both the total-body population dose and the average per-capita dose are insignificant compared with the doses received by the same residents from natural background radiation and other man-made sources. The external penetrating total-body dose from natural cosmic and terrestrial radiation sources in the Hanford vicinity has been measured at 75 to 92 mrem/yr.

In addition to this background, natural radioactive materials within the body, acquired from ingestion and inhalation, add another 25 mrem/yr to the total-body dose.⁴ The natural background per capita dose from external and internal sources is, therefore, about 110 mrem/yr and the

total population dose is about 27,400 man-rem/yr. Thus, the total exposure from Hanford sources (2.4 man-rem/yr) is 9×10^{-5} of that from natural background and would be imperceptible when compared to the normal 10 to 15% fluctuation which occurs annually in the natural background radiation levels.

Medical and dental radiation from diagnostic and therapeutic procedures received in the U.S. in 1970 totaled about 70 mrem/yr/capita according to the U.S. EPA.¹⁵ Other miscellaneous sources listed by the EPA totaled 2.6 mrem/yr per capita in 1970. These included 0.1 from television receivers, 1.0 from high altitude air flights, and 1.5 from miscellaneous consumer products containing radioactive materials (such as luminescent dials on watches).

The dose from high altitude jet aircraft travel includes an average of 670 mrem/yr per crew member and a total of about 200,000 man-rem/yr for passengers at a rate of 0.7 mrem/hr while flying at an altitude of 30,000 feet. The dose received during a single high altitude cross-country flight (~6 hours) would then be about 4 mrem.

Assuming the people within 50 miles of the Hanford project are typical of the national average, they probably received total population doses of 17,400 man-rem/yr from medical sources of radiation, 250 man-rem/yr from jet air travel, 25 man-rem/yr from television receivers, and 370 man-rem/yr from miscellaneous consumer products for a total of 18,000 man-rem/yr in addition to the natural background radiation.

The population dose of 2.4 man-rem calculated to be received as a result of Hanford operations is within normal fluctuations of doses received from natural background radiation. Therefore, relation of a dose of this magnitude to any environmental effect would be unrealistic to postulate and impossible to demonstrate.

III.1.1.2.6 Maximum Health Effects

The reports, "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation" (The BEIR Report)²⁰ and "Ionizing Radiation: Levels and Effects"²¹ have attempted to relate radiation dose to the population to a quantity called Health Effects. The health effects generally considered are cancer deaths, cancer cases, general ill health and genetic damage.

Both reports discuss the difficulties in arriving at dose to health effect relationships because of the very low number of health effects that might occur at the low doses of radiation being considered. Because of the lack of data at the very low actual dose rates (usually 10^{-3} or less rem/hr), health effect assumptions are extrapolated from data from radiation exposures at very high dose rates (many rem/hr). An additional assumption is then made that when the population doses (sum of the dose received by each member of a population group) for population groups of various sizes are equal, the number of health effects are the same for each group. It does not matter whether the doses are small and the populations are large or vice versa. The calculations make the conservative (yielding higher effects) assumption that the population dose health effects relationship is linear and passes through the origin of a plot, i.e., zero dose equal zero effect.

It has been stated that "There is no such thing as a harmless dose of radiation," or words to that effect (see NRDC letter, Appendix Exhibit 18). This statement is almost certain to be misleading unless very carefully qualified. If the intent is to state that at very low doses of radiation the existence or nonexistence of any effect has not been proven, this is correct and exactly those words should be used. If the intent is to state that there are no doses of radiation which are considered by the competent medical and scientific authorities to involve an acceptable risk, the statement is false.

For the analysis of the maximum potential number of health effects that might occur as a result of the 1972 environmental radiation doses due to the Hanford Waste Management Operations, the dose to maximum number of health effect conversion factors from the BEIR Report as summarized by EPA¹⁵ were used. These values are given in Table III.1-14.

TABLE III.1-14
CONVERSION FACTORS

Population Dose to Maximum Number of Health Effects

<u>Mortality</u>	
<u>Organ</u>	<u>Conversion Factors</u>
Total Body	200 cancer deaths/ 10^6 man-rem
Lung	50 cancer deaths/ 10^6 man-rem
Thyroid	5 cancer deaths/ 10^6 man-rem
(Weighted Average) ^(a)	
<u>Morbidity</u>	
Total Body	400 cancer cases/ 10^6 man-rem
Thyroid <1 year old	150 cancer cases/ 10^6 man-rem
1-19 years old	35 cancer cases/ 10^6 man-rem
>20 years old	5 cancer cases/ 10^6 man-rem
(Weighted Average) ^(a)	20 cancer cases/ 10^6 man-rem
Genetic Damage	300 effects/ 10^6 man-rem

(a) Weighted for an assumed population age distribution given by EPA in Reference 15.

For the population doses due to 1972 Hanford Waste Management Operations, the maximum potential health effects are summarized in Table III.1-15. For this calculation, the lung and genetic organ doses were conservatively estimated to be the same as the total-body dose.

TABLE III.1-15
MAXIMUM NUMBER OF HEALTH EFFECTS FOR
1972 ENVIRONMENTAL DOSE LEVELS

<u>Mortality</u>		
<u>Organ</u>	<u>Population Dose</u>	<u>Maximum Number of Health Effects(a)</u>
Total Body	2.4 man-rem	4.8×10^{-4} cancer deaths
Lung	2.4 man-rem	1.2×10^{-4} cancer deaths
Thyroid	12 man-rem	6.0×10^{-5} cancer deaths
 <u>Morbidity</u>		
Total Body	2.4 man-rem	9.6×10^{-4} cancer cases
Thyroid	12 man-rem	2.4×10^{-4} cancer cases
Genetic Damage	2.4 man-rem	7.2×10^{-4} genetic effects

(a) This column gives the total number of health effects through all future years for the doses received in 1972 from Hanford Operations.

Since the number of health effects are all far less than one, it may be concluded that there are no health effects due to Hanford operations for 1972. The naturally-occurring radiation background total-body dose is 11,400 times larger than the dose contribution from the Hanford operations for 1972 (27,400 man-rem background to 2.4 man-rem Hanford). The maximum numbers of health effects (cancer deaths, cancer cases and genetic effects) arising from this natural background is about 11,400 times the number of health effects calculated for Hanford operations.

This data on lung doses referenced in the previous section and the Appendix III-B have assumed uniform distribution.⁷⁰ This is the method adopted by the International Commission on Radiological Protection. However, it has been proposed that^{22,23} summing the energy released from radioactive material in the lung over the entire lung may not be a proper assessment of consequences. Particulate radioactive materials (hot particles) are considered in this proposal to produce a much larger health effect than would be expected from the total organ dose because of the very high dose delivered to the tissue by alpha particles from the deposited material.

The Radiation Alert Network of the Division of Atmospheric Surveillance, EPA, routinely collects airborne particulates from eleven stations across the U.S. for plutonium analysis.²⁴ The high, low and Seattle values are:

Anchorage, Alaska	$14 \times 10^{-18} \text{ Ci/m}^3$
Austin, Texas	$44 \times 10^{-18} \text{ Ci/m}^3$
Seattle, Washington	$20 \times 10^{-18} \text{ Ci/m}^3$

The measurements also for 1972 at Richland, Washington and other locations in the vicinity of the Hanford Operations averaged $19 \times 10^{-18} \text{ Ci/m}^3$. At this background level, it is not possible to measure the Hanford contribution to the general fallout plutonium. However, a calculation of the maximum plutonium concentrations at an offsite location can be made from the measured stack and vent emission rates and the measured dilution factors. The calculated maximum concentrations at the nearest occupied location is $1.5 \times 10^{-18} \text{ Ci/m}^3$, about one-tenth of the concentration of fallout background. The average concentration is considerably less.

In summary, the Hanford measurement of $19 \times 10^{-18} \text{ Ci/m}^3$ includes the calculated maximum addition from Hanford of $1.5 \times 10^{-18} \text{ Ci/m}^3$ and any

resuspension that would result from previous Hanford or fallout depositions. Thus, the Hanford contribution does not measurably contribute to the plutonium fallout background.

It is concluded from Tables III.1-14 and III.1-15, and from the plutonium measurements, that the Hanford Waste Management Operations for 1972 did not impact harmfully to any significant degree on the health and well being of the population in the Hanford environment.

As indicated in the BEIR Report, there is insufficient information and scientific data on which to base estimates of the actual risk of health effects attributable to a particular increase in the level of exposure of the general population to ionizing radiation. This report also recognizes that the assumptions and models used in making an analysis of health effects are fraught with uncertainty. There are responsible views to the effect that assumptions used in calculating so-called health effects are simply not correct. The President of the National Council on Radiation Protection and Measurements has stated:²⁵

"If this is true it becomes purely a matter of judgment as to where to set permissible standards, and that is precisely the dilemma into which we have worked ourselves during the past decade.

"In the development of this concept, there were many reservations and explanations but if the linear dose-effect relationship is taken at its face, and you literally accept the relationship as fact rather than as assumption or model, you can presumably calculate the number of people that will be killed by any level of radiation exposure that you wish to use. This is precisely what has happened during the past three or four years. A couple of authors predicted a 'kill' up to 100,000 people a year--in the minds of the average reader and the public--due to the use of current standards applied to the generation of electric power by nuclear means. Another author predicted that the medical profession would 'kill' a third of that number because radiologists are not sufficiently careful about diaphragming their x-ray beams. Still another author predicts a 'kill' of countless babies by exposure to radiation from power reactors at radiation levels far less than the natural background radiation. What has happened is that each of these people have taken the assumptions or models and used them as though they were facts."

There has been a history of disagreement with the established radiation protection standards on the part of some members of the scientific community. In some instances, the absence of sufficient data concerning biological effects from radiation at low levels has resulted in disagreement with the value judgment that utilization of materials and processes which produce radiation should proceed even though all risks may not be known. The BEIR report does not propose new numerical standards for radiation exposure but rather concludes that such decisions require technical, economic and sociological considerations of a complex nature.

III.1.2 Radiological Impact on Biota Other than Man

III.1.2.1 Terrestrial

The release of research and surveillance programs indicate that radioactivity to the terrestrial environment from plant operation since startup in 1944 has not affected the local biota. No change in community types is recognized except following major perturbation from construction activity. There is evidence that no significant amounts (in most cases no detectable amounts) of long-lived radionuclides have escaped the Hanford site boundary and accumulated in soils or biota.^{4,26} Similarly, the effects of routine operation, manufacturing and waste management programs on terrestrial ecosystems are not expected to be significant from a radiological standpoint.

Since some biological uptake and dispersion of radionuclides from waste management zones can be expected at least at a low level,²⁷ these potential vectors for exposure are discussed below.

Most biological uptake of waste radionuclides from current routine plant operations is from a soil substrate into plants. Burial grounds of one type or another represent the largest source of radionuclides accessible to local biota. Tumbleweed (Russian thistle), a noxious weed because of its opportunistic growth habit, has an affinity for radionuclides such as ⁹⁰Sr. The first tumbleweeds found growing into soil contaminated from a waste-pipe leak were reported to contain about 3 μ Ci ⁹⁰Sr-⁹⁰Y/g.²⁸

Soil at a depth of 4 feet contained about $6.6 \mu\text{Ci } ^{90}\text{Sr}-^{90}\text{Y/g}$, suggesting a concentration factor (CF) of about 0.5. Cytological examination of the growing tips failed to show differences between plants containing these radionuclides and those without. Tumbleweed populations are now controlled at radioactive as well as nonradioactive sites by several methods. Herbicides (almost exclusively "Krovar," 50% Bromacil, 50% Diuron, i.e., substituted ureas, or "trysben," 2,3,6-Trichlorobenzoic acid) are applied periodically when necessary to limited waste management areas under strict control procedures to eliminate mature tumbleweeds and other growth.

Over the years, deeper placement of buried materials and containment of transuranics in retrievable containers has reduced the likelihood of biological uptake problems. Another method used to discourage tumbleweed growth is the layering of a plastic sheet below the soil surface over the buried material. This reduces the need for herbicide treatment. Tank farm ground surfaces are covered with rock and gravel layers; herbicides are used to control weed growth.

Animal interaction with waste storage sites occurs when waterfowl find areas of open water (ditches and ponds). Vegetation control reduces the availability of food, cover and nesting sites. Potential problem areas, such as the 1301-N trench, are covered with wire mesh to prevent access by large mammals or waterfowl. Surveillance data for 1972 for various radionuclides in tissues of waterfowl are given in Table III.1-16. Data for other animals are given in the most recent Hanford Environmental Status Report.²⁹

The most significant interaction of terrestrial biota with waste management is related to the B/C Controlled Area which lies south of 200-E Area.⁶⁹ The B/C Controlled Area covers an area of about 4 square miles and was contaminated with radioactive animal feces and urine in 1960. A process liquid containing ^{90}Sr and ^{137}Cs which had been disposed of to the 216-B trenches was burrowed into by animals (presumably a badger) and a salt layer was exposed. Rabbits subsequently used the

TABLE III.1-16

AVERAGE RADIONUCLIDE CONCENTRATIONS IN MUSCLES OF WATERFOWL (1972)

Units of 10^{-6} $\mu\text{Ci/gm}$ (wet weight)

<u>Location</u>	<u>Species</u>	<u>Number of Samples</u>	<u>^{58}Co</u>	<u>^{60}Co</u>	<u>^{65}Zn</u>	<u>^{90}Sr</u>	<u>^{137}Cs</u>	<u>^{141}Ce</u>
Analytical Limit			0.15	0.15	0.20	0.002	0.1	0.16
U Pond	Ducks	2	--	--	--	0.006	27.	--
Redox Pond	Ducks	2	--	--	--	0.054	3.1	--
Gable Pond	Ducks	4	--	--	--	0.003	26.	--
B Pond	Ducks	4	--	--	0.11	0.003	3.3	--
300 Pond	Ducks	5	--	--	--	--	--	--
100-F Trench	Ducks	3	--	--	0.14	0.11	0.14	--
T Pond	Ducks	1	--	0.20	0.40	0.003	70.	--
West Lake	Ducks	1	--	--	--	--	4.2	--
Columbia River	Ducks	71	--	--	$0.096^{(a)}$	0.003	$0.070^{(a)}$	--
Columbia River	Geese	32	--	--	$0.079^{(a)}$	0.003	0.11	--

(a) Result smaller than analytical limit due to larger sample size.

sites as a "salt lick" and soon spread the radionuclides over a large area. The stability of this source of radioactivity under current environmental conditions is being studied. Air monitoring studies³⁰ indicate that concentrations of airborne ¹³⁷Cs (e.g., 0.19 to 3.0 x 10⁻¹⁴ μ Ci/cm³ air) are roughly 1 one millionth of guide values for radiation workers and are not far different than general onsite environmental surveillance data for 1972.²⁹

Changes in animal populations and vegetation abundance ascribable to the deposition of radionuclides are not evident. Studies of the uptake of radioactive materials by plants and animals have evaluated such uptake as a potential pathway of radionuclides to man. Comprehensive studies of the effects of the depositions of radionuclides in plants and animals have not been made.

III.1.2.2 Aquatic

III.1.2.2.1 Columbia River

The main sources of radioactivity presently entering the Columbia River are from the spring seepages along the banks below N Reactor. The aquatic biota in the Hanford section of the Columbia River are exposed to significantly lower levels of radionuclides in the water now than prior to December 1971 when the once-through cooling, plutonium production reactors were operating. Concentrations of the various radionuclides in the Columbia River are orders of magnitude less than during the period when several reactors were in operation.

Much data has accumulated on the concentrations of various radionuclides in the biota of the Columbia River from the start of reactor operation in 1944 until December 1972. Since then, studies were made of the declining concentrations of radionuclides in the biota of the Columbia River-McNary Reservoir ecosystem. Much of the evaluation presented here relies heavily on the results of studies made during periods when greater amounts of radionuclides were present, with inferences made to the present lower levels of radioactivity.

The most recent ecological study of a variety of Columbia River biota when several reactors were operating took place from February 1966 to September 1967 when six reactors were operating.³¹ Data comparing radionuclide concentrations in biota from earlier studies are given along with information on concentration factors (CF). Table III.1-17 presents a comparison of gamma emitting radionuclides in several organisms from 1957 to 1967.

No consistent changes could be attributed to the number of operating reactors; the same is true for total beta measurements. Evidently highest concentrations of most radionuclides are found in the lower trophic levels, such as plankton, algae, and sponges. These organisms have a large surface to volume ratio and present a relatively large surface for adsorption of radionuclides. In general, CFs were highest for the biologically important radionuclides ^{32}P and ^{65}Zn and were highest in the net plankton (9,000 to 68,000 for ^{32}P and 3,500 to 40,000 for ^{65}Zn) and periphyton (5,000 to 24,000 for ^{65}Zn) and decreased in higher trophic levels.

Considerable data have been collected on the movement of radionuclides from Columbia River water to biota and from one organism to another.³⁴ An early paper³⁵ on some of the principles involved with the transfer of radionuclides from water to higher organisms in the food web reported CFs of 150,000 for ^{32}P in shiners and 350,000 in caddis fly larvae. The relative concentration of beta emitters in Columbia River biota varies for three reasons: 1) the several radioisotopes involved have different relative proportions in the various organisms, 2) variation in moisture content exists between organisms, and 3) the relative position in the food pyramid is influential.³² A study³⁶ in 1957 provided data on CFs in various organisms from the Columbia River and considered the basic concepts governing the uptake and retention of radionuclides by aquatic biota. CFs were reported for several radionuclides in four organisms:

TABLE III.1-17

COMPARISON OF CONCENTRATIONS OF GAMMA EMITTING RADIONUCLIDES IN COLUMBIA RIVER ORGANISMS 1957-67³¹

		pCi/g wet weight						
		Plankton	Sessile Green Algae	Sponge	Caddisfly Larvae	Limpet Soft Parts	Limpet Shell	Minnows
³² P	1957	-	66,000	4,460	24,300	-	-	24,000
	1966			3,270	6,560	3,790	988	7,110
	1967		12,800	15,100	28,200	19,000	2,310	
⁴⁶ Sc	1957 ^(a)	-	1,730	94.7	70.6	-	-	0.702
	1967 ^(b)	5,690	3,020	2,130	968	87	475	0 ^(b)
⁵¹ Cr	1957 ^(c)	-	7,900	4,580	6,000	-	-	372
	1964 ^(c)	59,500	43,400	10,200	3,590	1,940	1,080	-
	1965 ^(c)	28,400	32,900	16,000	4,890	2,260	1,350	-
	1967	12,600	10,160	5,060	3,030	696	1,060	17.6 ^(b)
⁵⁴ Mn	1957	-	1,030	-	79.1			
	1967	791	1,080	603	447	136	359	0 ^(b)
⁵⁹ Fe	1957	-	1,640	-	-	-	-	-
	1967	1,250	1,360	860	537	260	274	28.4 ^(b)
⁶⁰ Co	1957	-	155	11.6	1.72	-	-	-
	1967	41	456	0	7	80	31	0
⁶⁵ Zn	1957	-	12,300	1,460	1,980	-	-	762
	1964	14,000	8,870	3,070	1,970	2,820	658	-
	1965	1,910	3,250	2,500	1,770	1,360	346	-
	1967	4,580	2,050	1,910	1,790	1,560	435	237 ^(b)

TABLE III.1-17 (Continued)

		pCi/g wet weight						
		<u>Plankton</u>	<u>Sessile Green Algae</u>	<u>Sponge</u>	<u>Caddisfly Larvae</u>	<u>Limpet Soft Parts</u>	<u>Limpet Shell</u>	<u>Minnows</u>
III.1-43	⁹⁵ Zr-Nb	1957	-	1,790	-	66.3	-	-
		1967	953	380	553	156	109	13
	¹⁴⁰ Ba	1957	-	901	-	42.2	-	-
		1967	1,910	459	510	367	96	117
	¹⁴⁰ La	1957	-	3,270	1,230	347	-	-
		1964	5,900	1,610	950	223	73	113
		1965	2,010	1,760	1,330	322	107	107
		1967	4,630	2,400	2,400	656	333	379
	²³⁹ Np	1957	-	2,690	401	311	-	-
		1967	3,010	1,750	1,080	384	79	173
								0(b)
								0(b)

(a) Reference 32

(b) Reference 31

(c) Reference 33

CFs for phytoplankton ranged from 500 for ^{64}Cu for filamentous algae; from 100 for ^{24}Na to 100,000 for ^{59}Fe and ^{32}P for insect larvae; and from 50 for ^{64}Cu to 100,000 for ^{32}P in fish. (a)

The factors governing the amounts and kinds of radionuclides accumulated by Columbia River fish have been investigated.³⁷ Radionuclide concentrations in fish are mediated by a host of factors including metabolic rates. Relative radionuclide concentrations in fish do not reflect the relative concentration of that isotope in the water; this is an example of selective uptake of essential elements. Concentrations of ^{32}P in whitefish varied over two orders of magnitude in one year; ^{65}Zn varied over one order of magnitude. Dilution of radionuclides in the water by runoff is a major contributing factor to these seasonal variations.

The pathways of accumulation of Columbia River radionuclides through food chains and the ultimate dose estimates to man have been considered in detail.³⁸ These pathways may be entirely aquatic, in which the food chain terminates in fish eaten by fishermen, or partially terrestrial, in which Columbia River water is used to irrigate crops. In each case, ^{32}P and ^{65}Zn were of greatest importance.

Columbia River plankton have been studied since the late 1940's. In 1953³⁹ plankton averaged about 3.7×10^{-3} μCi total beta/g wet wt, and no harmful influence from the Hanford Operations could be detected. Seasonal variation in radionuclide burden in the river biota has a wide range. In plankton, lowest radionuclide concentrations of ^{32}P and ^{65}Zn were found in the spring-summer runoff period; the increased biomass at this time resulted in a greater transport of ^{32}P and ^{65}Zn .⁴⁰ Concentration factors for ^{32}P ranged from 5,000 to 118,000 and for ^{65}Zn from 300 to 19,000; highest values were in the fall.

(a) Peak CF in whole fish. Annual average CF for flesh only in species actually eaten in Hanford environment is considerably less. (Table III.1-2).

The uptake of ^{32}P and ^{65}Zn by periphyton in the Columbia River was closely related to dry and ash weight of the periphyton and to chlorophyll a content.⁴¹ Net Production Rate was highly related to solar energy and chlorophyll a. The data suggest that adsorption was the dominant mode of uptake.

In laboratory tests, ^{65}Zn uptake by periphyton was proportional to ambient levels of ^{65}Zn in the water and adsorption was the dominant mode of uptake.⁴² The ^{65}Zn uptake could be decreased by addition of stable divalent cations, either zirconium or magnesium, demonstrating that uptake involves a competition for binding sites. Uptake of ^{65}Zn in this system was essentially complete after about 80 hours. While ^{65}Zn is strongly bound to periphyton in the pH range around 8.0, ^{65}Zn is not absorbed at a pH below about 4.0, which could be significant in transfer of ^{65}Zn from ingested particles in the intestines of higher animals like the sucker. Studies of the cycling of ^{65}Zn from water to periphyton to juvenile carp in laboratory streams showed that equilibrium concentrations for the periphyton were reached in about 28 days.⁴³ The effective half-life was about 15 days; approximate equilibrium in the fish was attained after about 43 days.

In situ radiation dose measurements made in periphyton communities near a reactor effluent outfall in 1969 ranged from 350 mR/day near the surface of the river to 230 mR/day near the bottom.⁴⁴ Twenty-four km below the reactors, dose rates were 20 mR/day and less. Twenty-two km below a reactor outfall, dose in the periphyton ranged from about 30 mR/day in March to September 1969, to about 34 mR/day from September to December.⁴⁵ Dose rates beneath stones were from 10 to 20% less than on the upper side. Doses to adult fish 23 km downstream of reactor outfalls ranged from 11 mR/day on the dorsal surface to 17 mR/day near the intestinal tracer. ^{32}P has been shown to be the dominant beta emitting isotope in crayfish and Cladocera.⁴⁶ Approximate retention times⁴⁷ for various radionuclides in limpet snails, with both a slow and fast component,

have been observed. The slow component for ^{65}Zn in the body resulted in an effective half-life of about eight days in November to thirty days in March. Data⁴⁸ on the accumulation of various radionuclides by aquatic insects in the Columbia River showed that CFs for caddis fly larvae ranged from 30 for ^{239}Np to 100,000 for ^{32}P .

Concentrations of ^{65}Zn in the tissues of freshwater mussels⁴⁹ have been shown to decrease in the following order: gills, mantle and palps, body mass (including the digestive gland, digestive tract, and gonad), adductor muscles, and foot. The total body burden was directly related to the ambient concentration of ^{65}Zn .

Studies of uptake, cycling, etc., of radionuclides by fish far outnumber studies of other organisms in the Columbia River at Hanford. The most recent data on radionuclide concentrations in various species was published in 1970.³¹ A bibliography⁵⁰ with abstracts of all aquatic bioenvironmental studies in the Columbia River at Hanford from 1945-1971 provides a guide to the extensive data available on fish and other aquatic organisms.

The above discussion attempted to put the radiological status of Columbia River organisms into some perspective as it related to water conditions while several reactors were in operation. Three studies provide data related to concentration and cycling of radionuclides by Columbia River biota when reactors were shut down. The first³³ presents information from a limited sampling program to document the effects of the closure of three reactors in 1965. A significant decrease of biologically important radionuclides was evident with some indication of a trophic level response. Also documented⁵¹ is the response of several organisms to a complete shutdown of all reactors for several weeks and subsequent reactions after the reactors were restarted.

A significant study of the cycling and retention of radionuclides in the Columbia River - McNary Reservoir ecosystems presently in progress was initiated the summer of 1971 following closure of all reactors except N Reactor. (Data from this study is still being processed, but cursory information has been published.⁵²) In general, the biota at White Bluffs and McNary Reservoir exhibited concentrations of various radionuclides of at least an order of magnitude lower by the winter of 1972. This was especially true of the organisms in the lower trophic levels while concentrations declined more slowly in fish due to their slower biological turnover. At present, levels of ⁶⁵Zn and ⁶⁰Co are just above detection limits in most biota in McNary Reservoir, while levels of ⁴⁶Sc, ⁵⁴Mn, and ¹³⁷Cs have essentially become unmeasurable.

The following comparisons may be useful in evaluating the impact of present operation upon portions of the food-web. In water, 15 to 35% of the ⁶⁵Zn was ionic when the reactors were operating, but less than 2% was present in ionic form in 1971 and 1972.

Ratios of ⁶⁵Zn can be compared in various organisms and in their principal food for that period. Suckers graze on periphyton communities and when the reactors were operating, approximately 10 times as much ⁶⁵Zn was in the periphyton as in the suckers. In 1971 and 1972, only about 2 times as much was in the periphyton. The same ratios, essentially, were found for the squawfish which prey on smaller forage fish. Manganese-54 has been undetectable in the plankton in McNary Reservoir for several months, yet it has the highest concentration of any radionuclide in the flesh of the freshwater mussels. Mussels utilize plankton for food and are known concentrators of ⁵⁴Mn; the present levels of ⁵⁴Mn (~10 pCi/g dry weight) are probably related to the long biological half-life of ⁵⁴Mn in Anodonta, about 1300 days.⁵³ Zinc-65 is also present in higher concentrations in mussels than in other organisms. Catfish have similar concentrations of ⁶⁵Zn as their food items, crayfish and forage fish.

In summary, extensive studies have investigated the relationship between the concentrations of radionuclides in water and in a wide range of lower and higher aquatic life forms. The concentration factors for various chemical forms of radionuclides and various aquatic life forms have been studied also. Studies of the radionuclide concentrations in aquatic organisms between times of widely varying radionuclide concentrations in the Columbia River show how these changes affect deposition in aquatic organisms. Comparisons of the quantity and species of aquatic organisms during the periods of substantially different radionuclide concentrations in the river indicates no gross effects from these conditions. Comprehensive studies of the effects on individual organisms are limited. Most studies have investigated the deposition in aquatic organisms as a pathway to exposure of man.

III.1.2.2.2 200 Areas Ponds and Ditches

Measurement of the radionuclide burden in the biota in the chemical processing areas of Hanford Reservation has been mainly concerned with the life forms that are potential vectors for the offsite transfer of radioactive materials to nearby uncontrolled regions. Because of their relatively low potential for the direct transfer of radioactivity, the aquatic life forms have not been as thoroughly studied as some of the other natural systems of the area.

An intercomparison of the concentrations of radioactivity in several of the surface waters receiving low-level radioactive waste is shown in Table III.1-18. These data indicate that the concentration of radionuclides is highly variable with no consistent pattern evident in the burdens in algae and bottom muds. A more extensive study of aquatic organisms within one of these ponds (Gable Mountain Pond) suggests a number of points concerning the distribution of radioactivity in a waste pond ecosystem (Table III.1-19). The concentration of radionuclides in the bottom muds is usually an order of magnitude greater than that of

TABLE III.1-18

COMPARATIVE RADIONUCLIDE CONCENTRATIONS - 200 AREAS SURFACE WATERS
(MARCH 1970)

Location	pCi/g wet wt					
	¹³⁷ Cs		Total Alpha		Total Beta	
	Mud	Algae	Mud	Algae	Mud	Algae
Laundry Ditch	10	74	3	6	140	630
U Pond - N.E. Shore	420	25	6	900	440	130
- S.E. Shore	500	2	14	2	320	5
Gable Mtn Pond Inlet	38	360	1	0.5	810	540
B Plant Ditch Inlet	44	-	1	-	290	-
B Plant Pond Inlet	59	32	0.7	2	320	320
Purex Chemical Sewer	58	3	240	2700	430	1900

TABLE III.1-19

CONCENTRATION OF RADIONUCLIDE IN GABLE MOUNTAIN POND BIOTA - 1972

Sample Type	pCi/g wet wt									Total Alpha June	239Pu June
	137Cs			95Zn			60Co				
	June	July	Sept	June	July	Sept	June	July	Sept		
Mud-lower end	11,300	16,400	6,900	910	382	218	56.0	40.8	26.0		1.99
Mud-near inlet	-	80.8	76.8	-	5.60	8.56	-	2.61	1.76		
Periphyton	74.5	7,480	516	8.30	398	37.4	1.10	25.1	4.00		
Rooted Plants											
Potamogeton sp.	174.5	1,460	161	9.36	29.5	16.2	0.70	4.55	0.250		
Snails	91.8	3.72	-	5.78	9.68	-	bkg	0.472	0		
Waterboatmen	13.2	3.36	12.0	2.30	0.330	1.69	bkg	0.400	bkg		
Dragonfly-adults	10.3	9.34	-	1.95	1.65	-	bkg	bkg	-		
Damselfly-adults	7.84	14.3	-	0.942	1.38	-	bkg	0.525	-		
Goldfish	130	75.7	67.5	7.28	3.20	3.11	1.79	0.42			1.06

the biota and is nonuniformly distributed. Burdens in plants, periphyton and rooted submergents, usually exceed that of the animal forms. Goldfish, which are a potential food source for aquatic birds, contain higher levels of radioactivity than some of the invertebrates. The adults of two of the major emergent insects in the ponds, damselflies and dragonflies, have very low radionuclide concentrations and appear to be of minor importance in the translocation of radioactivity from the pond.

Several studies involving the cycling of specific radionuclides by biota have been published.⁵⁴ When ^{137}Cs , at a concentration of 6×10^{-3} $\mu\text{Ci/ml}$ was added to a pond, the rapid uptake of ^{137}Cs by algae occurred (100 times the water concentration in 2 hours). Concentration factors for ^{137}Cs by various aquatic biota ranged from 50 for bullrush culms to over 10,000 in scuds.

Studies are currently in progress in Gable Mountain Pond (an effluent discharge pond) to explore the relationship between rate of radionuclide accumulation in goldfish and sediment radioactivity. Uncontaminated goldfish confined in a pen over sediments of relatively low radioactivity and permitted to feed naturally, approached equilibrium concentrations of about 300 pCi ^{137}Cs /gram net weight in approximately 15 weeks. A similar group of fish penned over higher level sediments attained body burdens nearly twice this high over a period of about 19 weeks. ^{137}Cs levels in the free-ranging native goldfish population were similar to those in experimental fish over the low-level sediments. The food base of the goldfish appears to be largely organic plant debris, presumably obtained from the pond bottom. Goldfish in U Pond have a similar food base.

Radiation doses at the sediment-water interface of Gable Mountain Pond, as measured with thermoluminescent dosimeters, ranged up to 230 mR/day during the first quarter of 1973. Large location-dependent differences

were in the measured dose, again indicating the heterogeneous distribution of radionuclides in the pond bottom.

Radiation doses to waterfowl and aquatic organisms were estimated from the radionuclide analyses previously listed in Tables III.1-17, -18, -19 and are given in Table III.1-20. All of the doses listed in Table III.1-20 are well below the levels where any observable radiological effects are expected.^{6,9} No such effects have ever been seen in the Hanford environment.

III.1.2.2.3 Radiation Doses to Aquatic Organisms

Radiation doses to waterfowl and aquatic organisms were estimated from the radionuclide analyses previously listed in Tables III.1-16 through III.1-19. In addition, external radiation doses for Columbia River organisms were also estimated from the release rates of radionuclides to the Columbia River in 1972. In the latter instance, external doses from bath water immersion and shoreline exposure were included. The results of these calculations are summarized in Table III.1-20. All of the doses listed in this table are well below the levels where any observable radiological effects should occur. Indeed, no such effects have ever been seen in the Hanford environment.

TABLE III.1-20

ESTIMATED RADIATION DOSES TO AQUATIC ORGANISMS AND WATERFOWL
FROM LIQUID RELEASES AT THE HANFORD PROJECT - 1972
(rad/yr)

<u>Organism</u>	<u>Location</u>	<u>Internal Dose(a)</u>	<u>External Dose(b)</u>
<u>Waterfowl</u>			
Duck	T Pond	0.11	-
Duck	U Pond	0.16	-
Duck	Redox Pond	0.02	-
Duck	Gable Mtn Pond	0.15	-
Duck	B Pond	0.02	-
Duck	West Lake	0.025	-
Duck	100-F Trench	0.003	-
Duck	Columbia River	6×10^{-4}	8×10^{-3}
Goose	Columbia River	8×10^{-4}	8×10^{-6}
Heron	Columbia River	-	8×10^{-6}
<u>Fish</u>			
Goldfish	Gable Mtn Pond	0.55	-
Salmon	Columbia River	-	4×10^{-4}
<u>Plants</u>			
Rooted Plants	Gable Mtn Pond	2.9	-
<u>Miscellaneous</u>			
<u>Biota</u>			
Muskrat, Raccoon	Columbia River	-	5×10^{-3}
Invertebrates	Columbia River	-	2×10^{-2}

(a) From radionuclide concentrations listed in Tables III.1-16 through III.1-19.

(b) Calculated from liquid effluent releases to the Columbia River.

III.1.3 Nonradiological Effects on Ecological Systems

III.1.3.1 Effects on Terrestrial Ecological Systems

Other than loss of habitat, the significant nonradiological impacts on terrestrial ecosystems that might result from routine waste management operations programs would be associated with 1) the use of herbicides for weed control, 2) waste oils used on unpaved roads for dust control, 3) fires arising from plant activity, and 4) vehicular traffic. In general, no serious threat is posed to higher biota and only localized interference occurs with lower life forms. In fact, observations of a variety of wildlife, even within the confines of exclusion area fences, suggest that several species are making use of the works of man to their advantage.

The total commitment of land to plant uses (as described in Section II.1) has always been a small fraction of the 570 square miles of the Hanford Reservation and in recent years has actually decreased with the retirement of older facilities. Positive actions taken by the Atomic Energy Commission to preserve for the future existing ecosystems include the dedication of the Arid Lands Ecology Reserve and the release of much of the Reservation north of the Columbia River for wildlife management. Although plant construction activities have been locally disruptive to vegetation, much of the affected land not in actual use has shown a succession of other local flora which may be more productive than the original.

Herbicides are selected from a list approved for use by federal agencies and are used under prescribed conditions. Such usage is necessary for weed control along roadsides and railroad rights-of-way, and especially around both liquid and solid waste disposal sites to prevent the uptake of radioactive materials in the soil by vegetation. About 17,000 lb of a soil sterilant (Krovar) and 104 gallons of oil-basic herbicides were used during CY-1972.

About 23,000 gallons of nonradiological waste oil are generated annually on the Hanford project and used to stabilize roads, parking lots and "blow" areas throughout the Reservation. This material also acts as a temporary soil sterilant in the immediate area of application, but has the compensating benefit of limiting the smothering of nearby vegetation by excessive dust.

Only minor amounts of insecticides are used on the Hanford area and then directly around and inside of buildings, especially for black widow spider control.

III.1.3.2 Effects on Aquatic Ecological Systems

The principal potential effects of the routine operation of Hanford Waste Management Operations programs on the aquatic environment include the following:

- the impingement of some fish on the traveling screens of water intake structures in the Columbia River
- the entrapment or entrainment of some fish in such intake structures
- destruction of drift organisms passing into the water withdrawal systems
- thermal and chemical stress on organisms residing in or passing through zones of elevated thermal or chemical concentrations, either at points of direct discharge in the Columbia River or as a result of waste streams reaching the Columbia River via groundwater movement and riverbank seepage
- thermal and chemical stress on organisms residing in or using other surface waters affected by plant discharges of cooling water
- effects on Columbia River water quality for other uses, including public water supply.

III.1.3.2.1 Effects of Intake Structures on Aquatic Ecological Systems

At present, intake structures are operating and withdrawing water from the Columbia River at 100-B, 100-K, 100-N and 300 Areas (listed in Table III.1-21). Only at 100-N Area is there a major withdrawal of water amounting to as much as 490 cubic feet per second (cfs) for the AEC N Reactor facility and up to 1260 cfs for the WPPSS power generation facility. The maximum withdrawal rate at the other structures is 30 cfs or less.

TABLE III.1-21

HANFORD INTAKE STRUCTURES DRAWING FROM THE COLUMBIA RIVER

<u>Location</u>	<u>Maximum Rate of Withdrawal</u>	<u>Maximum Velocity at Intake Screen</u>	<u>Type of Protection for Biota</u>
100-B Area	29 cfs	1.0 fps	Traveling Screens
100-K Area	22 cfs	0.5 fps	↓ No Screens
100-N Area	490 cfs	1.0 fps	
WPPSS	1260 cfs	0.89 fps	
300 Area	5 cfs	1.0 fps	

With the exception of the 300 Area, all intakes were designed in accordance with U.S. Fish and Wild Life recommendations and include traveling screens with continuous backwash capability and appropriate piping to return the dislodged biota back to the river. These screens are of approximately 1/4-in. mesh, typical for such facilities. The pump wells and traveling screens are protected by steel bars to prevent entry of any large river debris, but at such a spacing as to be no hindrance to the free passage of fish in either direction. Although velocities at the intakes and at the screens (the potential point of impingement) vary somewhat with facility and with river elevation, the range of screen velocities is generally 0.1 to 1.0 feet per second. Although

no studies have been completed which would quantify impingement of biota upon the traveling screens which protect each of these intakes, most juvenile fish should be able to escape impingement at average river flow rates. A study evaluating impingement and screen passage is in progress at the WPPSS intake structure.

The small fraction of the total Columbia River flow being withdrawn for plant use (less than 2%) implies a negligible effect on available food supplies to higher trophic levels from drift organisms entrained at the water intakes.

III.1.3.2.2 Effects on Aquatic Ecosystems of Dredging or Shoreline Disturbance

No dredging or other river bottom or shoreline disturbances are in progress or are planned by the AEC.

III.1.3.2.3 Thermal and Chemical Effects on Aquatic Ecosystems

III.1.3.2.3.1 Effects of Direct Thermal and Chemical Discharges to the Columbia River

Fourteen liquid effluent lines from Hanford facilities discharge their contents directly to the Columbia River. An EPA permit application made in 1970 is pending for these discharges. Pertinent data for these streams are summarized in Tables III.1-22 and III.1-23; a description of the discharges is given in Appendix II.1-D.

The lack of significant impact due to nonradiological contamination or heating of the Hanford stretch of the Columbia River is probably best illustrated by the various ecological studies discussed in Section II.1. In general, the heated effluents from up to nine plutonium-production reactors have had no detectable harmful influence on the number of salmon spawning in the Hanford Reach nor caused demonstrable biotic downgrading of the aquatic ecosystem in the almost 30 years of plant operation and concurrent scientific observation. Of special

TABLE III.1-22

DISCHARGE LINES TO COLUMBIA RIVER

Area	Discharge Lines	Discharge Rates, cfs or Quantities	Use	Temperature	Other Potential Water Quality Effects
100-B/C	12-in. steel pipe	6000 gallons twice a week	Backflush pump inlet screens	Ambient	None - untreated raw river water
100-B/C	42-in. steel pipe	2.2	Drains and filter backwash	2.8°C, Above ambient	Total Solids Turbidity Aluminum Sulfate Chloride
100-KE and KW		1.1 5000 gallons 3 times a year	Backflush pump inlet screens	Ambient	None - untreated river water
100-KE and KW	two 84-in. steel pipes	1.1	Drains, overflow and cooling water for compressors and pumps	2.8°C Above ambient	Total Solids Turbidity Aluminum Sulfate Chloride Chlorine (0.25 mg/l)
100-N		75,000 gallons 3 times a day	Backflush pump inlet screens	Ambient	None - untreated river water
100-N	3 by 4-ft concrete chute	1.1	Overflow from filtered water and raw water storage tanks, condensate from medium pressure steam system, filter backwash	11 to 20°C Above ambient	Total Solids Ammonia (as well as radioactive waste) Chlorine (0.05 mg/l) Turbidity
100-N	42-in. steel pipe	0.01	Filtered water overflow, and waste from floor drains	6 to 8°C Above ambient	Sulfate Chloride Chlorine (0.05 mg/l)
100-N	66-in. pipe to 12-ft concrete flume on riverbank	140	Turbine condenser cooling water and graphite heat exchanger cooling water	16°C Above ambient	Aluminum Turbidity
100-N	102-in. steel pipe	300 (extremes 140 and 410 cfs)	Steam condenser cooling water	5.5°C Above ambient	Turbidity Ammonia Sulfate, Iron Sodium (occasionally 0.3 mg/l ortho-phosphate) Chlorine - 2 to 40 ppb
WPPSS	132-in steel pipe	940 when river <25°C 1260 when river >25°C	Steam condenser cooling water	15 to 20°C Above ambient	(same as above)
100-D/DR	12-in. steel pipe	6000-gallons once a month	Backflush pump inlet screens	Ambient	None - untreated river water
100-D/DR	two 42-in. steel pipes	4.4 (2.2 to 22)	Filter backwash and process (coolant and wash) water, hydraulic test loop water	2.8°C Above ambient	Total Solids Turbidity Aluminum Sulfate Chloride chlorine (0.74 mg/l) (max. 2.2 mg/l)
300	24-in. concrete pipe terminating as a 30-in. half-round corrugated metal pipe	2.2 (average)	6 to 12/day batches of 12,000 gal	Filter backwash (from water treatment plant)	Ambient Total Solids Turbidity Aluminum Sulfate "Separon" (a proprietary polyacrylamide filter aid) chlorine (0.5 mg/l)
300	36-in steel pipe	0.01	Air conditioner cooling water and floor drains	25°C Above ambient	Aluminum Sulfate chlorine (~0.5 mg/l)
300	12-in. steel pipe	1.1 (0.04 to 2.3)	Drainage from roof and parking lot, tanks for aquatic organisms	2 to 3°C Above ambient	Total Solids Turbidity Organic nitrogen

TABLE III.1-23

TOTAL DIRECT CHEMICAL DISCHARGE TO COLUMBIA RIVER PER YEAR

<u>Materials</u>	<u>Quantity from All Facilities (tons)</u>
Aluminum sulfate	260
Chlorine	20
Polyacrylamide	0.8
Salt (rock)	22
Sodium Dichromate	2
Sulfuric Acid	650
Ammonium Hydroxide	60
Hydrazine	8
Morpholine	1.5
Sodium Hydroxide	230

interest in this regard is the annual aerial survey of chinook salmon nesting in the free flowing Hanford stretch of the river which shows a fairly constant increase in the number of chinook salmon redds from the late 1940's up through the fall of 1973.⁵⁵

Salmonids are singled out for mention frequently in evaluations not because they are more important ecologically than the other species nor because they are popular and economically important, but rather because: 1) scientific literature concerning them is extensive, 2) they are generally considered to be among the most sensitive of fishes to temperature alterations and chemical toxicants, and 3) they are seasonally abundant in the portion of the Columbia River in the vicinity of Hanford. It is reasonable to conclude that if there is not a significant impact on salmonids, a significant impact on other species is not occurring.

Thermal Effects on the Columbia River Ecosystems

At present, the only thermal discharges of sufficient magnitude to affect Columbia River temperatures occur either from 100-N Area or from the associated WPPSS power generating stations when the N Reactor is operating. Other discharges entering the river have sufficiently small flow rates and temperature increments as to affect at most a few square feet of river bottom or to impinge on drifting organisms for a few seconds.

The largest heated stream arising from N Reactor operation is the cooling water from the WPPSS Station (Table III.1-22) which has a flow-rate of 940 to 1260 cfs depending on incoming river temperature. Surveys⁵⁶ of the thermal plume created by this discharge showed a maximum measured temperature increment in the plume of 4.5°C with a river flow rate of 44,000 cfs, and a maximum increment of 2.5°C at 100 yards downstream at which point the width of the plume was less than 300 feet, 20% of the river width. Directly below an island some 4000 yards downstream, turbulent mixing occurs and the plume becomes well mixed across the river width. The calculated temperature increment for complete mixing at the minimum river flow rate of 36,000 cfs would be 0.6°C.

Outside a limited mixing zone, river temperatures would be in compliance with the Washington State Water Quality criteria⁵⁷ (abstracted in Appendix II.1-G) for incoming river water temperatures up to about 19°C. The temperature criteria were aimed especially at preservation of cold-water fish such as salmonids.

During N Reactor operation, a cooling water stream of about 140 cfs, with a temperature up to 16°C above ambient river temperature, discharges at the river shoreline via a concrete flume. The construction of this flume is such that the lower the river level, the more gradual the slope of the flume where the effluent enters the river.⁵⁸ This

tends to spread the discharge across the river surface where the heat will dissipate to the atmosphere more rapidly and will not be as likely to interact with the benthic biota. Although partial mixing with surface river water begins immediately, a potential for interaction between certain fishes and this heated water exists.

The principal migration routes of juvenile salmonids in the Columbia River are nearshore.⁵⁹ In a study, about 30% of the total migrating population was found near each shore, with the remaining 40% distributed across the expanse of the river. Therefore, a significant number of these salmonids could encounter this heated water while still only partially diluted. A recent review of laboratory studies conducted at Hanford on juvenile salmonids suggests that these fish would have to remain in the undiluted effluent of this line for 1/2 minute or longer before noticeable sublethal effects would occur. As long as no entrapping structures or circumstances are present, most fish are able to detect and avoid heated areas which are uncomfortable for them. Because of the turbulent flow, the consequent rapid decrease in the temperature increment, and the river velocity juvenile fish will be carried rapidly through the elevated temperature zone, if they encounter it. Exposure to the elevated temperatures is limited and the thermal impact would be of minimal significance to the survival of downstream migrants.

A limited area immediately downstream from the point of entrance of the heated water will be found where benthic aquatic life may be affected. The extent of this area will depend on the flow rate of the river but does not appear to represent a significant effect when compared to the entire free-flowing stretch of the Columbia River within the Hanford Reservation.

Effects of Other Water Quality Parameters on Columbia River Ecosystems

Other than direct thermal effects, potential effects of effluent releases on the river ecosystem would be associated with toxic

chemicals in effluent mixing zones and solids deposits on the river bed from water plant filter backwash streams. Routine river monitoring data²⁹ has shown the lack of effect of Hanford operations on river water quality after mixing.

Several of the smaller effluent streams, consisting largely of treated water, may contain free chlorine at concentrations up to a maximum of 1 mg/liter. In limited mixing zones for these discharges, concentrations in the river may exceed at times the 0.002 mg/liter guideline⁶¹ suggested for salmonids in water receiving a continuous discharge. The rapid disappearance of free chlorine from natural waters, coupled with the rapid mixing of the effluents in the river and natural avoidance mechanisms of most species, indicate any effects would be limited in extent and negligible in the overall impact on the river ecosystem.

Other chemical concentrations in treated water are mostly the result of the use of alum (aluminum sulfate) and small quantities of proprietary materials in the water filtration plant. None of these are present in the treated water in toxic concentrations and the usual small change in pH leaves the treated water well within the State water quality standards for aquatic life.

Filter backwash contains suspended solids, principally an aluminum hydroxide floc plus an accumulation of suspended solids removed from the raw river water during the filtration process. Although the effluent may be visibly of higher turbidity during the intermittent backwash operation, the daily fluctuation of several feet in river elevation along with the high river velocity and rapid mixing prevent any appreciable buildup of these solids at the discharge points.

III.1.3.2.3.2 Effects of Columbia River Bank Seepage

The degree of environmental impact caused by waste discharged to the groundwater is determined by the flow rates and concentrations of the various contaminants entering the Columbia River as well as the effects

of the contamination on groundwater quality under the Hanford Reservation. 100-N Area and the 300 Area are the two principal locations along the Hanford reach of the Columbia River where liquid effluents discharged to the ground form groundwater mounds which cause seepage "springs" to form at the riverbank. Nitrate ion is present in the groundwater along much of the shoreline, particularly at the 300 Area.

Much of the available information on the springs in the 100-N Area pertain to radioactive isotopes. However, the concentration of chemicals found in the seepage springs were measured in August of 1972 and compared to the ambient river concentrations. That comparison revealed that sulfate, calcium, chromium, nitrate and total solids were higher in the seepage water than in the river (Table III.1-24).

TABLE III.1-24

CHEMICAL CONCENTRATIONS AT 100-N AREA, AUGUST 1972

	<u>Riverbank Springs (mg/l)</u>	<u>Ambient River Concentration (mg/l)</u>
Sulfate	5.5	4.5
Calcium	24.5	17.
Chromium	20.	0.1
Nitrate	2.7	0.1
Total Solids	123.	81.
Aluminum	0.050	0.080
Iron	0.025	0.075
Magnesium	3.	3.
Ammonia	<0.1	<0.1
Nitrate	<0.002	<0.002
Strontium	0.080	0.120

Chromium appears to be the only nonradiological component of the spring water which, due to higher levels than the ambient river water, had any potential toxicity for aquatic life. Chromium discharge at N Reactor has now been eliminated. Nitrate, which is relatively low in toxicity⁶² is an important plant nutrient and would be expected to support a fairly luxuriant growth of attached algae at the point of emergence of the springs. Other than an increase in algae biomass supplying more food for shoreline benthic fauna, no impact to the ecosystem is predicted from the nitrate. Since the flow from these springs is relatively low (estimated observable flow at less than 0.1 cfs), the more than 300,000:1 dilution by the passing river water keeps the impacted area very localized. The riverbank seepage springs in the 300 Area were sampled routinely from May 1971 through March 1972. The components of the principal spring (which is about 100 yards upstream from the 300 Area water intake) were identified and their range of values over this sampling period is given in Table III.1-25.

TABLE III.1-25
300 AREA SPRING DISCHARGE

<u>Material</u>	<u>Concentrations</u> <u>mg/l</u>
Iron	0.002 to 0.150
Copper	0.006 to 0.080
Sulfate	13 to 40
Chloride	1.1 to 16.0
Fluoride	0.8 to 1.8
Nitrate	1.2 to 212.0
Chromium	0.001 to 0.023
Uranium	0.016 to 0.20

The pH of this spring discharge ranged from 7.4 to 8.2. When the data given in the table above were collected, 300 Area process waste was

being routed to the North Pond of the 300 Area waste treatment complex. The South Pond is not now used for waste disposal and is presently dry (it will be used in the future only on a temporary basis). The North Pond, which is now receiving the waste, has a much slower pond-to-river flow time. The waste ponds are now kept at neutral or basic pH which keeps the copper fairly well retained as copper hydroxide. Plans have been made to transport the waste component which contains most of the metals elsewhere on site to evaporation beds. A new pond location, more remote from the river, also has been selected and will be brought into use in the future. These actions should greatly reduce the metal input to the ponds and to the river.

Copper analyses made on the riverbank springs effluent since use of the South Pond was discontinued have contained 1 µg/liter or less of copper. Chromium concentrations can be toxic (reduced growth in chronic exposures) to juvenile salmonids at levels as low as 0.013 mg/liter. The few studies on the nonradiological toxicity of uranium compounds to aquatic life have observed effects on bacteria, algae, zooplankton and fathead minnows only at concentrations greater than 1.0 mg/liter.⁶⁴ With metals, the accumulation in lower trophic levels and the biomagnification as nutrients pass through food chains, are always potential problems. Copper, chromium and uranium have all been found to concentrate in these lower trophic levels.⁶³ Numerous studies have reported toxic effects due to fluoride; however, the lowest value found to produce toxic effects was 1.5 mg/liter.⁶⁴ Fluoride also was reported to accumulate in fish tissues, especially bone.⁶⁵

Nitrate generally does not pose a toxicity problem for aquatic life, but is a plant nutrient. In this instance, it may also be used as a tracer. River samples taken upstream from Hanford in early 1972 showed nitrate concentrations up to 0.96 mg/liter, while during the same period, the 300 Area spring sample contained up to 195.0 mg/liter, and the 300 Area water intake, which is about 100 yards downstream from

this seepage spring, contained a maximum of 6.0 mg/liter nitrate. A comparison with river concentrations indicates a 90% reduction would be a reasonable figure to apply for predicting dilution effects for the other spring effluent components for a 100 yard travel path. This observation leads to the conclusion that the metals and fluoride from the 300 Area springs will be restricted to a very localized area which should not have significant effects on the aquatic ecosystem of the Hanford reach of the Columbia River or the area immediately downstream, even after considering the potential for food chain interactions.

III.1.3.2.3.3 Effects on Aquatic Ecosystems of Discharges to Other Surface Waters

Numerous surface water ponds, trenches and ditches at the 100, 200 and 300 Areas on the Hanford Reservation, are used primarily for the disposal of cooling waters; several also receive nonradiological waste, as discussed in Section II.1.

The 100-N Area contains the only active reactor and has a 1600-ft long dispersal trench which receives some overflow from the waste crib. However, this trench has been screened to exclude game birds and the larger mammals.

The 200 Area has by far the majority of the onsite surface ponding, including about 30 previously or presently used sites covering the 180 acres of land. Data on the chemical composition of these ponds are not taken regularly, although ecological studies have been undertaken on Gable Mountain Pond and U Pond. Some potential may exist for mammals and migratory waterfowl to accumulate nonradiological pollutants, such as heavy metals, although there is no evidence of any effects.

In the 300 Area about 17 acres of pond surface serve as lagoons for waste generated in the various research and industrial locations. Since only one of the two ponds is used at a time, there are generally only 7 acres (North Pond) or 10 acres (South Pond) of standing water.

The inlet to the North Pond was analyzed routinely in early 1972 and found to contain potential pollutants in the ranges of concentrations as shown in Table III.1-26.

TABLE III.1-26

NORTH POND - INPUT CHEMICAL CONCENTRATION

<u>Material</u>	<u>Concentration Range</u> <u>mg/l</u>
Chloride	8.1 - 17.9
Copper	0.55 - 5.85
Iron	0.02 - 0.64
Fluoride	0.3 - 6.6
Nitrate	43 - 93
Sulfate	14 - 37
Chromium (+6)	0.001 - 0.008
Uranium	0.029 - 0.130

The pH ranged generally from 6.1 to 9.4.²⁹ In addition to these, the North Pond was found to contain an average of 0.58 µg/liter mercury (detection limit 0.5 µg/liter during the last quarter of 1972. Although the ponds are not suitable for most aquatic life and have not been studied ecologically, they are visited frequently by waterfowl. The close proximity of this area to the Columbia River suggests that the potential for transfer of certain chemicals, in particular the metals and fluoride, through algal or detrital food chains into the filter feeding waterfowl (and perhaps on to local hunters) would exist to a degree. The planned actions described in the preceding section to reduce the metallic waste input to the 300 Area waste ponds will largely eliminate this potential.

III.1.4 Effects on Land Use

The Hanford Reservation is now, as it was in the early 1940's, a reasonable choice for the location of facilities both for experimental and industrial application of nuclear processes. This land commitment does not substantially interfere with other offsite pursuits. Further nuclear industry development on the Hanford Reservation is viewed as increasing the importance of this commitment, rather than resulting in any conflict.

One potential constraint on future land usage onsite exists as a result of the nitrate and radioactivity in the groundwater beneath part of the Reservation. Major withdrawal of water from or discharge to the aquifer could affect existing local groundwater elevations and travel times. Such a constraint does not prevent further land use, although it may cause an economic penalty.

III.1.5 Effects on the Atmosphere

Although chemicals released to the atmosphere from Hanford power houses and other facilities were detailed in Section II, the more significant releases, SO_2 and NO_x , are presented in Table III.1-27.

TABLE III.1-27

POLLUTANT RELEASES TO THE ATMOSPHERE FROM
POWER HOUSE STACKS
(tons/yr - 1972)

	<u>100 Areas</u>	<u>200 Areas</u>	<u>300 Areas</u>	<u>Total</u>
SO_2	1000	1050	380	2430
NO_x	170	690	210	1070

Four atmospheric monitoring stations are located at farms east of the river in the vicinity of the 300 Area where the power house and other

facilities nearest the plant boundary are located. The nearest monitoring station is about 1 mile east of the 300 Area where measurements made during 1972 indicated levels of NO_x <0.006 ppm (Table III.1-28). The standard for NO_x concentrations at such sites is 0.05 ppm.⁶⁶ Similarly, the concentrations of SO_2 were measured and found to be <0.01 ppm during the first quarter of 1972, and <0.005 during the remainder of the year. The accepted standard for SO_2 concentrations at such sites is 0.02 ppm⁶⁶ on an annual basis. Since emissions from the 300 Area stacks are occasionally noticeable for some distance, these stack releases may constitute a visual nuisance.

TABLE III.1-28

AIR QUALITY MEASUREMENTS
ANNUAL AVERAGES - 1972

Location	No. of Samples	NO_2 (ppm)		
		Max.	Min.	Avg.
Opposite Richland (Hobkirk Ranch)	109	0.034	<0.0008	0.006
Opposite N. Richland (Gillum Ranch)	109	0.014	<0.0008	0.004
Opposite 300 Area (Sullivan Ranch)	109	0.019	<0.0008	0.004
Ringold (Keys Ranch)	103	0.010	<0.0008	0.004

III.1.6 Effects on Water Use

III.1.6.1 Effects of Surface Water and Groundwater Withdrawals

The withdrawal rate of Columbia River water needed for conduct of the manufacturing and waste management program is expected to average approximately 11 cfs to 45 cfs through FY-1985. This does not include the cooling water used and returned to the river at 100-N Area. Based on historical flow data presented in Section II, these withdrawals would range from about 0.03 to 0.13% of the expected minimum river flow (on the order of 36,000 cfs). Since upstream dams extensively control the Columbia River flow, record low flows are not expected to be repeated in the future. Thus, these withdrawals would only range from about 0.01 to 0.04% of the annual Columbia River flow (55-year average flow of 120,800 cfs) in the vicinity of Hanford and have no significant effect on water availability for other uses.

Most of this withdrawal is discharged to the ground as industrial waste or sanitary sewage while a small portion is returned to the river essentially unchanged (e.g., back flushing at pump inlets). This leaves a minor portion that is actually "consumed" through evaporation or storage in high-level radioactive waste tanks.

Groundwater withdrawn from various wells on the Hanford Reservation amounts to an average of about 0.32 cfs (28,000 ft³/d) including a present withdrawal of 0.05 cfs (4200 ft³/d) for WPPSS construction purposes. About 80% is obtained from the unconfined aquifer and the rest from lower, confined aquifers. Uses of this water include sanitary, construction and emergency cooling systems supplies. However, this groundwater withdrawal from the unconfined aquifer is completely overshadowed by a factor of about 100 by the disposal of process water to the ground. The groundwater withdrawal is about 0.7% of the largest withdrawal rate from the Columbia River for manufacturing and waste management programs. The groundwater withdrawal is inconsequential

relative to alteration of the site-wide groundwater elevations, flow-paths and flowrates caused by groundwater inputs.

III.1.6.2 Effects on Water Quality for Other Uses

In addition to the process waste discharges already discussed, sanitary waste is generated in all operating areas, as well as animal waste in 100-F and 300 Area. Most of the sanitary waste is discharged through septic tanks and tile fields. The animal waste and 300 Area sanitary waste are discharged to leach trenches instead of tile fields, and some sanitary waste goes to the Richland sewer system. Water quality monitoring in the river is designed to measure the overall effect on river water quality of all plant discharges.

Washington State Standards⁵⁷ for biological and chemical quality applicable to the local river reaches have been abstracted in Appendix II.1-G. In accordance with these standards, routine measurements are made either at Richland or the 300 Area upriver from the Richland water plant, for the parameters for which quantitative criteria are given. These parameters are pH, turbidity, dissolved oxygen, coliform organisms, BOD, and temperature (Tables III.1-29 thru III.1-31).

Enterococci measurements are made to clarify the types of coliforms present. In addition, those parameters which are most likely to be affected by the Hanford facility, i.e., temperature and nitrate ion, are measured both upriver at Priest Rapids or Vernita, and downriver at Richland (Tables III.1-29 thru III.1-31).

TABLE III.1-29

TEMPERATURE OF COLUMBIA RIVER WATER IN 1972
°F

Priest Rapids			Richland		
Daily			Daily		
Maximum	Minimum	Average	Maximum	Minimum	Average
66.7	33.8	51.8	66.2	31.5	50.2

TABLE III.1-30
COLUMBIA RIVER CHEMICAL ANALYSES FOR 1972

	<u>NO₃</u> (ppm)		<u>pH</u>		<u>Turbidity</u> (Jackson Turbidity Unit)		<u>Dissolved O₂</u> (ppm)	
Standard ⁶⁷	45		6.5 to 8.5		5 + Background		8.0 min.	
	<u>Vernita</u>	<u>Richland</u>	<u>Vernita</u>	<u>300 Area</u>	<u>Vernita</u>	<u>300 Area</u>	<u>Vernita</u>	<u>300 Area</u>
# Samples	51	52	47	224	48	219	34	181
Maximum	1.3	1.0	9.2	9.4	28.	30.	13.6	14.7
Minimum	(a)	0.14	7.4	7.2	0.6	0.05	4.0	8.1
Average	0.36	0.37	8.1	8.0	5.0	4.6	11.0	10.

(a) Less than the analytical limit.

TABLE III.1-31
COLUMBIA RIVER BIOLOGICAL ANALYSES FOR 1972

	<u>Coliform</u> (N/100 ml)		<u>Enterococci</u> (N/100 ml)		<u>BOD</u> (ppm)	
Standard	240 (median value)		No Standard		No Standard	
	<u>Vernita</u>	<u>Richland</u>	<u>Vernita</u>	<u>Richland</u>	<u>Vernita</u>	<u>Richland</u>
# Samples	14	11	14	11	14	11
Maximum	210.	460.	280.	88.	4.1	4.2
Minimum	1.0	2.0	1.0	2.0	1.0	1.2
Average	49.	88.	37.	34.	2.6	2.9

Columbia River water analysis for biological quality indicates an increase in coliform organisms and a slight increase in BOD between the Vernita and Richland measurement points. These additions are related to drainage from farming and animal husbandry activities not associated with Hanford facilities. Additionally, this section of the river is heavily populated by waterfowl which contribute to the biological load. However, essentially identical values for enterococci at both upstream and downstream locations indicated that coliform increases were not of fecal origin, and demonstrates compliance with the water quality standards. On the average, nitrate was the same at upstream and downstream measurement points. Turbidity, pH and dissolved oxygen measurements were made only at 300 Area during 1972. The range associated with these measurements is believed to be of natural origin and not associated with the Hanford facilities. In addition there was a net decrease in average Columbia River temperature between Priest Rapids and Richland for 1972, as indicated in Table III.1-29.

The results of this program indicate no effects from Hanford operations which would affect the use of the Columbia River for other purposes assigned by the Washington State Water Quality Standards, including domestic use, recreation, and fish and shellfish rearing.

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III.2 WASTE MANAGEMENT ACCIDENTS

III.2.1 Introduction

This section discusses the range of accidents which might be expected from waste management operations. These accidents were selected on the basis of present facility design and operations. Previous accidents and other possible accidents, more severe than have been experienced at Hanford, were also considered. In both the selection of accidents and methods and assumptions made for analysis (Appendix III-C contains a discussion of methods), a consistent attempt was made to be conservative (that is, to analyze the worst conditions credible). The possible effects of maximum credible natural forces (earthquakes, tornadoes, high winds and flooding) were also considered even though the site has not experienced the maximum credible natural forces and the probability of their occurrence is extremely small.

Each of the selected accidents is described and estimates are made of the probability of its occurring, the resulting release of radioactivity (source term), and possible impacts. The accidents considered are:

- Tank Leaks
- Tank Gaseous Release
- Tank Dome Failure
- Line Leaks
- Filter Failure (B Plant)
- Onsite Liquid Waste Shipping Accident
- Solid Waste Accidents
- Range Fire
- Criticality at Ground Disposal Sites
- Accidents Due to Natural Forces.

While not detailed relative to the type of sabotage or kinds of attacks, the accidents analyzed also represented potential consequences of sophisticated sabotage directed at waste management operations. For example, tanks leaks, pipe leaks, or surface spills might be the result of sabotage. Explosives added to a waste tank might lead to consequences such as the tank dome failure.

Onsite transportation accidents might result from less sophisticated sabotage.

III.2.2 Leakage of High-Level Liquid Waste from Storage Tanks

There is a total of 153 large underground storage tanks at Hanford for high-level waste (described in Section II.1). The older tanks are single-wall, carbon steel lined, concrete tanks; the newest tanks are of a double-wall, carbon steel--concrete design. Currently, all high-heat liquid waste is only stored in the new double-wall tanks and low-heat waste and salt cake is stored in the older single-wall tanks.

Since 1958, there has been a total of 18 confirmed tank leaks (described in Section II.1 and Appendix II.I-C). All leaks have been from the single-wall tanks. The causes of leaks have been either corrosion of the carbon steel tank liner (general corrosion, pitting corrosion or stress corrosion cracking) or mechanical failure of the steel liner (thermal expansion due to local overheating or buckling due to other causes). These tank leaks have varied in size from very small to 115,000 gallons for the 106-T tank leak in 1973 (described later).

During the time that liquid waste is being converted to salt cake, additional tank leaks are expected to occur. Extrapolation of past data would indicate that future leaks may occur at a rate of 2 to 3 per year. As the amount of liquid stored in tanks is reduced, this expected number of leaks will decrease. Further, in the future, an increasing fraction of the liquid waste will be stored in double-wall tanks. Here, a leak in the inner tank will be detected and corrective action taken without escape of liquid from the outer tank to the ground.

III.2.2.1 Leak Detection Capability

The capability to detect tank leakage varies with tank design, type of stored waste and tank service. These variations include:

- Radiation and conductivity monitors on the double-wall tanks (AY and AZ tanks) will allow detection of leakage at less than 100 gallons.
- Special leak collection sumps under the newer single-wall tanks (AX tanks) will allow detection of leakage at less than 100 gallons.
- For those single-wall tanks which have radiation monitoring lateral wells directly under the tank, detection of leakage at less than about 5,000 gallons is expected.
- For older single-wall tanks, the leak detection depends on liquid level measurement and vertical radiation monitoring wells. The expected leak detection capability is from about 2,000 gallons up to 30,000 gallons. This variation depends on several factors including the degree of evaporation which makes liquid level interpretation difficult, the degree of floating salt crust in the tank, and the proximity of the leak to one of the dry wells, etc.

With the improved leak detection systems, procedures and increased frequency of monitoring and management attention, future leakage is expected to be detected at less than 30,000 gallons. It is not believed that a leak as large as the 106-T quantity of 115,000 gallons could again occur under normal plant operations.

III.2.2.2 Description of the 106-T Leak

The 106-T tank leak is described here since it is the largest leak that has occurred from Hanford high-level waste storage tanks. A detailed report on the reasons for and results of this leak has been prepared.

On June 8, 1973, the 241-T-106 underground liquid waste storage tank, located in the 200 west Area, was confirmed as leaking. Subsequent investigation of this tank revealed that 115,000 gallons of radioactive liquid waste had leaked into the adjacent sediments. Soon after the leak volume and the radiochemical constituents of the waste liquid were determined, it was predicted that the waste liquid would be sorbed

in the dry sediments near the 241-T-106 tank and would not percolate to the underlying water table. This prediction was based on knowledge of the geology and hydrology underlying the 241-T tank farm and on more than 20 years of experience with liquid waste effluents in 200 West Area sediments.

To confirm this prediction, a study was conducted to define the boundary of the contaminated zone and the depth to which this liquid waste had percolated toward the water table.¹ Sixteen wells were drilled to delineate the contaminated zone. The deepest penetration observed in the wells drilled was 89 feet below ground surface or 115 feet above the water table. The one microcurie per liter ruthenium isopleth was used to delineate the contaminated zone. The volume of sediments was calculated to be about 880,000 cubic feet.

Based on results of the study described above and the basic knowledge of liquid movement in Hanford sediments, further movement of the radioactivity from its present location will be negligible.

III.2.2.3 Postulated 800,000 Gallon Tank Leak

Although no such release is considered credible, the following tank leak is described for the purpose of analyzing the impact from a so-called "worst case." The tank has a volume of 1,000,000 gallons and is assumed to contain 80% liquid, and 20% sludge which does not leak. Such a leak is more than five times greater than any leak previously experienced at Hanford.

III.2.2.3.1 Calculated Source Term for the 800,000 Gallon Leak

The waste composition in the tanks was taken from radionuclide data presented in Appendix III-D. The supernate composition is:

Na ⁺	4.0 <u>M</u>
Ca ⁺⁺	0.002 <u>M</u>
SO ₄ ⁼	0.25 <u>M</u>

OH^-	0.24 <u>M</u>
AlO_2^-	0.06 <u>M</u>
K^+	0.016 <u>M</u>
pH	11.9
$\text{NO}_3^- + \text{NO}_2^-$	3.22 <u>M</u>
$\text{CO}^=$	0.75 <u>M</u>
^3H	$4.21 \times 10^{+4}$ $\mu\text{Ci/gal}$
^{90}Sr	$3.72 \times 10^{+2}$ $\mu\text{Ci/gal}$
^{99}Tc	$1.40 \times 10^{+3}$ $\mu\text{Ci/gal}$
$^{106}\text{Ru} - ^{106}\text{Rh}$	$7.42 \times 10^{+5}$ $\mu\text{Ci/gal}$
^{125}Sb	$1.38 \times 10^{+2}$ $\mu\text{Ci/gal}$
^{129}I	6.15×10^{-1} $\mu\text{Ci/gal}$
^{134}Cs	$1.12 \times 10^{+4}$ $\mu\text{Ci/gal}$
^{137}Cs	$4.34 \times 10^{+5}$ $\mu\text{Ci/gal}$
^{239}Pu	1.43×10^{-1} $\mu\text{Ci/gal}$

The PERCOL Model² was used to simulate the leak of the contents of a full tank. Input parameters for the analysis were those laboratory-measured values determined on soil samples from wells in the 200-West T tank farm. Only those soils below the backfill were used. The thin silt and caliche layers known to exist under some of the tank farms were omitted. This does not imply that soil profiles are the same everywhere but illustrates the effect of a "worst case" leak.

The following assumptions were made:

- the tank leaks 800,000 gallons
- the tank is 170 feet above water table
- average porosity of the soil is 0.35

- a silt layer typical of 200-W Area controls the waste percolation rate
- measured distribution coefficients for high salt waste on 200-West T tank farm soils are applicable
- the spreading of the waste laterally wets a circular area 126 feet in diameter
- a conservative specific retention for the soils is 6% of the pore volume or 2% of the total column volume
- seepage velocity is slow enough for sorption and chemical equilibrium to be attained.

The soil pore volume in the soil column 126 feet in diameter and 170 feet high is $7.42 \times 10^5 \text{ ft}^3$. Six percent of this volume is $4.45 \times 10^4 \text{ ft}^3$. The tank leakage volume is $1.07 \times 10^5 \text{ ft}^3$ of which only $6.25 \times 10^4 \text{ ft}^3$ (or 4.7×10^5 gallon) drains into the groundwater, within the time scale that allows for a measureable impact on groundwater quality.

The empirical concept of specific retention (Appendix II.3-D) was used to remove from the analysis that portion of liquid that takes thousands of years to drain to the water table. The assumed specific retention value of 2% of the column volume was selected to cause some liquid to pass through the column and show the capacity of the soil to sorb radionuclides. If 6% of the total column volume were assumed as the specific retention volume, no liquid would reach the water table within a reasonable time and the PERCOL model could not be applied to the analysis.

The soils beneath the 200 Area plateau consist mainly of layers of sand and silt mixed with gravels. In 200-W Area, a layer of caliche up to several feet thick was identified in many of the wells. The soils beneath this caliche are generally classed as the Ringold Formation. This caliche does not exist in 200-E Area. The assumed soil layers for

this analysis are schematically shown in Figure III.2-1. The sorption results of the leak solution flowing down to the water table are illustrated in Figure III.2-2, III.2-3 and III.2-4.

Figure III.2-1 shows the regions within the soil profile where the ^{90}Sr , ^{137}Cs , and ^{125}Sb are sorbed. Figures III.2-2, III.2-3 and III.2-4 show the concentration-distributions of ^{90}Sr , ^{137}Cs , and ^{125}Sb on the soil as a function of depth:

- ^{90}Sr is removed by ion exchange and by precipitation as SrCO_3 close to the source
- ^{137}Cs is sorbed within the first 15 feet
- ^{125}Sb sorbs only on the fine silt and in the Ringold sediments where higher clay contents exist
- ^{106}Ru generally is not sorbed on the soil and travels with the water.

In order to treat the nonsorbed nuclides, ruthenium, technetium, iodine, and tritium, it was assumed the only reduction in concentration was due to the decay during transport to the Columbia River. Therefore, the convective groundwater flow transport rates in both the partially saturated zones down to the water table and in the saturated zone to the Columbia River became the governing factor in determining efflux rates to the environment.

The rate of flow through the one-dimensional partially saturated column is difficult to calculate because of the changing hydraulic conductivity, moisture content and potential gradient. In the layered soil system, the soil with the lowest hydraulic conductivity will control the flow.

Using the flow rate of the 106-T tank leak as typical for leaking tanks and restricting the flow to the 126-ft diameter column, the first arrival of liquid at the water table occurs in approximately 2 to 11 years. Subsequent to the first arrival, 1 year is assumed to be required for

FIGURE III.2-1 SORPTION OF RADIONUCLIDES IN SOIL BENEATH WASTE TANK

FIGURE III.2-2 SORPTION OF ^{90}Sr BENEATH WASTE TANK

FIGURE III.2-3 SORPTION OF ^{137}Cs BENEATH WASTE TANK

FIGURE III.2-4 SORPTION OF ^{125}Sb BENEATH WASTE TANK

the bulk of the water to enter the water table. This is known to be conservative since the rate of entry will decrease as the moisture content decreases.

The shortest estimated groundwater travel time to the Columbia River from the 200 Areas under present water table conditions is 20 years. From the above analysis, the 2-year travel time for the liquid down to the water table, with the 1-year duration of flow into the water table, followed by a 20-year travel time down the fastest flowpath to the riverbank were assumed. These assumed travel time values mean that the tritium, technetium, iodine and ruthenium reach the river in about 22 years. The bulk of the leaked liquid is assumed to emerge within about a year after first arrival since dispersion effects were neglected.

The total amounts of these nuclides reaching the river are given in Table III.2-1 with radioactive decay taken into account where significant. Analysis of this tank leak case with "worst case" assumptions demonstrates that the cesium and strontium never reach the river. for the nonsorbed or slightly sorbed radionuclides, only ^{99}Tc reaches the river undiminished. The remaining nuclides, ruthenium, tritium, antimony and iodine are discharged to the river at negligible levels due to the small quantities initially present (tritium, iodine), radioactivity decay (ruthenium, antimony) or due to sorption in the soil (antimony).

III.2.2.3.2 Calculated Radiological Impact on Man from 800,000 Gallon Leak

The calculated radiation dose to the maximum individual and to the population within 50 miles of the postulated accident is given in Table III.2-2. The effective half-lives in the body of all of the nuclides involved are short enough so that essentially all of the listed dose is received in the first year. The total potential dose was calculated by summing the contributions from eating foods irrigated with the

TABLE III.2-1

SOURCE TERM FOR THE POSTULATED WASTE TANK
LEAK TO GROUND

<u>Radionuclides</u>	<u>Quantity^(a) Released to River (Ci)</u>
^3H	58
^{125}Sb	2.4×10^{-16}
^{106}Ru	8.2×10^{-2}
^{99}Tc	650
^{129}I	0.29

(a) Assumed to be released in 1-year period following a 22-year travel time from the tank site.

TABLE III.2-2

RADIATION DOSE FROM POSTULATED
800,000 GALLON TANK LEAK

	<u>Dose</u>	
	<u>Maximum Individual (rem)</u>	<u>Population (man-rem)</u>
Total Body	4.4×10^{-5}	1.9×10^{-1}
G.I. Tract	3.0×10^{-4}	1.1×10^0
Bone	5.3×10^{-6}	2.0×10^{-2}
Thyroid	1.7×10^{-4}	6.9×10^{-1}

involved water, eating fish in equilibrium with the water, drinking the water, and participating in aquatic recreation such as boating, water skiing, swimming, etc.

III.2.3 Tank Gaseous Releases

III.2.3.1 High-Heat Waste Tanks

The high-heat waste resulting from Purex Fuel Processing operations is stored in the A-AX-AY-AZ tank farm complex located in 200 East Area. In the past, this waste has contained sufficient fission product decay heat to cause boiling and self-concentration. Currently only one tank contains sufficient decay heat to sustain boiling.

Each of the tanks in A, AX, AY and AZ tank farms vents through a baffled stainless steel header which is common to the tanks in each tank farm and then through either a primary or secondary ventilation system. The tank vent systems from the A, AX and AY farms join together near the filtration building in a common line which conducts the gas and vapors through a series of decontamination equipment and then through filtration. Motive force is provided by one of two exhaust fans located downstream of the filters. One of these fans is maintained in standby for automatic activation if the operating fan fails. Both fans are supplied with emergency power by diesel generators. The gas exhausted by the stack is continuously sampled and monitored for radioactive material. A standby ventilation system serves, as the name implies, to backup the primary ventilation system in the event of an emergency.

III.2.3.1.1 Normal Releases

Six thousand-nine hundred cfm is a typical measured discharge from the stack. The maximum 1972 and 1973 daily radioactivity release of 0.957×10^{-7} Ci/day total alpha and 0.497×10^{-5} Ci/day total beta indicate that the releases were well within the release guides.

III.2.3.1.2 Filter Failure

The manifold piping arrangement with shut-off valves for each of the six filters operating in parallel permits manual isolation of each filter as required when filter failure due to overloading or breakthrough occurs. Should a breakthrough occur in all filters simultaneously, the release (and its consequences) would be expected to be less than the seal failure case discussed below.

III.2.3.1.3 Seal Failure in Exhaust Piping

Emergency venting of the waste storage tanks is provided by a 24-inch line from the vapor header directly to the standby stack. This line contains a water-filled seal pot that relieves at a pressure of 60 inches of water positive or 6 inches of water negative. Instruments indicate the seal pot water level.

The effect of a tornado hitting a high-level waste farm (discussed later under capability of facilities to resist natural forces) was indicated to be significant damage to above ground facilities which includes the ventilation system. The release of radioactivity resulting from the total severance of the system in the unfiltered noncondensed vapor has been estimated to be less than 5 Ci/hr. For the single tank involved, emergency control should be established in less than 24 hours, (total calculated maximum release, 120 Ci). Since this source term is on the same order of magnitude but is less than that estimated for the tank dome failure case presented later in this section, the consequences of seal failure are not analyzed here.

III.2.3.1.4 Solution Rollover (Bumping)

Solution rollover has been experienced in the past to the degree that the emergency venting of a waste tank occurred. Venting is not likely to occur again since an elaborate air circulation system has been incorporated. However, should venting happen, the result would be similar to that described under seal failure in exhaust piping except that recovery could be effected within a few hours.

III.2.3.2 Low-Heat Waste Tanks

Presently a number of tanks containing low-heat waste are vented to an aboveground air cooled condenser. This venting is primarily for vapor surge capacity when the tanks are being filled and is being replaced with a filtered exhaust system similar to that used on tanks containing high-heat waste.

Since the low heat waste does not produce as much vapor as the high-heat waste, accident conditions involving the filter system on low-heat waste tanks are not expected to be as severe as for high-heat waste tanks. Accidents for the low-heat waste gaseous release system are, therefore, not analyzed here.

III.2.4 Salt Cake Storage Tank Dome Failure

No dome failure of the high-level waste tanks has occurred at Hanford or at any other site. Modeling tests have indicated a margin of safety of 4 to 5 times the earth load (~1500 tons) over the tanks. A life of 100 years and probably longer could be reasonably expected based on life of other reinforced concrete structures (bridges, dams, etc.). High-heat waste is contained in the newest double-wall tanks (<3 years old).

The oldest tanks containing low-heat liquid waste are about 30 years old. Free liquid waste will be removed from these tanks within the next few years (before 1980). Thereafter, the salt cake will remain until a final disposal method is developed. During this interim period, the tank volume between the salt cake and the dome will not be filled in order to avoid increasing the volume of contaminated material to be handled should removal of salt cake be required for ultimate disposal. This void volume could be filled (with sand, clay, etc.) should serious weakening of the dome be detected.

A dome failure of a tank filled with salt cake, while highly improbable, could be possible before ultimate disposal of the waste is accomplished.

These waste tanks with reinforced concrete dome tops are unique structures for which failure probabilities have not been definitely established. Hanford experience appears to be the only basis for estimating failure probabilities and has accumulated 2,500 tank years without a failure.

Considering the safety factor used during design and the controls on tank contents and overhead load, a failure rate of 4×10^{-4} per tank year is estimated.

III.2.4.1 Source Term of Dome Failure

If the dome on a waste tank were to collapse onto salt cake, it would result in the release of particulate salt cake to the atmosphere.

Based on evaluations of aerosol behavior, a cubic meter could be expected to contain 5 grams of solids with particle diameters less than $10\text{ }\mu\text{m}$.³ Particles in this size range could be easily carried away from the accident site by air currents. Since the free volume above the salt cake prior to the dome failure is approximately 2800 m^3 , 14 kg of solids with particulate diameters less than $10\text{ }\mu\text{m}$ could be expected to be entrained in the air following the accident. At least half the entrained solid is expected to be particles of soil and debris from the collapsed dome. This leaves 7 kg of solidified waste made airborne from the dome failure which is equivalent to the fission products associated with 60 liters of liquid solution.

The above analysis assumes the salt cake is a dry solid. If the salt cake is moist so that liquid surface tension and viscous effects must be overcome prior to entrainment, then the air concentration of fission products is at least two orders of magnitude lower.³ The 60 liter estimate is, therefore, considered to be conservative because the salt cake is not completely dry. The quantity of radionuclides estimated to be released under these conditions is given in Table III.2-3.

III.2.4.2 Calculated Radiation Doses for Postulated Dome Failure Accident

The calculated radiation doses to the maximum individual and to the population within 50 miles of the postulated accident are given in Table III.2-4.

TABLE III.2-3

SOURCE TERM FOR POSTULATED DOME FAILURE

<u>Isotopes</u>	<u>Quantity Released from Dome Failure, Ci</u>
^3H	6.7×10^{-4}
^{89}Sr	1.6×10^{-10}
^{90}Sr	6.0
^{95}Nb	2.4×10^{-6}
^{95}Zr	1.2×10^{-6}
^{103}Ru	5.0×10^{-13}
^{106}Ru	1.2×10
^{129}I	9.8×10^{-6}
^{134}Cs	1.8
^{137}Cs	7.0
^{144}Ce	1.9×10
^{147}Pm	1.2×10^2
^{238}Pu	1.0×10^{-3}
^{239}Pu	2.3×10^{-3}
^{240}Pu	7.9×10^{-4}
^{241}Pu	4.3×10^{-2}
^{242}Pu	1.2×10^{-7}
^{241}Am	5.8×10^{-2}
^{242}Cm	2.0×10^{-4}

TABLE III.2-4

RADIATION DOSES FOR POSTULATED DOME FAILURE

	First Year Dose		50 Year Dose Commitment	
	Maximum Individual, rem	Population, man-rem	Maximum Individual, rem	Population, man-rem
External				
Total Body	6.2×10^{-6}	1.5×10^{-3}	6.2×10^{-6}	1.5×10^{-3}
Inhalation				
Total Body	1.4×10^{-2}	2.3	1.3×10^{-1}	21.4
Lung	3.6×10^{-1}	6.0×10^1	6.5×10^{-1}	1.1×10^2
Bone	1.9×10^{-1}	3.1×10^1	1.4	2.4×10^2
Thyroid	1.9×10^{-7}	3.1×10^{-5}	2.2×10^{-7}	3.6×10^{-5}

III.2.5 Postulated Liquid Waste Transfer Accidents

Two general types of high-level liquid waste are transferred in underground pipes: high-heat waste and low-heat waste. The high-heat waste is produced from fuel dissolution in the Fuel Processing Plant and is sent to the B Plant for removal of ^{90}Sr and ^{137}Cs (long-lived heat emitters). The waste is then sent to the boiling waste tanks for a period of about 5 years to permit decay of the shorter lived heat emitting fission products. Thereafter, the liquid waste becomes low-heat waste. Low-heat waste is also generated in the dissolution of fuel cladding, by organic wash water, from reactor and equipment decontamination, from laboratory operations which handle radionuclides, etc.

High-heat waste is transferred in encased lines which provide drainage to sumps where leaks can be detected. Low-heat waste, for the most part is also transported in encased lines, but some unencased lines are still in use within the older tank farms. A number of unencased lines for liquid waste transfer have been replaced within the last 5 years. All new transfer lines which will be constructed under new projects in the future will be encased.

Appendix II.1-C lists the liquid waste transfer line leaks (nine to date) which have resulted in soil contamination. Leaks in lines with encasements do not result in release of radioactive material to the environment and, in addition, can be readily detected. Usually such a leak will be limited to less than 100 gallons. Line leaks in unencased lines are more difficult to detect and leaks up to 36,000 gallons have occurred. Procedures have been modified to detect this type of leak earlier. Material balances are made with each transfer and the transfer line is patrolled with a vehicle-mounted radiation monitor.

Based on past experience, three types of leaks are considered:

1. Leakage of high-heat waste from the inner encasement of a doubly encased line to the outer encasement and drainage to a sump. Less than 100 gallons would probably be involved. Since no release to the environment occurs, this event does not result in an environmental input.
2. Leakage of a few thousand to a few tens of thousands of gallons of low-heat waste to the soil surrounding a non-encased line. If the line is near the surface and the leakage rate is high, most of the leaked material may form a surface pool before seepage into the soil.
3. Leakage of an upper limit of 100,000 gallons of low-heat waste of which a fraction forms a surface pool. Such large leaks have not been experienced to date and are not expected.

For analysis, a so-called "worst case" transfer line leak of 100,000 gallons was selected. It is assumed that 1/4 (or 25,000 gallons) of the waste would reach the surface and form a pool and that the remainder of the waste would be released to the soil beneath the spill. An inventory of 5 year old waste with 95% of the strontium and cesium removed by B Plant processing was selected for consideration.

The probability of the 100,000 gallon leak occurring is difficult to assess. At Hanford, during the last 30 years, approximately 40 unplanned releases of this general type occurred, most of them remaining underground. A total of 16 of these leaks were associated with fission product transfer operations.⁴ Of these 16, six resulted in no surface contamination, while in six others the surface became wet. In three cases, liquid flowed onto the surface and in one case an airborne spray was produced. The postulated accident assumes that the liquid, including solids, flows onto the surface. Similar events

occurred three times in 30 years. Based solely on this past record, similar events may have a mean recurrence interval of approximately 10 years, assuming a constant level of transfer operations and taking no credit for any newly installed double-wall transfer lines or deterioration of other existing lines.

The accident being evaluated assumes the existence of unfavorable high winds at the same time. Winds greater than 10 m/sec (22 mph) can be expected to occur at the Hanford site about 5.8% of the time.⁵ Therefore, the probability that both the spill and the high winds will be coincident is once in 170 years.

III.2.5.1 Source Term for Liquid Waste Transfer Accident

Assuming a transfer leak does occur, the radioactive material that reaches the surface will be exposed and available for atmospheric dispersal until corrective action is taken (corrective action is assumed to occur within 12 hours). The important variables are 1) the fraction of the radionuclides in the top few centimeters of soil and 2) the fraction that is entrained in the air and travels offsite.

Past experience involving spills of approximately one third this size indicates that the liquid would be expected to percolate into the ground and the solid fraction of the waste would be expected to be filtered out and remain in the top few centimeters of the soil column. Thus, the top few centimeters would contain all the solid fraction and, if the liquid penetrated the soil to a depth of 10 cm, perhaps as much as 1/10 of the liquid fraction. Usually the depth of liquid penetration would be more than 10 cm and, consequently, the liquid contributions would be much lower, perhaps only 1/100 or 1/1000 of that leaked.

In addition to the distribution of radionuclides in the soil, the fraction of the nuclides which are available for entrainment and actually get entrained in the air currents is a fundamental factor in determining the release to the environment. Based on experimental studies, carried

out at Hanford (discussed in detail in Appendix III-D), no more than 0.1% of the waste exposed to surface erosion would be expected to be effectively entrained in the air. In the 12-hr release period envisioned, the top centimeter of soil, which contains all the solids and 1/10 of the liquids, would be expected to be exposed to surface erosion. Since the spill was postulated to form a 25,000-gal surface pool, this last statement is equivalent to stating that all the solids and 1/10 of the liquids associated with the 25,000 gallons of waste would be made airborne and dispersed offsite.

The calculated source term for a surface pool of 25,000 gallons of liquid waste is given in Table III.2.5.

TABLE III.2-5

SOURCE TERM FOR POSTULATED SURFACE SPILL
OF NEUTRALIZED 5 YEAR OLD WASTE

Isotope	Quantity Released to Air, Ci	Release Rate Ci/sec (12-hr duration)
^3H	3.4×10^{-3}	7.9×10^{-8}
^{89}Sr	4.8×10^{-11}	1.1×10^{-15}
^{90}Sr	3.1×10^{-1}	7.2×10^{-6}
^{95}Zr	3.0×10^{-7}	6.9×10^{-12}
^{95}Nb	5.6×10^{-7}	1.3×10^{-11}
^{103}Ru	1.9×10^{-13}	4.4×10^{-18}
^{106}Ru	1.2	2.8×10^{-5}
^{129}I	5.4×10^{-8}	1.3×10^{-12}
^{134}Cs	1.4×10^{-3}	3.2×10^{-8}
^{137}Cs	3.9×10^{-2}	8.9×10^{-7}
^{144}Ce	1.6	3.8×10^{-5}
^{147}Pm	7.4	1.7×10^{-4}
^{238}Pu	5.4×10^{-6}	1.3×10^{-10}
^{239}Pu	1.2×10^{-4}	2.7×10^{-9}
^{240}Pu	4.1×10^{-5}	9.5×10^{-10}
^{241}Pu	2.4×10^{-3}	5.5×10^{-8}
^{242}Pu	5.9×10^{-9}	1.4×10^{-13}
^{241}Am	3.0×10^{-3}	6.9×10^{-8}
^{242}Cm	1.6×10^{-5}	3.7×10^{-10}

III.2.5.2 Calculated Radiological Impact on Man

The calculated radiation dose to the maximum individual and to the population within 50 miles from the postulated accident is given in Table III.2-6. The values for the first year dose and the 50 year dose commitment are given.

TABLE III.2-6

DOSES IN REM FROM POSTULATED TRANSFER LINE LEAKAGE
OF 100,000 GALLONS OF WASTE

	<u>First Year Dose</u>		<u>50 Year Dose Commitment</u>	
	<u>Maximum Individual, rem</u>	<u>Population, man-rem</u>	<u>Maximum Individual, rem</u>	<u>Population, man-rem</u>
External				
Total Body	3.5×10^{-6}	3.3×10^{-3}	3.5×10^{-6}	3.3×10^{-3}
Inhalation				
Total Body	5.4×10^{-3}	1.9	5.9×10^{-2}	3.7×10^1
Lung	1.3×10^{-1}	4.6×10^1	2.6×10^{-1}	9.0×10^1
Bone	7.0×10^{-2}	2.6×10^1	5.6×10^{-1}	2.0×10^2
Thyroid	4.6×10^{-9}	1.7×10^{-6}	5.5×10^{-9}	2.0×10^{-6}

III.2.6 Filter Failure in B Plant

The strontium and cesium removal from the high-level waste greatly reduces the length of boiling time for high-level liquid waste. For the tank inventory given in Appendix III-D, the time can be reduced by a factor of 14, from 85 years to about 6 years.

Analysis of the safety of the cesium and strontium recovery and liquid tank storage is presented in the B Plant safety analysis report.⁶

A similar review of the encapsulation and storage of these materials is continued in a separate safety analyses report⁷ for those operations. Based on these evaluations, the accident with the largest potential impact was a fire in the B Plant ventilation filter. Other postulated accidents within B Plant or the encapsulation and storage facility have less potential consequences.

The B Plant exhaust ventilation system provides for the removal of process-generated heat and control of the release of contaminated air from the canyon. The system comprises a canyon supply air system and a filtered exhaust system discharging to atmosphere. The 45,000 cfm capacity system is operated to maintain a negative pressure in the canyon with respect to atmosphere of 0.2-in. water gauge to ensure directional flow of contaminated air. The filtered and washed supply air enters near the top of the canyon, flows downward around process cell cover blocks, into the cells and through openings into the canyon exhaust air tunnel.

Exhaust air is filtered through three (A, B, and C) underground, reinforced concrete filter bays operated in parallel. Each filter bay consists of a roughing prefilter followed by two banks of High Efficiency Particulate Air (HEPA) filters in series. Metal screens are

provided following the prefilter and the first bank of HEPA filters to prevent mechanical damage to the following filters. Each filter bay is connected to a common underground exhaust plenum through a structural baffle which, when filled with water, will isolate from service any one or all of the filters. Above grade stainless steel duct work connects the plenum to two electrically driven exhaust blowers and one standby steam turbine driven exhaust blower which discharge through a 200-ft tall concrete acid brick lined stack.

The exhaust ventilation system is equipped with an air sampler, monitors and alarms to measure radioactive discharges and to detect off-standard conditions. An isokinetic sampling probe located in the exhaust stack provides for continuous sampling of air exhausted to the atmosphere. An existing exhaust air sandfilter (25,000 cfm) paralleling the HEPA filter system remains in serviceable standby, although isolated from the system by water seals. The sandfilter can be activated automatically by removal of its seal water and by adding water to the HEPA filter seals. The diversion of the exhaust air system is designed to be accomplished within five minutes. The 221-B process cells and the filter system incorporate several fire detection and control systems for protection of the filters.

For this postulated accident, one of three roughing/prefilter banks in C cell is assumed to burn and release its entire inventory to the first bank of HEPA filters. Thus, the inventory on the first HEPA filter in that bank becomes 1/3 of the entire inventory in C cell, shown in Table III.2-7. Following the destruction of the prefilter, 5 of the 25 HEPA filters are assumed to burn through releasing their inventory to the final HEPA filter bank in that section. At elevated temperatures, the transmission through the last filter bank could be as high as 1.0%⁸ at the expected condition.

TABLE III.2-7

ESTIMATED INVENTORY OF RADIONUCLIDES ON B PLANT FILTERS

	Quantity on Prefilters and First HEPA Filter Bank, Ci	
	<u>^{137}Cs</u>	<u>^{90}Sr</u>
A Cell	3.6×10^3	4.0×10^4
B Cell	2.3×10^3	2.5×10^4
C Cell	3.5×10^3	9.9×10^3

The probability of a fire occurring in the B Plant filter system was estimated based on Hanford experience. Three fires in the ventilation and filter system of processing facilities at Hanford have been recorded over the past 30 years. The fires involved the burning of lint or other residue on hood filters or prefilters. In all cases, no filter failures or resulting environmental impacts resulted from these fires. Conservatively estimating that an annual average of 100 process ventilation systems were operative during the 30-year period, the probability of a fire occurring in a filter system is 10^{-3} per plant year. Since none of these fires were of the magnitude postulated in B Plant, and since fire preventative controls have increased during this 30-year period, the probability of a postulated fire is expected to be at least one or two orders of magnitude less than that estimated by Hanford experience. Therefore, a probability of less than 10^{-4} per year has been assigned to the postulated B Plant filter fire.

III.2.6.1 Calculated Source Term for Filter Failure in B Plant

Recent radiation measurements provided estimates of the radionuclide inventory on the B Plant exhaust filter system. From these radiation measurements taken at specific locations, with relation to the filter banks in each of the three filter cells (designated A, B, and C cells),

estimates were made of the probable radionuclide loading on the pre-filters and the first bank of HEPA filters in each cell. The prefilter system was assumed to remove between 90% and 75% of the particulate material with the remaining amount deposited on the first bank of HEPA filters. The loading of radionuclides on the second bank of HEPA filters was assumed to be insignificant and was not considered as a contributor to the radiation dose measurements used to estimate the exhaust system inventory.

The ^{137}Cs inventory was inferred directly from the radiation measurements. Since ^{90}Sr is primarily a beta radiation emitter, direct determination by the techniques used was not possible. The ^{90}Sr inventory within each filter cell was estimated, using ^{137}Cs : ^{90}Sr ratios developed assuming attenuation of beta radiation by varying depths of dirt deposited on the filter. The estimated maximum inventories of ^{137}Cs and ^{90}Sr contained in each filter cell are shown in Table III.2-7.

The calculated source term for the filter fire described earlier in this section is shown in Table III.2-8. The release occurs as an elevated release from the 200-ft 291-B ventilation stack.

TABLE III.2-8

SOURCE TERM FOR POSTULATED B PLANT FILTER FIRE

<u>Radionuclides</u>	<u>Quantity Released to Air, Ci</u>	<u>Release Rate (duration 10 minutes) Ci/sec</u>
^{137}Cs	2.3	3.8×10^{-3}
^{90}Sr	6.6	1.1×10^{-2}

III.2.6.2 Calculated Radiological Impact on Man

The calculated radiation dose to the maximum individual and to the population within 50 miles of the postulated accident are given in Table III.2-9.

TABLE III.2-9

RADIATION DOSE FOR CESIUM AND STRONTIUM PROCESSING
POSTULATED FILTER FAILURE

	<u>First Year Dose</u>		<u>50 Year Dose Commitment</u>	
	<u>Maximum Individual, rem</u>	<u>Population, man-rem</u>	<u>Maximum Individual, rem</u>	<u>Population, man-rem</u>
External				
Total Body	1.0×10^{-6}	2.3×10^{-4}	1.0×10^{-6}	2.3×10^{-4}
Inhalation				
Total Body	2.5×10^{-3}	2.8×10^{-1}	4.9×10^{-2}	5.4
Lung	4.3×10^{-2}	4.8	1.0×10^{-1}	1.2×10^1
Bone	9.1×10^{-3}	1.0	4.8×10^{-2}	2.2×10^1

III.2.7 Liquid Waste Shipments Accidents

III.2.7.1 Leakage from an Overfilled Rail Tank Car

The diverse research and development activities at Hanford utilize large quantities of radionuclides. During these studies, liquid waste streams of intermediate-level are frequently generated. This waste is collected and transferred to 200-W using specially designed 20,000-gal rail tank cars. These same cars are also used to transfer intermediate-level waste from N Reactor to 200-W. The liquid waste received from these shipments is incorporated into the high-level liquid waste processing operations in the 200-W Area. The car is loaded and unloaded from the top ports arranged on a top flange closure plate. Valves and disconnect-fittings which mate with the piping in the loadout facilities are mounted on the fill and vent line nozzles. During transport, caps are installed on each line. Liquid level and temperature gauges are installed on their respective nozzles and remain in place during transport.

During shipment, the tank car normally contains a 7-in. air space between the surface of the liquid and the top of the car. A pressure buildup of 0.70 psig is enough to discharge liquid through the fill/discharge line if all the flanges in the air space are leak tight and the valve and cap in the fill/discharge line are not leak tight. The liquid could be discharged onto the external surfaces of the car. This requires a temperature rise of 5°F. Also, if one of the vent flanges leaks, permitting the tank to be filled up so there is no air space, then the tank will leak with any temperature increase. Since this last case is considered the most likely to result in a release, it was selected for evaluation.

In the case evaluated, the tank car, due to equipment failure or improper use, would be completely filled with waste at 60°F leaving no expansion air space and then transported to 200-W from the 300 Area.

The trip would take two hours, with an average speed of 20 mph. On that particular day, the sun was assumed bright and the air temperature was 110°F. The rate of expansion of the liquid under these conditions would determine the amount of liquid released during transfer.

III.2.7.1.1 Probability of Event

The absolute failure or leakage probability was not estimated because improper loading or sealing and plugging of the line can lead directly to some leakage. The mean time to failure for valves, seals and gaskets is probably less than 20 years. Failure of these components might have an occurrence rate of once every 10 to 20 years.

III.2.7.1.2 Calculated Source Term for Leakage from an Overfilled Rail Tank Car

In 1972, an estimated 47,000 Ci of radioactivity contained in 340,000 gallons of liquid was shipped to 200-W from laboratory operations (300 Area). Analytical data indicated that two cars contained the major fraction of this radioactivity. One car contained an estimated 21,000 Ci and another contained 10,000 Ci. The estimated amount of radioactivity shipped in each of the remaining 15 shipments ranged from 50 to 4,000 Ci. The radionuclide content of a typical shipment is shown in Table III.2-10.

TABLE III.2-10

RADIONUCLIDE CONTENTS OF A TYPICAL
TANK CAR SHIPMENT FROM 300 AREA

<u>Radioisotope</u>	<u>Activity Contained in Liquids and Solids, Ci</u>	
	<u>Filtrate</u>	<u>Solids</u>
Total Beta (a)	572	3220
Total Alpha (b)	0.84	2.50
^{60}Co	<0.45 (c)	<3.5 (c)
^{90}Sr	23.0	27.6
$^{106}\text{Ru} - ^{106}\text{Rh}$	3.18	30.2
^{137}Cs	24.3	2.88

- (a) Total beta is calculated as a hypothetical, nonvolatile nuclide emitting a beta particle of energy 0.3 MeV.
- (b) Total alpha is calculated as ^{239}Pu .
- (c) "Less than" is used when the results were below detection level concentrations in the shipments.

For the postulated accident, the heatup rate was calculated to be 3.75°F/hr. Based on the volume expansion of water with temperature, this rate of heating corresponds to a resulting liquid discharge rate of about 10 gal/hr. The total amount which would be spilled in the 2 hour trip is estimated not to exceed 20 gallons.

The radioactive materials dissolved in the liquid could become airborne in two ways: 1) formation of small droplets by film break-up and 2) small particles formed by the evaporation of solution. An estimate of 10% was used for the airborne release of the radioactive material from a tank car leak. The potential quantity of radioactive materials released is shown in Table III.2-11.

TABLE III.2-11

SOURCE TERM FOR POSTULATED RELEASE
FROM LEAKING TANK CAR

Radionuclide	Quantity Released to Air, Ci	Release Rate, Ci/sec 2 Hour Duration
Total Beta ^(a)	0.379	5.26×10^{-5}
Total Alpha ^(b)	3.33×10^{-4}	4.63×10^{-8}
⁶⁰ Co	$<3.93 \times 10^{-4}$ ^(c)	$<5.46 \times 10^{-8}$
⁹⁰ Sr	5.06×10^{-3}	7.03×10^{-7}
¹⁰⁶ Ru- ¹⁰⁶ Rh	3.34×10^{-3}	4.64×10^{-7}
¹³⁷ Cs	2.72×10^{-3}	3.78×10^{-7}

-
- (a) Total beta is calculated as a hypothetical, non-volatile nuclide emitting a beta particle of energy 0.3 MeV.
- (b) Total alpha is calculated as ²³⁹Pu.
- (c) "Less than" is used when the results were below detection level concentrations in the shipments.

III.2.7.1.3 Calculated Radiological Impact on Man

The calculated radiation dose to the maximum individual and to the population within 50 miles of the postulated accident is given in Table III.2-12. The values for the first year dose and the 50 year dose commitment are given. The leakage is assumed to take place near the 300 Area, the nearest area to the City of Richland.

TABLE III.2-12

RADIATION DOSE FROM A POSTULATED LEAKING RAIL TANK CAR SHIPMENT

	<u>First Year Dose</u>		<u>50 Year Dose Commitment</u>	
	<u>Maximum Individual, rem</u>	<u>Population, man-rem</u>	<u>Maximum Individual, rem</u>	<u>Population, man-rem</u>
External				
Total Body	9.4×10^{-9}	9.2×10^{-7}	9.4×10^{-9}	9.2×10^{-7}
Inhalation				
Total Body	8.5×10^{-4}	2.9×10^{-2}	3.8×10^{-2}	1.3
Lung	1.5×10^{-2}	7.1×10^{-1}	3.7×10^{-2}	1.4
Bone	3.3×10^{-2}	1.1	1.4	4.7×10^1

III.2.7.2 Rail Tank Car Transport Accident

Three rail tank car events were identified that could result in a major release from the tank: 1) car derailment, 2) collision with another train, and 3) a grade crossing accident. The credible accidents would be similar to any other train accident. The train shipments are operated in a conservative manner and the tracks are maintained in a good state of repair.

The probability of rail accidents occurring was examined and the recurrence rate for an accident at Hanford involving mixed trains (more than just a tank car, which is normal practice for such shipments) was estimated to be once in 240 years. Grade crossing accidents which could result in tank failure were estimated to occur once every 1000 years, assuming the same train usage. Derailments would be expected to be caused by defective equipment such as trucks, wheels, and axles on non-Hanford maintained cars in a mixed car shipment. These would be expected to occur at high speed, outside the yard.⁹ Although experience suggests that only one out of 100 derailments will cause a tank car to rupture, some cars ahead of a tank car may provide corners which could rupture a tank car. It is assumed that 10% of the derailments would result in a rupture of the tank car. Based on current Hanford practice and experiences, a derailment and a rupture of a tank car may occur at a rate of once every 2400 years. This frequency would be reduced to once every 10,000 years if only the waste tank car is transported during a shipment.

III.2.7.2.1 Calculated Source Term for Rail Tank Car Transport Accident

The consequences of the tank car rupture with the entire contents of the tank spilling onto the ground was evaluated. It was assumed that the material was not covered over for a 12-hr period. During this time some

of the spill was postulated to dry up and blow away. The solids would stay in the top layer of soil and the liquid would soak into the ground. The depth of penetration would depend on the type of soil, the land contour and the volume of the spill. It appears likely that a 20,000-gal spill would soak into a depth of about 10 cm over 2 acres of land. As discussed in Appendix III-E, for liquid spills on soil, it is assumed that no more than 0.1% of the content of the tank would become airborne under the most adverse circumstances.

Table III.2-13 gives the source term for the postulated release using the 0.1% airborne release fraction.

TABLE III.2-13

SOURCE TERM FOR POSTULATED TANK CAR DERAILMENT AND RUPTURE

Radionuclide	Quantity Released to Air, Ci	Release Rate, Ci/sec 12 Hour Duration
Total Beta ^(a)	3.3	7.6×10^{-5}
Total Alpha ^(b)	2.6×10^{-3}	6.0×10^{-8}
^{60}Co	$<3.5 \times 10^{-3(c)}$	$<8.2 \times 10^{-8(c)}$
^{90}Sr	3.0×10^{-2}	6.9×10^{-7}
^{106}Ru - ^{106}Rh	3.1×10^{-2}	7.1×10^{-7}
^{137}Cs	5.3×10^{-3}	1.2×10^{-7}

(a) Total beta is calculated as a hypothetical, non-volatile nuclide emitting a beta particle of energy 0.3 MeV.

(b) Total alpha is calculated as ^{239}Pu .

(c) "Less than" is used when the results were below detection level concentrations in the shipments.

III.2.7.2.2 Calculated Radiological Impact on Man

The calculated radiation dose to the maximum individual and to the population within 50 miles of the postulated accident is given in Table III.2-14.

TABLE III.2-14

RADIATION DOSE FROM A POSTULATED RAIL TANK CAR TRANSPORT ACCIDENT

	<u>First Year Dose</u>		<u>50 Year Dose Commitment</u>	
	<u>Maximum Individual, rem</u>	<u>Population, man-rem</u>	<u>Maximum Individual, rem</u>	<u>Population, man-rem</u>
External				
Total Body	7.8×10^{-9}	3.0×10^{-6}	7.8×10^{-9}	3.0×10^{-6}
Inhalation				
Total Body	5.6×10^{-4}	5.2×10^{-2}	2.2×10^{-2}	2.1
Lung	1.2×10^{-2}	1.1	2.7×10^{-2}	2.5
Bone	1.8×10^{-2}	1.7	7.7×10^{-1}	7.1×10^1

III.2.8 Solid Waste Transfer and Storage Operation Accidents

III.2.8.1 Fire from Vehicle Accident

Contaminated solid waste is generated in all Hanford facilities handling radioactive materials. The contamination varies with each building depending upon the nature of the development programs and waste generating operation. The solid contaminated waste from each of the facilities is sorted and packaged by standardized waste disposal procedures. In accordance with these procedures, contaminated solids integrally possessing less than 0.05 Ci of β , γ are packaged in 4.5 ft³ cardboard boxes. Additionally, the total amount of plutonium in one of these boxes should not exceed 10 nCi per gram of waste in the box. Waste with greater than these limits are shipped in 30 or 50-gal steel

drums or treated on an individual basis, depending upon the dose rate on the surface of the container. Containers with a surface dose rate in excess of 100 mR/hr cannot be routinely handled without undue radiation exposure to transport workers. Solid waste with greater radioactivity than stated above is shipped in special containers with some form of shielding, such as concrete.

The cardboard waste boxes are disposed of in burial trenches in the 200-W Area. Drums with surface dose rates less than 100 mR/hr are stored in the same trench. The special containers with higher dose rates are placed in burial caissons. Drums containing plutonium activity are taken to the 20-year retrievable transuranic storage trenches.

For this postulated event, a solid waste carrying truck bound for a burial ground is assumed to be involved in an accident with a resultant fire. A defective vehicle or spontaneous combustion in one of the packages while being transported could also lead to a fire.

The probability of a truck accident occurring is 2.45×10^{-6} per mile.¹⁰ Of those accidents, 1.26% would result in fire.¹¹ Thus, the probability of an accident which results in a 30-minute fire is less than 1×10^{-7} per mile. On an annual basis, the loaded truck makes no more than 4 trips/week of 35 miles; the total annual mileage for the loaded truck on the Hanford site is approximately 7200 miles. The probability of an accident and ensuing fire is less than 10^{-3} /year. Thus, the mean recurrence interval between probable dispersals of solid waste during transport from a vehicle accident accompanied by fire is greater than 1000 years.

III.2.8.1.1 Calculated Source Term for Fire from Vehicle Accident

The truck is assumed to carry a maximum load of 100 cartons of waste averaging 20 pounds each and is involved in an accident just outside

the 300 Area. Fifty cartons contain potentially contaminated plutonium waste in an amount equal to the allowable limit of plutonium (i.e., 10 nCi/g) and the other 50 boxes contain a total of 5 Ci of mixed fission products, a factor of two greater than the allowed packaging limit. A fire lasting 30 minutes is assumed to ensue following the accident and 50% of the radioactivity is dispersed to the air. The value of 30 minutes for the fire duration is based on the probable response time of the Fire Department and an analysis of transport accidents being carried out at Sandia Laboratories. This study indicates that less than one in four of this type of fire will last longer than 30 minutes.

Experiments carried out at Hanford^{12,13} indicate that from 10 to 50% of the material present in combustible waste can be expected to be airborne. In the consequence calculation, it is conservatively assumed that the radioactive material followed the airborne ash and that there was no short distance fallout. The source term for this postulated accident is given in Table III.2-15.

TABLE III.2-15

SOURCE TERMS FOR POSTULATED SOLID WASTE FIRE DURING TRANSPORTATION

<u>Radionuclide</u>	<u>Total Inventory (Ci)</u>	<u>Fraction Released (%)</u>	<u>Amount Released (Ci)</u>	<u>Release Rate (Ci/sec)</u>
F.P. (a)	5	50	2.5	1.4×10^{-3}
²³⁹ Pu	4.5×10^{-3}	50	2.3×10^{-3}	1.3×10^{-6}

(a) Assumed to be ⁹⁰Sr

III.2.8.1.2 Calculated Radiological Impact on Man

The calculated radiation dose to the maximum individual and to the population within 50 miles of the postulated accident is given in Table III.2-16.

TABLE III.2-16

RADIATION DOSE FROM POSTULATED FIRE ACCOMPANYING
A WASTE VEHICLE ACCIDENT

	First Year Dose		50 Year Dose Commitment	
	Maximum Individual, rem	Population, man-rem	Maximum Individual, rem	Population, man-rem
External				
Total Body	6.8×10^{-12}	3.7×10^{-9}	6.8×10^{-12}	3.7×10^{-9}
Inhalation				
Total Body	1.9×10^{-2}	9.1×10^{-1}	4.2×10^{-1}	2.0×10^1
Lung	3.1×10^{-1}	1.5×10^1	7.6×10^{-1}	3.6×10^1
Bone	1.0×10^{-1}	4.8	2.9	1.4×10^2

III.2.8.2 Fire in Solid Waste Burial Trench

Solid waste is routinely accepted and buried twice a week on the 200 Area plateau. The activity and volume of waste associated with an average and maximum burial day are shown in Tables III.2-17 and III.2-18, respectively.

After the day's inventory of waste is placed into the burial trenches, a heavy equipment operator, using one of two bulldozers, covers the waste with clean dirt. Any waste which arrives after the operator began to cover the waste is refused burial and the truck must return the waste to its point of origin. Normally, high winds are no deterrent to burial unless rigging equipment is being used, in which case high winds would result in unsafe operation for riggers.

Since the dry waste is combustible and can potentially contain reactive chemicals, fire by spontaneous combustion is possible. In addition, sparks from vehicles, a carelessly thrown cigarette, or lightning could cause ignition.

TABLE III.2-17

CHARACTERISTICS OF DRY WASTE BURIED ON AN AVERAGE DAY

<u>Source</u>	<u>No.</u>	<u>Container</u>	<u>Volume (ft³)</u>	<u>Activity, Ci</u>
222-S Bldg. (Hot cell)	4	30-gal	30	20.0 F.P. (a)
	9	Cardboard boxes	40	0.6 F.P.
221-T	14	Cardboard boxes	60	0.1 F.P.
Laundry	9	Cardboard boxes	40	
Misc.	5	Cardboard boxes	20	
BNW	70	Cardboard boxes	300	<5 F.P.
HEDL	45	Cardboard boxes	200	

(a) Fission Products

TABLE III.2-18

CHARACTERISTICS OF THE MAXIMUM VOLUME OF DRY WASTE BURIED ON ANY DAY

<u>Source</u>	<u>No.</u>	<u>Container</u>	<u>Volume (ft³)</u>	<u>Activity, Ci</u>
222-S Bldg. (Hot Cell)	5	30-gal	38	70 F.P. (a)
	22	Cardboard boxes	100	3 F.P.
221-T	22	Cardboard boxes	100	2 F.P.
Laundry	22	Cardboard boxes	100	
Miscellaneous, (Tank Farms, etc.)	22	Cardboard boxes	100	
BNW	150	Cardboard boxes	~700	<10 F.P.
HEDL	75	Cardboard boxes	~350	

(a) Fission Products

One significant fire in a burial ground has occurred in the 30 years of Hanford operation. Based on this experience, the probability of a significant fire in a burial trench could be estimated at 0.03/year. However, this accident occurred when there was no requirement to cover the waste accumulated during each day. This requirement reduces the probability of a similar accident by the fraction of the time the burial ground is left uncovered at the end of the day, and, of course, reduces the amount of combustible and radioactive material available for involvement in a fire. A recurrence interval of once in 300 years is estimated for this postulated event.

III.2.8.2.1 Calculated Source Term for Fire in Solid Waste Burial Trench

It is assumed that the fire in the burial ground burns for 4 hours and that:

- a total of 10 Ci of activity is accessible to the fire in the trench in cardboard boxes
- the waste in the 30-gal steel drums is unaffected by the fire
- waste is left uncovered due to trouble with the bulldozers.

The source term for this postulated accident is given in Table III.2-19.

TABLE III.2-19

SOURCE TERM FOR POSTULATED SOLID WASTE FIRE IN BURIAL GROUND

Radionuclide	Total Inventory (Ci)	Fraction Released (%)	Amount Released (Ci)	Release Rate (Ci/sec)
F.P. (a)	10.0	50	5.0	3.5×10^{-4}
^{239}Pu	6.8×10^{-3}	50	3.4×10^{-3}	2.4×10^{-7}

(a) Assumed to be ^{90}Sr

III.2.8.2.2 Postulated Radiological Impact on Man

The calculated radiation dose to the maximum individual and to the population within 50 miles of the postulated accident is given in Table III.2-20.

TABLE III.2-20

RADIATION DOSE FROM POSTULATED FIRE IN SOLID WASTE BURIAL TRENCH

	First Year Dose		50 Year Dose Commitment	
	Maximum Individual, rem	Population, man-rem	Maximum Individual, rem	Population, man-rem
External				
Total Body	1.1×10^{-11}	9.4×10^{-9}	1.1×10^{-11}	9.4×10^{-9}
Inhalation				
Total Body	1.3×10^{-3}	4.3×10^{-1}	2.8×10^{-2}	9.2
Lung	2.1×10^{-2}	6.9	5.0×10^{-2}	1.7×10^1
Bone	6.3×10^{-3}	2.1	1.7×10^{-1}	5.7×10^1

III.2.9 Range Fire on Contaminated Land

As a result of Hanford Waste Management Operations, some isolated land areas were contaminated with varying amounts of radioactivity. A range fire on this land can serve as a release and transport mechanism for some of the surface contamination. The contamination associated with the plant foliage can be volatilized, while the contamination held by the top soil can be reentrained by the wind erosion following a fire. Thus, a fire on contaminated land can be a potential release mechanism for presently stable surface or near surface contamination.

Most of the contaminated land on the Hanford site is within controlled zones and was stabilized by covering the zone by clean overburden and/or by selective herbicide treatment. Since these areas are within operational areas, any fires would be quickly detected, controlled and the area restabilized. However, the B/C controlled area, including the B/C Crib near 200-E area, is a region of land contamination which is not inside an operational area. The B/C Crib Controlled Area is approximately a 2,100 acre plot of typical desert terrain situated due south of the 200 East Area. A fire in this region could release some of the contained radioactivity.

At present, the radioisotopes in the area are associated with various contaminated materials on the surface and in the sandy soil to the depth of 8 inches or more. Transfer of the radioisotopes is believed to be from urine, decay of rabbit fecal pellets, and possibly leaching of soluble materials from fecal pellets.

The probability of a range fire burning the B/C Crib Controlled Area was estimated based on a 10 year summary of such a fire at Hanford. (This summary is included as Appendix III-F.) An average of 12 fires per year have occurred, ranging from less than 1 acre to less than 32,000 acres. The median fire burns about 6 acres and occurs at the end of June. In the last 10 years a total of three fires have burned an area at least as great as the B/C Crib Controlled Area. Based on these statistics, a probability of 2×10^{-3} per year was estimated for a fire burning the entire B/C Crib Controlled Area at about a 500 year recurrence rate.

III.2.9.1 Calculated Source Term for Range Fire on Contaminated Land

The radionuclide inventory in and above the top cm of soil in the Controlled Area was estimated to total 32 Ci of ^{90}Sr and 8 Ci of ^{137}Cs held in the vegetation, organic debris, animal droppage, sagebrush, and soil. For ^{137}Cs the distribution is as shown in Table III.2-21.

TABLE III.2-21
POSTULATED
DISTRIBUTION OF ^{137}Cs IN AVERAGE SQUARE METER PLOT
(depth of 1 cm)

	<u>Vegetation</u>	<u>Organic Debris</u>	<u>Animal Droppings</u>	<u>Sagebrush</u>	<u>Soil</u>
Mass Grams	166.7	522.2	45.1	733.7	20862.4
Percent of Mass	0.74	2.33	0.20	3.28	93.44
Activity μCi	9.10×10^{-3}	1.90×10^{-1}	1.11	4.59×10^{-2}	1.19×10^1
Percent of Activity	0.1	1.4	8.3	0.4	89.8
Specific Activ- ity $\mu\text{Ci/g}$	5.46×10^{-5}	3.64×10^{-4}	2.46×10^{-2}	6.26×10^{-5}	5.70×10^{-4}

The fire was assumed to have burned the entire area and released 10% of the radioactive material. (The source term for this postulated event is shown in Table III.2-22.) The Hanford site experienced within recent years several large range fires in which the burning rate ranged from 200 to 350 acres per hour. Based on this rate, the release was assumed to occur over a 6-hour period. This 10% release has been demonstrated as conservative by an experiment conducted where flammable materials collected from the B/C Crib Controlled Area were burned. In this experiment, only 0.04% of the ^{137}Cs was made airborne at a windspeed of 2.5 mph at 1 foot above the surface.^{12,13}

TABLE III.2-22

SOURCE TERM FOR POSTULATED RANGE FIRE ON B/C CRIB CONTROLLED AREA

<u>Radionuclides</u>	<u>Quantity Released to Air, Ci</u>	<u>Release Rate Ci/sec (6 hour Duration)</u>
^{137}Cs	0.8	3.7×10^{-5}
^{90}Sr	3.2	1.5×10^{-4}

Following such a fire, the area would probably take some time to stabilize. The flammables would be burned to some extent. Thus, some release of the remaining activity that was contained in the flammable material would follow the fire. For this situation, about 50% of this remaining activity would be released over a 24 hour period. The source term for this postulated event is shown in Table III.2-23.

TABLE III.2-23

SOURCE TERM FOR POSTULATED WIND DISPERSAL OF REMAINING ACTIVITY
FOLLOWING A FIRE IN THE B/C CRIB CONTROLLED AREA

Radionuclides	Quantity Released to Air, Ci	Release Rate Ci/sec (24 hour Duration)
^{137}Cs	3.2	3.7×10^{-5}
^{90}Sr	12	1.4×10^{-4}

III.2.9.2 Calculated Radiological Impact on Man

The calculated radiation dose to individuals and to the population within 50 miles of the postulated accident is given in Table III.2-24 for the direct effect of a range fire and in Table III.2-25 for the effects of wind dispersal of radioactive materials following a range fire.

TABLE III.2-24

RADIATION DOSE DUE TO POSTULATED FIRE ON CONTROLLED AREA

	First Year Dose		50 Year Dose Commitment	
	Maximum Individual, rem	Population, man-rem	Maximum Individual, rem	Population, man-rem
External				
Total Body	2.7×10^{-7}	1.0×10^{-4}	2.7×10^{-7}	1.0×10^{-4}
Inhalation				
Total Body	1.0×10^{-3}	2.8×10^{-1}	2.0×10^{-2}	5.5
Lung	1.7×10^{-2}	4.7	4.2×10^{-2}	1.1×10^1
Bone	3.8×10^{-3}	1.0	8.3×10^{-2}	2.3×10^1

TABLE III.2-25

RADIATION DOSE DUE TO POSTULATED WIND DISPERSAL
AFTER FIRE ON CONTROLLED AREA

	First Year Dose		50 Year Dose Commitment	
	Maximum Individual, rem	Population, man-rem	Maximum Individual, rem	Population, man-rem
External				
Total Body	4.4×10^{-7}	4.2×10^{-4}	4.4×10^{-7}	4.2×10^{-4}
Inhalation				
Total Body	2.9×10^{-3}	1.1	5.8×10^{-2}	2.1×10^1
Lung	5.0×10^{-2}	1.8×10^1	1.2×10^{-1}	4.3×10^1
Bone	1.1×10^{-2}	3.9	2.4×10^{-1}	8.5×10^1

III.2.10 Criticality at Ground Disposal Sites

Several ground disposal sites in the 200 Area which, in the past, were used for the disposal of low and intermediate-level waste have accumulated kg quantities of plutonium (Table III.2-26). With the exception of U Pond, these sites are referred to as covered trenches. The designs vary considerably. The Z-9 Crib is a large enclosed area, 20 feet deep with a 60 by 120-ft concrete roof and a dirt floor of 60 by 30 feet. Some others consist of underground caverns with wooden cribbing to prevent cave-in and are covered with earth, whereas some are like underground tile fields. These cribs are no longer used for disposal of plutonium.

TABLE III.2-26

ESTIMATED INVENTORIES OF PLUTONIUM IN DISPOSAL SITES
CONTAINING MORE THAN 1 KILOGRAM OF PLUTONIUM¹⁴

Disposal Site	Plutonium (kg)
216-U-10 U Pond and Ditches	8.3
216-B-7 224-B, 221-B 5-6 Cell and Construction Waste	4.3
216-S-1 & 2 Redox Process Condensate	1.2
216-T-32 224-T Waste	3.2
216-Z-3 D-6 Waste	5.7
216-Z-7 213-Z Waste - 300 Area Waste	2.0
216-Z-9(a) Recuplex CAW Waste	38.0 ^(b)
216-Z-12 D-6 Waste	24.8
216-T-18 Scavenged Waste	1.8
216-Z-1 & 2 D-6 Waste	7.0
216-Z-1A -a, 236 & 242-Z Waste	30.0
-b, 236 & 242-Z Waste	16.6
-c, 236 & 242-Z Waste	10.8
216-Z-18 236 & 242-Z	21.7

(a) "Z-9" Crib

(b) Reference 15 estimates the system to contain between 25 and 70 kilograms of plutonium.

In all cases, liquid waste, containing trace amounts of plutonium, was discharged to these sites. In the case of U Pond, contamination was from trace amounts laundered off potentially contaminated protective clothing. The water in these low-level waste streams drains into the ground, and the plutonium remains within the top soil layers. This occurs either because the plutonium is in the form of solids and filters out or because it is in a soluble form and is adsorbed by the soil. In either case, the plutonium concentrates in the top few feet of soil. Once the site is deactivated, it will begin to dry out as it reverts back toward its original state. The presence of water has three effects: 1) water acts as a neutron absorber, which reduces reactivity, 2) water moderates (slows down) the neutrons, which increases reactivity, and 3) water located around or adjacent to plutonium reflects neutrons back into the system, which increases reactivity.

As the site dries out, neutron absorption and reflection decrease and the average energy of the neutrons increase. The net effect in the Z-9 crib was a possible slight increase in reactivity, but far from the amount of increase necessary for criticality to occur. A most probable k effective for the Z-9 crib was identified as 0.5, well below that required for criticality.¹⁶ It is believed that other trenches, as they dry out, will have a lesser reactivity increase than Z-9 or even a decrease in reactivity.

The addition of water to a crib or trench at the optimum water concentration would then make the system more reactive by the addition of a reflector. Too much water would once again poison the system. For the system to reach criticality, sufficient plutonium must be available and the soil and water must be physically rearranged.

For the above postulated event to occur, there must not only be a total lack of monitoring, but there must also be a total lack of administrative control, to the extent that man must actually take positive action to make the crib or trench critical, i.e., rearrangement of the plutonium and soil in the trench which became flooded. For this reason, criticality in these trenches is not considered credible under the present mode of operation and no accident analysis was performed. Also, it is currently planned to mine the 216-Z-9 crib for recovery of the plutonium, thereby greatly reducing the contamination of the facility. Information obtained from this mining operation will provide input for any decision concerning the other trenches.

III.2.11 Effects of Natural Forces

Consideration of the environmental impact of potential accidents must also include possible initiation by natural forces such as flooding, seismic activity, tornadoes, etc. The following is a discussion of Hanford waste management facilities with regard to the potential effect of natural forces.

III.2.11.1 Effect of Natural Forces on Radioactivity Stored in the Ground

No credible natural forces event other than major flooding by the Columbia River (described later) can be postulated that will release a significant amount of radioactivity from the groundwater or ground storage sites.¹⁷ Natural forces evaluated include those resulting from seismic activity, heavy rains, heavy snow melt, flooding, tornadoes, and high winds.

The selection of ground storage sites was based on extensive geological data and considerable soil measurements of cation exchange capacity. Essentially all sites are below the ground surface in which at least 4 feet of ground cover have been applied. These sites are not subject to disturbance by winds and tornadoes.

Increased rate of movement in ground or in groundwater can only arise from the addition of inordinate amounts of water which is far in excess of what can be credibly considered to arise from rains, snow melt and flooding.¹⁸

III.2.11.2 Capability of Facilities to Resist Natural Forces

Natural force resistance has been included in the designs of Hanford's waste management facilities over the past 30 years using state-of-the-art knowledge and applicable criteria at the time of the design.

Natural force resistance criteria (seismic and wind) for various waste management facilities are summarized in Table III.2-27 and beneficial use dates are listed.

III.2.11.2.1 Designs for Seismic Activity

Different structural design practices have been used on Hanford waste management facilities in the time periods 1943 to 1949, 1949 to 1968, and 1968 to the present.

1943-1949: In the period 1943 to 1949, preceding the inclusion of seismic provisions in the Uniform Building Code, Hanford's above ground waste management structures were designed for static, vertical live and dead loads. Design calculations were performed manually and approximation techniques were used for indeterminate structures. Lateral wind forces, based on projected area, were included in the designs. During this period, Hanford was designated as a low intensity, minimum occurrence earthquake zone. Thus, only small lateral earthquake design forces related to the mass of the structures, generally not governing in designs, were considered.

In this same period, below ground waste tank structures were designed for soil backfill: 1) live loads on the ground above, and 2) internal hydrostatic pressures. Empirical design data for concrete cylinders and dome shell structures were used. Design and operating considerations were included for the elevated temperatures to be encountered. Wind forces were not considered for the buried structures. Buried structures have considerable inherent earthquake resistance because they are stiff and strong as required to support the backfill, and a properly placed backfill will restrict relative motions between the structure and ground during an earthquake.

TABLE III.2-27

NATURAL FORCE DESIGNS WASTE MANAGEMENT FACILITIES

Waste Management Facility (year)	Dynamic Seismic Design Earthquake Magnitude 6.8 0.25 g	Static Structural Design Uniform Building Code ^(a)	Winds	
			Circular (Tornado)	Straight
Double-Wall Underground Waste Tanks (1971-1974) (Boiling Waste)	X		(c)	X
Single-Wall Underground Waste Tanks (1944-1974)	(c)	x(b)		X
Fractionization (B) Plant 1944	(c)	X		X
Waste Encapsulation Plant 1974	X		(c)	X
242-S Evaporator 1973	X		(c)	X
242-A Evaporator 1976	X		(c)	X
AR Vault 1968		X		X
CR Vault 1952		X		X
242-T Evaporator 1951		X		X
ITS-1 Evaporator 1965		X		X
ITS-2 Evaporator 1967		X		X
Sluicing Facilities 1968		X		X
Decontamination (T) Plant 1944	(c)	X		X
222-S Laboratory 1952		X		X
Boiling Tank Vent System 1971	X			X

- (a) Early site structures were designed for static, vertical live and dead loads and have limited seismic resistance, since area was classified as a low intensity, low frequency earthquake zone followed later by a classification as Zone 2 on the Uniform Building Code Seismic Risk Map and currently as an area of moderate to low seismicity. Some seismic resistance inherent in structures because of design for winds (lateral forces), nonstructural elements (reserve strengths), stability requirements, limits on deflections, plus safety factors included in design and working stress values for materials.
- (b) Buried structures have considerable inherent earthquake resistance because they are stiff and strong as required to support the backfill, and the backfill will restrict relative motions between the structures and ground during an earthquake.
- (c) See text.

1949-1968: In the period 1949 to 1968, Hanford's above ground waste management structures were designed for static, vertical live and dead loads in accordance with the Uniform Building Code which included seismic provisions. Design calculations were performed manually. State-of-the-art improvements in designs, construction practices and construction materials were incorporated. Lateral wind forces related to areas were specified according to the Uniform Building Code. Lateral earthquake towers related to the mass of structures were specified according to the Uniform Building Code seismic provisions which designated Hanford as Zone 2.

Below ground structures were designed similar to designs of the time period 1943-1949 including some increases in waste tank temperatures, based on operating experience.

1968 to date: Since 1968, Hanford's above ground waste management structures, facilities, and equipment have been designed for the most severe possible combination of dead, live, and operating loads plus seismic forces from a maximum credible earthquake. Rigorous state-of-the-art analyses, including dynamic, elastic analyses for 0.25 g ground motions are performed using digital computers. The structures must have the capacity to resist the above conditions and maintain radiological safety during and after experiencing the 0.25 g ground accelerations. (Hanford Plant Standard SDC-4.1, Standard ARCH-Civil Design Criteria, Design Loads for Structures.)

The maximum credible earthquake is postulated to be a Richter Magnitude 6.8 earthquake (with an epicentral distance approximately 10 miles from the Hanford waste management facilities) which produces a maximum horizontal ground acceleration at the waste management facilities of 0.25 g and a simultaneous vertical ground acceleration two-thirds of the horizontal acceleration.¹⁹ The 0.25 g earthquake has an occurrence associated with an unlimited time span per occurrence whereas the probability of 0.20 g would be once in 16,700 years, 0.15 g once every 4,000 years, 0.10 g once every 1,850 years, and 0.05 g once every 840 years.²⁰

Since 1968, structural designs for below ground concrete waste tanks have included elastic and nonlinear time dependent analyses, which account for creep and cracking in the structure, for dead, live, thermal, pressure, and hydrostatic loads. Rigorous dynamic, finite element analyses of the tank structure for the 0.25 g ground motions are performed. The overall adequacy of the tanks are assessed under the combined service loads and the 0.25 g ground motions.²¹

III.2.11.2.1.1 Previous Seismic Activity

The largest local earthquake of historical record occurred at Corfu, a few miles north of the site, in 1918. Various damage estimates have been reported resulting in a classification of Modified Mercalli V or VI. A number of estimates of the peak ground acceleration have been made for this Corfu event which range from 0.01 to 0.03 g.

III.2.11.2.1.2 New Facilities

Table III.2-27 shows that the newer facilities, the Double-Wall Underground Waste Tanks (1971-1974), the Waste Encapsulation Plant (1974), the 242-S Evaporator (1973), the 242-A Evaporator (1976), and the Boiling Tank Vent System (1971) include 0.25 g seismic forces in their designs.

III.2.11.2.1.3 Single-Wall Underground Waste Tanks

In 1969 to 1971, Illinois Institute of Technology performed a "Strength and Stress Analysis for Waste Tank Structures at Hanford, Washington." Results of analyses of the A Farm single-wall underground waste tanks for 0.25 g seismic forces "indicate no additional risk of containment loss beyond the risk associated with static loading."²²

III.2.11.2.1.4 Fractionization B Plant

A preliminary assessment has been made of the capability of the Fractionization B Plant Canyon Building to withstand strong earthquake ground motions with a 0.25 g peak horizontal acceleration (Richter Magnitude 6.8, epicentral distance approximately 10 miles). Results of a first phase elastic analysis indicate that the canyon walls will be substantially overstressed near the roof (above the crane rails), and at the canyon wall-gallery slab intersections. The overstressing would be due to high bending moments. Primary load bearing, reinforced concrete walls in the B Plant canyon would be damaged in the event of 0.25 g ground motions. Technical judgment is that these walls will be able to experience this overstressing, to have the capacity to satisfy the 0.25 g earthquake ductility demands and lateral loads, and to avoid collapse, such that process cell integrity can be maintained. A second phase inelastic analysis will be performed to finally establish if this is the case.

Seismic analyses and evaluations of the B Plant cooling water piping (outside the building, in the pipe gallery, through the cells) plus the emergency power and pumping systems have not been made. Problem areas requiring at least the need for minor modifications would be revealed by such analyses.

The three HEPA filter cells for the B Plant exhaust ventilation air do not have potential seismic problems like those found during the review of the sandfilter; these filter cells are the units normally in use. A review of design drawings for the B Plant exhaust ventilation air sandfilter (backup) revealed potential structural deficiencies such that additional seismic resistance studies will be performed.

Detailed seismic analyses of the B Plant reinforced concrete ventilation exhaust stack have not been made, but little or no damage was noted in stacks of this type after the 1971 San Fernando earthquake.

The Waste Processing (B) Plant has not been affected by the low seismic forces experienced during its 30-year active life. No structural damage nor radiological impact is expected from the low seismic forces expected in its projected remaining operating life (approximately 10 years).

III.2.11.2.1.5 Other Structures

Seismic effects on the Decontamination T Plant (1944) would be similar to those for the Fractionization B Plant (1944) since these structures are virtually identical.

Other waste management structures such as the AR Vault (1968), the CR Vault (1952), the 242-T Evaporator (1951), the ITS-1 Evaporator (1965), the ITS-2 Evaporator (1967), Sluicing Facilities (1968), and the 222-S Laboratory (1952) have not been analyzed for the effects of 0.25 g seismic forces.

III.2.11.2.2 Designs for Winds

Hanford's waste management facilities have been designed to withstand straight winds according to the Uniform Building Code. At Hanford, a peak gust wind (straight) of 80 miles per hour was measured on January 11, 1972 at the 50-ft level of the Hanford Meteorological Tower. Hanford's waste management facilities have not been designed to withstand tornado (circular) winds. Tornadoes are rare in this region and tend to be small; their occurrence is associated with little damage. On June 16, 1948, a tornado was observed near the east end of Rattlesnake Mountain approximately 10 miles south of Hanford's waste management facilities, and no damage resulted.

Current policy and practice impose a criterion²³ that those facilities which contain fissile radioactive materials such as reactors and structures for the storage²³ of plutonium shall be able to withstand:

1. Wind force - horizontal wind of 175 mph, over the full height of the structures
2. Pressure transient - 0.75 psi atmospheric pressure drop in 3 seconds, and return at the same rate
3. Missiles -
 - 2" x 12" plank, 12 ft long, traveling end-on at 100 mph, at any height
 - 4' x 8' plywood sheet, 3/4" thick, traveling end-on at 150 mph, at any height
 - 26" x 20' sheet of No. 20 corrugated steel siding traveling end-on at 150 mph, at any height

All facilities covered by the Hanford Plant Standard SDC-4.1 category have been modified to withstand the specified loading. Most of the waste management facilities are massive concrete structures inherently resistant to tornado forces. Utility lines to these facilities and ventilation exhaust systems from these facilities do not possess this inherent tornado resistance.

The exhaust ventilation filters for the Waste Encapsulation Plant (1974) have been located below grade which would provide protection from tornado forces. The heavily shielded interior cells of the Waste Encapsulation Plant (1974) would receive little damage from a tornado.

The reinforced concrete walls of the 242-S Evaporator (1973) and the projected 242-A Evaporator (1976) are thick, providing resistance to tornado forces. Ventilation exhaust capability from these facilities could be damaged by a tornado. Both facilities possess an inventory dumping capability to return the radionuclide inventory to underground storage tanks in a few minutes. The relatively low (3 Ci/gal) radionuclide concentration of the liquid in the evaporator system would not create a severe radiological impact during and following a tornado.

The most vulnerable Waste Management Operations facility to tornado forces is a boiling waste tank farm system, because the above ground facilities are not protected or shielded and the radionuclide concentration is sufficiently high to continue boiling for long periods of time. An evaluation of the effects of a tornado on a boiling waste tank farm system is included below.

Hanford's boiling waste tank farm systems above ground support facilities were not designed to withstand tornado winds. They would withstand straight winds according to the Uniform Building Code. The probability of a tornado hitting a boiling waste tank farm system at Hanford is approximately six in a million per year. For a large tornado, the probability would be much less because of the specific meteorological conditions present in the Pacific Northwest east of the Cascade Mountains. Significant damage to the above ground facilities and utilities could be experienced.

These "surface" utilities and facilities consist of steam; normal electrical power; emergency electrical power; instruments and controls; cooling water; "make-up water" systems (to replace that boiled off);

condensers; instrument air; circulator process air; ventilation heaters, filters, exhausters, and stack; de-entrainer vessels; liquid seals in vapor system; and buildings housing instruments and equipment. Dependent on the specifics of the tornado and the area that it hit, part or most of these utilities and facilities could be damaged.

If the air lift circulators are not reactivated within 12 to 24 hours, temperature gradients could develop in the sludge and "bumps," (or "burps") as experienced in the past, could occur. These "bumps" were the result of steam bubbles which built up at localized points within the liquid which relieved their pressure when it reached a level in excess of the overlying hydrostatic head. The calculated vacuum transient within a boiling waste tank is expected to be less than 1 psi dampened by increased boil-off from the liquid surface. It is not expected that the tank contents will "burp or bump".

A preliminary assessment of the impact of the tornado concludes that no structural damage would be experienced by the underground tanks and their envelope structures. Credible tornado damage has not been postulated which would seal the tank farm vapor system. Pressure transients have been calculated for the boiling waste vapor system if the tank farm were hit by a tornado, and vacuum effects have been calculated to be negligible. Two factors dampen the pressure transient: 1) resistance to flow in the vapor system and 2) vapor boil-off from the thermally hot liquor as the pressure is reduced.

Should Hanford boiling waste tank farm be hit by a tornado and the "surface" utilities and facilities be damaged, the activity release from the vapor system during the tornado has been estimated in the range of a fraction of a curie to a few curies. No significant adverse effects should be experienced offsite by such a release and activity at the Hanford site boundary should be less than the maximum permissible air concentration for uncontrolled areas set by Atomic Energy Commission Manual Chapter 0524. Following destruction of the "surface" utilities

and facilities, additional activity could be released in the unfiltered noncondensed vapor at a rate estimated at less than 10 Ci/hr; this release rate should not create an offsite problem but could create a local site problem which would require recovery operations. Re-establishment of control could be effected within 48 hours.

III.2.11.3 Columbia River Flood

Disposal of radioactive and chemical waste at sites adjacent to the processing area was previously a common Waste Management Operations practice at Hanford. Solid waste burial grounds, cribs for low-level liquid waste, and waste retention basins are located in the 100 Areas and the 300 Area. The only sites remaining active in these areas are for 100-N Area. Because of their proximity to the Columbia River, the impact of involvement and release of some of the contents of these waste disposal sites during flooding is evaluated.

Material which may be vulnerable for dispersal during a flood include: 1) the buried sludge in the retention and storage basins in some of the 100 Areas, 2) the content of the 1301-N Crib, and 3) the 100 and 300 Area burial grounds. The radioactive materials in the deactivated reactor buildings are assumed not to be affected significantly by a flooding condition and are ignored in this analysis.

Radioactivity in the 100 Area burial grounds is found in a diversity of carriers including paper, rags, wood, structural concrete and steel, and a variety of metal objects of aluminum, steel and zircaloy. At the time of burial, more than 99% of the radioactivity was contained in a solid metal matrix. The remainder was surface contamination accumulated over a period of time from the coolant stream. This "crud" contains activation and fission products.

The radioactivity contained in the metal is primarily in the form of activation products, with the major contributor being ^{60}Co . The source of this activity is irradiated aluminum process tubes and dummy fuel elements. Other metallically-contained activity includes:

- ^{95}Zr - ^{95}Nb in zircaloy process tubes
- ^{65}Zn in aluminum tubes
- ^{59}Fe and ^{60}Co in steel reactor components.

The primary radioactivity found in the sludge and soil surrounding the 100 Area retention basins is ^{152}Eu and ^{239}Pu . Most predominant in the irradiated fuel basin sludge are ^{90}Sr and ^{137}Cs .

The 300 Area burial grounds and retention basins are estimated to contain significant amounts of uranium and copper from past and present operations. The amount of uranium has been estimated to be about 30 metric ton (MT) (~ 10 Ci).

The inventory of copper in the pond has been estimated to be 200 MT (the range on this number is from 150 to 220 MT). Additionally, an estimated 300 Ci of ^{147}Pm and 10 Ci each of ^{90}Sr and ^{137}Cs are buried near the 307 Building as a result of a spill in 1970.

The flooding condition used in the following analysis is the dam regulated "Probable Maximum Flood" (PMF) previously predicted²⁴ by the U.S. Army Corps of Engineers. This prediction was derived using extensive data and computer modeling techniques, and incorporating assumptions of a combination of conditions which were the most severe considered "reasonably possible" for the Columbia River Basin.^(a) Contributing factors which were maximized were winter snow accumulation, spring melting and runoff-season rainstorms.

The basic cause of the PMF is spring snowmelt runoff following exceptionally cold and wet weather during the October to April snow accumulation season. It was assumed that, over the Columbia River Basin as a whole, the October to April precipitation equaled 1.3 times the normal annual precipitation. Unusually rapid melting due to meteorological

(a) The Basin Area's 260,000 square miles include major parts of the States of Washington, Idaho and Oregon, small segments of Montana, Wyoming, Utah and Nevada, and most of the Southeastern portion of the Canadian Province of British Columbia.

conditions was predicted as a result of the assumption of extreme seasonal values for air temperatures, dew point, solar radiation albedo, and wind speed.

In addition, two hydrologically significant (the most severe considered "reasonably possible") basin-wide rainstorms were assumed. It was assumed that rain contributions to the PMF fell entirely during two 5-day periods during the snowmelt season. The first was arbitrarily chosen in mid-May, the second was timed to maximize the natural peak discharge of the Lower Columbia River.

In Table III.2-28, taken from Reference 24, the discharge rate of the dam regulated PMF flood was compared along with others to the calculated natural discharge rate of the PMF at The Dalles, Oregon. The comparison was made at The Dalles because it is a key gauging station with daily records back to 1878 and maximum discharge records back to 1858. Also shown in Table III.2-28 for comparison is a flood calculated to be the most severe, using assumptions "reasonably characteristic" of the Columbia Basin. This flood is called the "Standard Project Flood" (SPF).^(a)

For the dam regulated PMF, the discharge rate remains greater than 80% of the peak rate for almost a month. Consequently, inundated regions would be subjected to erosion for an extended period.

Flow rates along the Hanford Reservation are considerably less than that indicated in Table III.2-28 because the Snake and other smaller rivers empty into the Columbia River downstream from Hanford. Upstream from Richland, the Corps of Engineers applied a regional adjustment to the peak discharges predicted in Reference 24. This increases the peak discharge predicted for the regulated PMF from 1.36 million cfs to 1.44 million cfs. Therefore, this latter value represents the flow rate at the Hanford site that is reasonably possible as a result of natural phenomena during the present era of river management.

(a) The "Standard Project Flood" is related to a general Columbia River condition and not meant to be inferred the condition of the Columbia River at the Hanford Reservation.

TABLE III.2-28

PREDICTED AND MEASURED PEAK DISCHARGES OF
THE COLUMBIA RIVER AT THE DALLES, OREGON

<u>Flood</u>	<u>Peak Discharge 1,000 cfs</u>	<u>Ratio of Each Peak to Natural PMF</u>
Natural Probable Maximum Flood (PMF)	2,660	1.0
Regulated PMF	2,060 (a)	0.77
Natural Standard Project Flood (SPF)	1,550	0.58
Regulated SPF	840	0.32
Greatest Peak of Record (1894)	1,240	0.47
2nd Greatest Peak of Record (1948)	1,010	0.38
3rd Greatest Peak of Record (1876)	958	0.36
100 yr. Frequency Natural Peak	1,200	0.45
100 yr. Freq. Reg. Peak as of 1975	690	0.26
Mean of Obs. Annual Peaks	583	0.22
Greatest Median Daily Discharge	495	0.19

(a) The Columbia River flow rate in the Hanford area used in this analysis for this flood condition is 1.44×10^6 cfs.

The portions of Hanford project that would be inundated during the PMF is shown on the project map of Figure III.2-5. The reactor areas inundated are N, D, H, and F. In addition, virtually all of the populated area of Richland is inundated while most of the 300 Area becomes an island.

FIGURE III.2-5 MAP OF FLOOD POTENTIAL

With the 100-year flood as the basis, an estimate was made of the probability of the PMF occurring. It is a highly unlikely event, as can be seen from an examination of Table III.2-28. The discharge rates for the PMF are more than double the corresponding peak discharges for the 100-year frequency flood.

Since the 100-year discharge rate is similar to the SPF (Table III.2-28), the difference in the frequency can be credited with the October to April precipitation accumulation. (The SPF October to April precipitation is assumed equal to the normal annual precipitation. For the PMF, the October to April precipitation is assumed to be 1.3 times the normal annual precipitation.)

In addition to unusually great winter snow accumulation, both the SPF and the PMF require unusually hot sunny spring weather and two unusually heavy, basin-wide spring storms (with the PMF assumptions more extreme than the SPF ones). Clearly, the compounding of probabilities for these additional assumptions requires for the PMF an average recurrence frequency of many thousand years. Since climatic changes invalidate extrapolations for thousands of years based upon data accumulated in the last century, a more precise estimate of this quantity is not feasible. Nevertheless, this information may be used to infer that the probability of the PMF occurring during any given year in the near future is less than one in a thousand.

III.2.11.3.1 Calculated Source Term for Columbia River Flood

In the postulated flood, erosion of protective cover over buried radioactivity was assumed and thus, some fraction of the radionuclides could be picked up by the river. While entrainment of major portions of the sludge and uranium and copper contaminated soil might be possible, this is not so for metal objects in which ^{60}Co was produced by activation. Nevertheless, buried metal objects do corrode and at widely varying rates.

Before much of a metal object was corroded away, radioactive decay would reduce its ^{60}Co activity to insignificant levels. Since corrosion rates in the soil cannot be well defined due to the variation of storage environments, all uncontained radionuclides with half lives exceeding 1 year (including the ^{60}Co in the metal), and all other chemicals, in all inundated areas shown in Figure III.2-5, are assumed entrained during a 24-hr period at the peak of the PMF of the Columbia River. These materials are assumed to be soluble and uniformly mixed into the quantity of water equal to 24 hours flow at 1.44×10^6 cfs (3.53×10^{12} liters). Table III.2-29 presents the quantities of copper and radionuclides assumed released (the contents of the 1301-N Crib and of the D, H. and F burial ground, the radioactivity in the retention and storage basin sludges and surrounding soils in these 100 Areas, and radioactivity buried in the 300 Area). Also tabulated are the resulting concentrations of individual radionuclides or mixtures of individual radionuclides in the flood waters.

III.2.11.3.2 Calculated Radiological Impact on Man

Evaluation of the consequences of such a flood can be treated in several ways. In actual practice, the residents of the Tri-City and other towns along the Columbia would probably be evacuated. The movement of activated metallic pieces, such as dummy fuel element, down the river is considered a possibility under this degree of flooding.

The radiation doses from ingestion of Columbia River water and fish and exposure to the contaminated shoreline were estimated, assuming that the listed mixtures of radionuclides (Table III.2-29) were made up of equal proportions of each component radionuclide. The calculated radiation doses for Total Body, GI Tract and Bone in the first year following the consumption of 2 liters of water and 200 g of fish harvested from the contaminated flood waters and assumed to be in equilibrium with the radioactivity in the river are listed in Table III.2-30. Since the residents of the Tri-Cities and other towns along the Columbia River would

TABLE III.2-29

STORED RADIONUCLIDE QUANTITIES ($T_{1/2} > 1$ yr) AND TOXIC CHEMICALS
INUNDATED BY THE PEAK FLOW OF THE PROBABLE MAXIMUM FLOOD OF
THE COLUMBIA RIVER AND THEIR CONCENTRATIONS IF MIXED WITH 1 DAY'S
RIVER FLOW AT THE PMF PEAK

Radionuclides	Quantity Released (curies)	Estimated Concentration in River, (b) ($\mu\text{Ci}/\text{ml}$)
^{60}Co	11,400	3.2×10^{-6}
^{90}Sr	60	1.7×10^{-8}
^{90}Sr , ^{137}Cs , ^{239}Pu (a)	40	1.1×10^{-8}
^{137}Cs , ^{134}Cs	450	1.3×10^{-7}
^{152}Eu , ^{239}Pu (a)	200	5.7×10^{-8}
^{106}Ru	80	2.3×10^{-8}
U	10	2.8×10^{-9}
^{147}Pm	300	8.5×10^{-8}
Toxic Chemicals	grams	(ppb)
Copper	2×10^8	52

(a) For purposes of dose evaluation, the activity will be assumed to be equally divided among the components of these mixtures.

(b) The material was assumed to be all released to the river in one day and diluted by the volume of the PMF (144×10^6 cfs or 3.53×10^{12} liter/day).

TABLE III.2-30

RADIATION DOSE FROM POSTULATED COLUMBIA RIVER FLOOD

	Maximum Individual, rem
Total Body	6.1×10^{-3}
GI-Tract	3.5×10^{-3}
Bone	5.0×10^{-3}

probably be evacuated, the doses given are highly hypothetical. Consequently no calculation was attempted for population dose.

The external exposure to the shoreline during the first year following the flood, assuming an avid fisherman would spend 500 hours on the contaminated shoreline is included in the total-body dose given in the Table III.2-30.

The highest total calculated dose listed in Table III.2-30 is about 6×10^{-3} rem to the total body in the first year. About 70% of this dose would come from ^{134}Cs and ^{137}Cs in the fish, presumably harvested from the contaminated flood water. Only about 1% of the dose is from drinking water. About 40% of the GI tract dose would result from consumption of fish, with most of this dose resulting from ^{60}Co . Most of the bone dose, from both the drinking water and fish consumption would be due to ^{90}Sr .

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IV UNAVOIDABLE ADVERSE EFFECTS

Unavoidable adverse effects from the Hanford Waste Management Operations program may arise from radioactive, chemical, or thermal components in waste effluents being released to the atmosphere, Columbia River, or the ground. The adverse effects may be both onsite, such as limiting use of actual waste disposal areas for other purposes, and offsite, such as the populations radiation dose incurred as a result of Hanford programs.

Reduction of adverse environmental impacts from Hanford Waste Management Operations are initiated by 1) cleanup of gaseous waste prior to release, 2) concentration and storage in tanks of high-level radioactive waste and 3) controlled burial of solid radioactive waste. Transuranic waste is segregated and buried to permit retrieval in 20 years without loss of packaged containment integrity. An environmental surveillance and evaluation program is maintained independent of waste handling operations to detect and permit corrective action if abnormal conditions are found. Several installations have been completed to avoid accidental releases of radioactive materials into ditches and ponds due to cooling coil failures by monitoring such streams and switching their flow to contained systems for reprocessing where adverse quantities of radioactive materials are found.

Facilities to solidify high-level radioactive waste (evaporators) are in operation and additional units are being built to speed the solidification effort. New double-wall waste tanks are being built and improved equipment and procedures are now in place to monitor for liquid waste tank leaks.

Onsite, about 3% of the 365,000-acre Hanford Reservation is used for structures and waste disposal sites. The areas directly associated with the major waste disposal sites are committed to long-term control (thousands of years). The small total area committed for such control and use does not constitute a significant adverse effect to the Hanford ecological community.

The waste management practices utilizing cribs and trenches probably prohibit major irrigation projects for much of the onsite land because of the changes in the water table levels that would result. Similarly, the use of large reactor cooling channels or lakes would require study to determine their possible influence on the groundwater system.

Also, the groundwater onsite contains some radionuclides, principally tritium and ^{106}Ru - ^{106}Rh and nitrate ion.

The offsite effect for 1972 due to Hanford Waste Management Operations was the small individual and the small population doses that resulted from releases of radioactive materials to the atmosphere and the Columbia River. The average per capita dose rate in 1972 was 9.6×10^{-3} mrem/yr while the maximum individual total-body dose was 0.58 mrem/yr. Table IV-1 summarizes the maximum annual doses to an individual and relates the resulting dose to its exposure pathways. The total-body dose for the 249,000 people living within 50 miles of the Hanford Waste Management Operations facilities was 2.4 man-rem/yr for 1972. Table IV-2 summarizes the population annual dose and relates the dose to its exposure pathways. The total-body dose contributions of 2.4 man-rem/yr compares to a total-body dose due to natural background radiation for the same population of 27,400 man-rem/yr. The Hanford contribution is only 0.01% of the dose received from the natural background radiation. The Hanford-contributed doses result principally from gaseous releases of ^{41}Ar from N Reactor (1.3 man-rem/yr) with lesser contributions of tritium in drinking water (0.3 man-rem/yr) and from consumption of irrigated crops (0.3 man-rem/yr).

When N Reactor is shutdown, the current release of ^{41}Ar and some tritium and ^{131}I , as well as other activation and fission products in the N Reactor effluents, will cease. At that time, the air submersion dose to the population will be reduced to about 1.3×10^{-3} man-rem/yr and the dose attributable to the liquid effluents will be reduced as the

TABLE IV-1

ESTIMATED MAXIMUM DOSE TO AN INDIVIDUAL FROM THE EFFLUENTS
RELEASED AT THE HANFORD PROJECT IN 1972(a)
(mrem/yr)

Pathway	Annual Exposure	Skin	Total Body	GI-LLI	Thyroid	Bone
<u>Gaseous Effluents</u>						
Air Submersion	8766 hr	0.088	0.011	(0.011) (d)	(0.011)	(0.011)
Tritium-Inhalation & Transpiration	8766 hr	2×10^{-4}	2×10^{-4}	2×10^{-4}	2×10^{-4}	----
Radioiodine-Inhalation	7300 m ³ air	--	--	--	0.0019	--
Milk	274 liters ^(b)	--	--	--	0.056	--
Vegetables	30 kg ^(c)	--	--	--	0.042	--
Total Air Pathways		0.088	0.011	0.011	0.11	0.011
<u>Liquid Effluents^(e)</u>						
Drinking Water	730 liters	--	0.015	0.036	0.30	0.066
Fish Consumption	40 kg	--	0.30	1.02	0.31	1.63
Irrigated Foods	710 kg	--	0.16	0.25	0.33	0.33
Shoreline	500 hr	0.10	0.090	(0.090)	(0.090)	(0.090)
Swimming	100 hr	0.0032	0.0026	(0.0026)	(0.0026)	(0.0026)
Boating	100 hr	0.0016	0.0013	(0.00013)	(0.0013)	(0.0013)
Total Water Pathways		0.10	0.57	1.4	1.0	2.1
Total (Adult)		0.19	0.58	1.4	1.1(f)	2.1
<u>Infant Thyroid Dose</u>						
Airborne Tritium	8766 hr				0.0001	
Air Submersion	8766 hr				(0.011)	
Inhalation	2045 m ³				0.002	
Milk	274 liters ^(b)				0.46	
Drinking Water	292 liters				0.95	
Total					1.4(f)	

(a) Using releases tabulated in Tables III.1-2, 3, 4, 8, 9 and 10.

(b) One liter/day for a 9-month grazing season.

(c) 200 g/d for a 5-month produce season.

(d) () indicates internal dose from external exposure.

(e) Essentially all from 100-N effluents.

(f) Does not include contribution from ¹²⁹I in the environment from previous years' operations estimated to be ~0.4 millirem/yr to both the maximum individual adult and infant.⁶

TABLE IV-2

SUMMARY OF ESTIMATED POPULATION DOSES RECEIVED AS A RESULT
OF THE OPERATION OF THE HANFORD PROJECT IN 1972

<u>Pathway</u>	<u>Total Body Dose man-rem/yr</u>	<u>Thyroid Dose man-thyroid rem/yr</u>
<u>Gaseous Effluents</u>		
Air Submersion	1.3	(1.3) ^(a)
Tritium (Inhalation and Transpiration)	0.02	0.02
Radioiodine (Inhalation, Milk, Vegetables)	--	0.5
<u>Liquid Effluents</u>		
Drinking Water	0.45	8.9
Fish Consumption	0.11	0.12
Aquatic Recreation	0.40	(0.40)
Irrigated Foods (Produce, Eggs, Milk)	0.16	0.33
Total	2.4	12 ^(b)

(a) () indicates internal dose from external exposure

(b) Not including the contribution from ¹²⁹I in the Hanford environs presumably as a result of previous years of operation. This contribution can be estimated to be an additional 4 man-thyroid rem.^{1,2}

radioactive materials already in the river sediments decay. The radionuclides reaching the Columbia River from the groundwater system (mostly tritium and ^{106}Ru - ^{106}Rh) will, at their maximum rate of discharge, contribute less than 0.1 man-rem/yr to the local population dose. The population total body dose in the first year after N Reactor is shutdown is not expected to exceed 0.5 man-rem/yr and will then continue to decrease as the river inventory decays.

For the population doses due to 1972 Hanford Waste Management Operations, the maximum potential health effects are summarized in Table IV-3. For this calculation, the lung and genetic organ doses were conservatively estimated to be the same as the total-body dose.

TABLE IV-3
MAXIMUM NUMBER OF HEALTH EFFECTS FOR
1972 ENVIRONMENTAL DOSE LEVELS

<u>Mortality</u>		
<u>Organ</u>	<u>Population Dose</u>	<u>Maximum Number of Health Effects</u>
Total Body	2.4 man-rem	4.8×10^{-4} cancer deaths
Lung	2.4 man-rem	1.2×10^{-4} cancer deaths
Thyroid	12 man-rem	6.0×10^{-5} cancer deaths
<u>Morbidity</u>		
Total Body	2.4 man-rem	9.6×10^{-4} cancer cases
Thyroid	12 man-rem	2.4×10^{-4} cancer cases
Genetic Damage	2.4 man-rem	7.2×10^{-4} genetic effects

Since the number of health effects are all far less than one, it may be concluded that there are no health effects due to Hanford operations for 1972.

About 550 cfs of Columbia River water is withdrawn at the Hanford Reservation, including 440 cfs for cooling purposes. From this withdrawal, 140 cfs and 300 cfs are heated to 16°C and 10°C, respectively, above ambient river temperatures and returned to the river. This cooling water is withdrawn at a rate of about 0.4% of the average river flow rate and about 1% of the low river flow rate. Upon return to the river, rapid mixing of this warm water with the main body of the river occurs. Minimum local effects due to the warm water return may take place. For 1972, the Richland daily average river temperature was 10.1°C, compared to an upstream (Priest Rapids) daily average of 10.9°C. Hence, on the average there was a slight cooling trend in the Hanford Reservation stretch of the Columbia River. Any possible adverse effects due to heat have not been detected but would be limited to local areas, probably not reaching more than a few hundred yards from the point of discharge.

Water withdrawal from the Columbia River for Hanford use is generally at pipe intake velocities sufficiently low to avoid fish entrapment. Studies during the previous years of Hanford operation have demonstrated no significant effect on the river ecosystems due to entrainments, even when substantially larger quantities of water were removed for plant use. Also, no changes were obvious in the numbers of phytoplankters or their species composition over the past years. Such studies indicate that any adverse effects due to water pumping and removal of lower level aquatic life are insignificant to the overall food chain of the larger species and have not led to observable adverse effects.

Chemical releases to the atmosphere and the Columbia River produces only limited impacts on nearby biota. Chemical disposals to the ground do not give rise to adverse effects other than the very local effects near seepage areas where cribs and ponds located on the Columbia River bank discharge into the river. Chromium, nitrate ion, and total solids are added to the river in concentrations above ambient river

concentrations. These small additions are quickly diluted and any adverse effects (none were observed) would be limited to the immediate area of the discharge. Approximately 2,300 tons of SO_2 and nearly 1,200 tons of NO_x were released from the power plant stacks in 1972, but the accepted standard limits of SO_2 and NO_x were not exceeded at offsite locations. No adverse environmental effects have been demonstrated over approximately 30 years of plant operation. No chemical disposal activities or waste emissions led to any known adverse effects on humans.

IV REFERENCES

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2. J. K. Soldat, et al., Radioecology of ^{129}I : An Interim Report, BNWL-1783, Battelle, Pacific Northwest Laboratories, Richland, WA, 1973.

V ALTERNATIVES

V.1 INTRODUCTION

This section discusses the range of reasonable alternatives to the current Waste Management Operations Program at Hanford, particularly those that might enhance environmental quality and avoid or reduce adverse environmental effects. The alternatives considered deal with high-level liquid radioactive waste, other radioactive liquid waste, radioactive gaseous waste, radioactive solid waste, nonradioactive waste, and other environmental pollutants. The discussion of each alternative is preceded by a short statement of the current waste management plan for comparison purposes.

The present existence of approximately 72 million gallons of radioactive waste (liquids, salt cake, and interstitial liquids) requires some type of waste management program. Therefore, the analysis of an alternative that does not require a waste management program is not considered reasonable. Alternatives currently under consideration for ultimate storage of Hanford's high-level waste are briefly discussed but additional research and development is required before the best waste form and storage location can be determined.

This section also includes an analysis of the environmental impact which would occur if the primary production facilities at Hanford (N Reactor and Purex) were to cease to operate.

The current program plan does involve the generation of new waste primarily from the processing of N Reactor fuel in the Purex processing facility and from research and development activities. This waste is expected to amount to an addition of a few percent per year to the existing waste inventory.

An analysis of reasonable alternatives to the current operations solely on the basis of changes in radiation dose to the general population

clearly indicates that comparatively little change in the radiation dose would occur. The radiation dose resulting from the current practices is small (about 2.4 man-rem/yr) and the resulting health effects (based on the assumptions discussed in Section III) also pose a small comparative risk. However, consideration of the long-term requirements for control and isolation of radioactive waste materials from man's environment requires that reasonable alternatives be evaluated in terms beyond the projected radiation dose to the population. Therefore, the analysis of alternatives also includes such concepts as improved controls, retrievability, and reduction of discharges to the environment to as low as economically and technically practicable.

A range of alternatives for each level and each type of waste generated at Hanford is examined. For the high-level liquid waste, five major alternatives, most with several sub-options, are examined. Table V-1 summarizes these alternatives. For other radioactive liquid waste, the alternatives are summarized in Table V-2. The current plans and reasonable alternatives for handling of solid and gaseous radioactive waste as well as all other forms of waste generated at Hanford are then discussed.

In most cases, the alternatives are not mutually exclusive and several could be simultaneously adopted.

For example, the number of new double-walled tanks (4-12) which could be beneficially used would depend on the operating period of the N Reactor and Purex as well as when a solidification method for the final residual liquids is developed. Purex could be shutdown with or without continuing N Reactor operation. New facilities for solidifying the final residual liquid will be needed whether or not waste generating facilities (N Reactor and Purex) are operated in the future.

TABLE V-1

HIGH-LEVEL WASTE ALTERNATIVES

- 1) Continue Present Program
 - a) Replace all single-wall tanks
 - b) Replace older single-wall tanks
 - c) Final Solidification
- 2) Shutdown N Reactor
- 3) Shutdown Purex
- 4) Discontinue Solidification to Salt Cake
 - a) New double-wall tanks
 - b) Calcine
 - c) High temperature melt formations
 - d) Insoluble formation
- 5) Ultimate Disposal
 - a) Leave salt cake in tanks
 - b) Leave salt cake in tanks plus containment improvements
 - c) Remove salt cake, convert to immobile form with storage at Hanford
 - d) Remove salt cake, convert to immobile form with storage offsite

TABLE V-2

LIQUID EFFLUENT WASTE ALTERNATIVES

- 1) N Reactor Effluent Treatment
- 2) 5 Million Dollar Effluent Cleanup
- 3) 50 Million Dollar Effluent Cleanup

V.2 ALTERNATIVES TO HIGH-LEVEL WASTE TREATMENT

V.2.1 Continue Present Program

Approximately 47 million gallons of liquid waste and 25 million gallons of solidified waste are currently stored in underground tanks at Hanford. This waste was generated during the period 1944 to 1974. This quantity of high-level waste represents about 90% of the total high-level waste expected to be generated through the operation period of the Hanford plutonium production facilities. Based on current production plans, the operation of N Reactor¹ and the Purex processing plant results in the generation of approximately one million gallons of high-level waste each year.

The thrust of the current program for high-level waste is to convert stored and currently generated high-level waste from a liquid to a salt cake form. The existing evaporators, along with one evaporator currently under construction, will solidify most of the stored and currently generated liquid waste to salt cake. A residuum of highly caustic liquid will remain which cannot be further evaporated with these evaporators. These evaporators are scheduled to be in equilibrium with currently generated waste in CY-1976. The residuum will be treated to produce a solid either by chemical addition or a special type evaporator. These alternatives are now under development.

The solidification of the liquid waste, along with the current construction of three additional double-wall tanks to contain the liquids in interim periods, is considered to be the current program for management of the high-level waste. The objective of this program is to continue to maximize the isolation of the high-level waste from man's environment.

Within the current program, a number of facilities and activities are planned for the current budget cycle, FY-1973 through FY-1975. All of these programs are designed to further improve total containment of radioactive materials and to maintain their release to the environment to the lowest level technically and economically feasible. Just over

33 million dollars worth of improvement are budgeted or currently under construction. The programs are summarized in Table V-3.

TABLE V-3

WASTE MANAGEMENT FACILITIES AND ACTIVITIES
PLANNED OR UNDER CONSTRUCTION, FY-1973 THROUGH FY-1975

In-Tank Solidification Systems, Auxiliaries \$2,500,000

The project provides additional concentrate routing facilities to permit transfer of slurries from the 242-S Evaporator to existing tanks in the 241-U Farm.

Additional Waste Concentration and Salt Cake Storage Facilities \$30,000,000

This project provides a waste evaporator system, additional underground storage tanks for cumulative capacity of at least three million gallons of highly radioactive waste, routings for new tanks and existing underground storage tanks, underground lines, encasements, pumps and auxiliaries, which are needed for the waste concentration program and for minimizing the potential for leakage of radioactive liquids to the ground.

Provision of the proposed facilities will allow acceleration of the waste solidification program. The liquid waste in 30 of the older waste tanks, some of which are associated with the existing waste concentration systems, can be emptied at least one year sooner for solidification by evaporation-crystallization. Also, most of the liquid waste can be stored in single-wall 200 East Area waste tanks of later improved design or the new double-wall waste tanks provided by this project instead of the older tanks which otherwise would be utilized. This will reduce the potential for future leaks.

Waste Tank Leak Detection Laterals \$330,000

A set of three laterals will be provided about nine feet below the bottom of the 102-S and 103-S waste tanks to permit radiation monitoring of the ground for early detection of possible leaks. These tanks serve as the feed and dump tanks for the 242-S Waste Evaporator.

Groundwater Monitoring Wells \$100,000

Additional wells will be drilled at selected strategic locations to enhance the existing routine groundwater monitoring capability.

TABLE V-3

(continued)

<u>Encase Waste Lines 232-Z to 241-Z</u>	<u>\$50,000</u>
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A short run of existing piping which transports incinerator scrubber waste from the plutonium incinerator building to a sump will be replaced with an encased pipeline, thus affording double containment provisions.

<u>Tank 241-C-106 Sluicing Facilities</u>	<u>\$400,000</u>
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Tank 241-C-106 contains a considerable amount of ⁹⁰Sr-bearing sludge which originated as entrainment from sludge washing operations associated with removal of sludges from the 241-A, AX tank complex. This project will provide facilities for removal of the sludge from which the strontium will be recovered in B Plant. The recovered strontium will then be solidified, encapsulated and stored in the encapsulation plant facilities.

Total Dollars	<u>\$33,380,000</u>
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The current program also includes research and development to determine the best ultimate disposal method for the salt cake. The focus is on alternate solid forms and storage methods which would have minimum dispersability characteristics over very long periods of time. Research and development efforts directed toward final disposal of high-level waste from the commercial power industry will be studied for possible applicability to Hanford waste.

Alternatives within the present high-level waste management program are:

- replace all single-wall tanks with new double-wall tanks
- replace all of the older single-wall tanks with new double-wall tanks
- add materials to salt cake tanks to solidify all residual liquids
- build a special evaporator to solidify all remaining residual liquids associated with salt cake formation and storage.

At the present time, dilute and interstitial liquid waste awaiting processing by the evaporators is stored in single-wall tanks. After this waste is processed through the evaporators, approximately 11 to 17 million gallons of liquid waste will remain for underground storage. Two to three million gallons will be from combined dilute and aging waste; two to five million gallons from combined interstitial and concentrate liquids in the evaporator loops and seven to nine million gallons of residual liquids. The dilute liquids are liquids which have not been processed through the evaporators; combined liquids are those processed through the evaporator at least once; and residual liquids are liquids which cannot be further solidified in the evaporator or crystallizer.

Two storage alternatives to the present program are currently under consideration. The first is to store all liquid waste in new double-wall tanks. The second is to store the highest level liquid waste in new double-wall tanks and continue to use the newer of the single-wall tanks for selected liquid waste.

V.2.1.1 Replace All Single-Wall Tanks

This alternative requires the construction of up to 12 double-wall tanks of one million gallon capacity each to permit storage of all liquid waste in double-wall tanks including the residuum liquids in the evaporator bottoms loops. After processing the current liquid waste inventory through the evaporators (1976), a minimum of 11 million gallons of liquid waste would remain for tank storage or other treatment. The present Hanford evaporators would not be able to further concentrate this 11 million gallons because of its chemical content. The 12 double-wall tanks would provide the needed liquid waste containment capacity plus some spare capacity to meet emergency needs.

Building 12 new double-wall tanks would provide improved containment of high-level liquid waste. Leakage of these liquids to the soil would be eliminated by the second tank wall. Monitoring for leaked liquids

between the inner and outer tank walls would provide leak detection. Leaking tanks could be taken out of service before material leaked from the second wall to the soil.

The magnitude of the construction activity for the adoption of this alternative would present major material supply and tank fabrication problems. After funding is obtained, an estimated four years minimum would be required before these tanks could be procured and placed into operation. The cost would exceed \$60,000,000.

Based upon the extrapolation of past leak data some leakage from the existing tanks would be expected during the time these tanks were being constructed and the liquid waste was being processed by the evaporators. The population dose resulting from the current waste tank storage program including any contributions from leaking tanks is essentially zero ($<1 \times 10^{-6}$ man-rem/yr). Adoptions of this alternative would not change this population dose significantly, but would over a period of time reduce the quantity of liquid waste leaked to the ground from tank containment failure.

V.2.1.2 Replace Some Single-Wall Tanks

This alternative requires storing the highest level liquid waste in new double-wall tanks and continuing the use of newer single-wall tanks for selected liquid waste. For example, construction of six additional double-wall tanks of one million gallon capacity each to replace some of the older single-wall tanks would provide a combination dilute waste receiver and feed tank for each evaporator, and would permit storing approximately 70% of the residual liquid inventory in double-wall tanks. The other 30% of the residual liquid inventory would be stored in the newer single-wall tanks that have improved leak detection capabilities. Rapid leak detection and tank pump-out would keep the loss of liquid waste to the soils to a few thousand gallons or less per leak.

Process development of partial neutralization and reconcentration of residual liquids is continuing and its application, should the process prove successful, might reduce the stored inventory to 70% of the

original volume. If the process is developed, then the single-wall tanks with the improved leak detection equipment would hold the solids formed by this process. The remaining residual liquids would then be stored in the new double-wall tanks. The unused single-wall tanks would remain available as emergency spares.

New tanks could be available three to four years after funding. The cost is approximately \$5 million per tank.

Adoption of this alternative would result in the continued storage of all but one to six million gallons of liquid waste in double-wall tanks. This remaining liquid waste would be stored in the best single-wall tanks. No change in population dose would result from adoption of this alternative.

V.2.1.3 Final Solidification

As part of the current waste management program, development work is proceeding now to solidify the residual liquids which the existing evaporators cannot further evaporate. Nearly ten million gallons are expected to require such treatment at the end of the solidification program. Development work is proceeding to reduce the quantity of residual liquids at the end of the program by nitric acid addition. Acid addition should precipitate some additional salts which should permit further evaporation of residuum in the existing evaporators.

Two basic processes are under consideration for the final solidification: 1) addition of materials such as clay or phosphoric acid which would react with the residual liquids to form a solid product, and 2) evaporation of the highly caustic residual liquids by a different type evaporator, such as wiped film evaporator.

V.2.1.3.1 Material Addition for Residual Liquids

The residual liquid and new liquid waste after completion of the current solidification program could be immobilized by the addition of chemicals or materials which would either react with the water or absorb it.

Typical examples are phosphate compounds which form hydrates and clays which absorb the water.

These possibilities have not been studied in sufficient detail for decision making. Several additional years of effort are necessary before the decisions can be made on the best method and its costs. Final solidification of all liquids would, of course make liquid leaks impossible. There would be no change in the essentially zero population dose ($<1 \times 10^{-6}$ man-rem/yr) now received from the liquid waste management program. Further contamination of soil from tank leaks would not occur.

V.2.1.3.2 Further Evaporation for Residual Liquids

After completion of solidification of most of the liquids by use of the evaporators, about ten million gallons of saturated bottoms liquid will remain. A continuous supply of new liquid waste of from one to two million gallons per year will be generated by research and development activities plus operation of Purex.

Because of the chemical composition of these remaining residual liquids, the current evaporators cannot make the final solidification. Installation of special evaporators which can remove essentially all liquid will be necessary. The desired product from the special evaporators would be a dry solid which would be stored in the single-wall underground tanks.

The design and costs for this equipment is not known. Engineering studies have not progressed far enough to identify suitable special evaporators. Final solidification of the residual liquids by this approach terminates the leakage potential from liquid waste storage tanks since no liquids would be present. There would be no change in the essentially zero population dose resulting from the liquid waste management program.

V.2.2 Shutdown of N Reactor

An alternative to generating and processing most new radioactive waste is to shut down N Reactor and Purex. As stated earlier, the primary role of these facilities is production and recovery of plutonium and other materials for national defense and research and development activities. The need for this material is beyond the scope of this statement. This section and the one following include an analysis of the environmental impact if these production facilities cease to operate to provide a basis for comparing the impact of managing the waste to be generated in the future with managing the waste that has been generated over the last 30 years.

The shutdown of N Reactor would result in the following changes:

- 625 ton/yr of uranium fuel would not be irradiated
- 750 kg/yr of plutonium would not be produced
- 4.5 billion kW hr/yr of electricity would not be produced
- 200 Ci/yr would not be added to N Crib soil column
- <10 Ci/yr would not be released to the Columbia River
- <500 Ci/yr tritium would not be sent to groundwater
- 5000 ft³/yr of solid waste would not be generated
- 100,000 Ci/yr of ⁴¹Ar would not be released to the atmosphere
- 2.3 man-rem/yr of population radiation dose would not be received
- Purex would be shutdown when N Reactor fuel was processed
- One to two fewer new double-wall tanks would be required.

The shutdown of N Reactor would not substantially change the inventory of radionuclides to be added to the presently stored waste. The 200 Ci/yr not added to the N Crib is only a few percent of the current crib inventory. The 200 Ci/yr of tritium not added to the groundwater is only a few thousands of 1% of the current groundwater tritium inventory. The 5000 ft³/yr of waste not generated is about 0.02% of the

solid waste already stored. The 2.3 man-rem/yr of radiation dose not received is about 0.01% of the radiation dose received from natural background each year.

V.2.3 Shutdown of Purex

The alternative of shutting down Purex presents two options: 1) shutdown after processing all N Reactor fuel currently on hand and 2) shutdown now with the existing inventory of irradiated N Reactor fuel either shipped offsite for processing or stored onsite without processing.

V.2.3.1 Shutdown of Purex After Processing Current Inventory

The shutdown of Purex after processing the current inventory of irradiated N Reactor fuel would result in the following changes compared to planned operations:

- 625 ton/yr of uranium fuel would not be processed
- 225,000 gal/yr of boiling waste would not be generated which is equivalent to 30,000 gal/yr of salt cake not produced
- 2 wk/yr of evaporator operating time would not be needed
- 125 Ci/yr of fission products would not be sent to cribs
- 10,000 Ci/yr of tritium would not reach the groundwater
- 1.2 billion gal/yr of cooling water would not be used
- small reductions in solid waste volumes would occur
- power plant fuel consumption and waste emissions would be reduced
- the population radiation dose would be reduced by <0.1 man-rem/yr
- One to two fewer new double-wall tanks would be required.

The shutdown of Purex would change the inventory of radionuclides to be added to the presently stored waste. The reduction of 225,000 gal/yr of boiling waste would require one less boiling waste storage tank every 4 years. The 125 Ci/yr of fission products not absorbed on soil columns would be a reduction of about 0.1% of the current crib soil column inventory. The 10,000 Ci/yr of tritium not reaching the groundwater

would be a reduction of less than 0.02% of the tritium now in the groundwater. The 1.2 billion gal/yr of cooling water not used represents less than 1 hour of average flow of the Columbia River.

V.2.3.2 Shutdown of Purex Immediately

For immediate shutdown of Purex, two alternative methods for irradiated fuel handling may be considered: 1) ship fuel offsite in the near term for processing, and 2) store the fuel for an indefinite period (in reactor or in storage basin). The total amount of irradiated fuel available for processing through FY-1978 is about 3700 tons, of which 1200 tons are now in inventory.

V.2.3.2.1 Ship Fuel Offsite

This alternative would require the irradiated fuel produced by N Reactor to be processed either at a commercial plant or at the AEC Savannah River Plant (SR).

No commercial processing capability is available at the present time. Approximately 400 tons of NPR fuel were sent to Nuclear Fuel Service near Buffalo, New York in the mid 1960's. Difficulty was encountered in processing the fuel utilizing a chop-leach method of fuel dissolution. Also, the metallic N Reactor fuel is brittle and massive fracture with fuel element disintegration in the fuel shipment cask was encountered. As a result of these problems, commercial plants have been unwilling to process this type fuel, particularly since the projected commercial power reactor oxide fuel will probably fully utilize existing plants and those under construction.

Savannah River could process the fuel. Significant plant and capital investments would be required. Total capability to process the fuel would be available about 5 years after funding was obtained. The plutonium and uranium would be in an unusable form requiring carefully controlled storage for 3 to 5 years.

No significant change in the quantity of high-level liquid waste would result with processing at SR. Since SR also produces salt cake, there would be no change in total salt cake quantity. The following changes would result:

- The waste products would be disposed of at SR.
- Shipping costs are estimated at 2.5 million dollars/yr.
- Shipping casks would be required at a cost of approximately \$20 million.
- 125 Ci/yr less fission products would be released to the cribs at Hanford.
- Capital costs for modifications to the SR plant would be an estimated 30 million dollars.
- Processing cost would be about equal for either plant.
- Radiation dose to the population would be increased due to some low exposures along the shipping route.
- Three to four fewer new double-wall tanks would be required.

Since the radioactive material would require more handling and cross-country shipment, some increased potential for worker radiation exposure and for accidents would occur. Shipment costs and capital modification costs would increase total processing cost.

The reduction of 125 Ci/yr released to the cribs at Hanford would result in this activity having to be managed at Savannah River.

V.2.3.2.2 Store Irradiated Fuel

Irradiated N Reactor fuel could be stored without processing. Results of adoption of this alternative would be:

- Modifications would be made to old reactor fuel storage areas to accept long-term irradiated fuel storage.
- 125 Ci/yr of fission products would not be sent to cribs.
- Fuel cladding corrosion could result in the release of an unknown amount of radioactivity to the air and to the ion-exchange cleanup systems at the fuel storage areas.

- The quantity of strontium and cesium requiring separation from high-level waste would be decreased by a few percent.
- Long-term storage would probably preclude processing due to lack of suitable facilities.
- Uranium and plutonium values in the fuel would not be realized.
- No change would occur in population dose.
- Three to four fewer new double-wall tanks would be required.

The technology for long-term storage of irradiated fuel would need to be developed. Extensive control systems to detect fuel element failure, to cleanup storage areas, and to re-package or otherwise repair corroding fuel elements would need to be developed. The total quantity of radioactive material to be handled would remain the same, but irradiated fuel storage would add another and a new type of waste management system to be monitored and controlled. The presence of plutonium in the fuel elements would require perpetual control and surveillance of the fuel elements as transuranic waste.

V.2.4 Discontinue Solidification to Salt Cake

The present fractionization and solidification program could be discontinued with the goal of 1) converting the high-level liquid waste to a better solid form for interim storage, or 2) holding the remaining liquid waste until an ultimate disposal method is developed and implemented. Implicit in these options is the need to construct new double-wall tanks. Extensive R&D and conceptual design work would be required and take years to implement.

Converting to an acid waste storage system is not an attractive alternative to continuing solidification to salt cake because of the large volume of basic waste already on hand (47 million gallons) and the relatively small volume of liquid waste yet to be generated by Purex under current planning (4 million gallons). None of the waste storage tanks now at Hanford are suitable for acid waste storage. At least 4 new double-wall acid waste storage tanks would need to be constructed at a total cost in excess of 20 million dollars. There would be no flexibility in handling the acid waste since it would always be limited to the special tanks and systems designed for it.

The generation of two different waste characteristics would lead to a possible need for two processes for conversion for long-term or ultimate storage. Maintaining a single waste type would seem to be the wisest course of current action.

V.2.4.1 Construct New Double-Wall Tanks

This alternative would discontinue the current waste solidification program and would provide new double-wall tanks of one million gallon capacity each for high-level liquid waste storage. New double-wall tanks would avoid tank leakage to soil. To discontinue the solidification program and hold the current liquid inventory in presently available tanks would, over the years, lead to many leaks.

The waste would be stored in the double-wall tanks until a better form for interim storage is developed (5 years to develop plus 5 years to implement) or until an ultimate storage mode is developed (selection by 1985, implementation at least 5 years later) and implemented.

Double-wall tanks would be required for:

- 47 million gallons of current liquid
- 4 million gallons of additional Purex waste
- 5 million gallons of research and development generated waste

for a total of 56 million gallons for the period through FY-1978.

Fifty-six double-wall tanks of one million gallon capacity each would be required. Current construction cost estimates are 5 million dollars per tank for a total cost of 280 million dollars.

New waste resulting from continued operation of Hanford facilities would initially be put into existing double-wall tanks. Simultaneously, the construction of new double-wall tanks in 200 East and 200 West Areas would be started, and as these new tanks with their associated piping and ancillaries were made available, the liquid waste now stored in the single-wall tanks would be transferred into them. Of the 152 tanks

present in the complex, approximately 80 contain liquid that would be transferred under this alternative. The old tanks, whether empty, partially filled, or totally filled with solids, would be isolated and held pending ultimate disposition of their contents. Twenty-five million gallons of solids are being held at this time.

The ability of industry to respond to such a massive tank building program would be severely taxed. A large increase in capital expenditures would be required. The construction program would result in the irretrievable commitment of additional resources such as steel (360 tons per tank) and concrete. The new tanks would require a total of about 50 acres of additional land that would be committed to the radioactive waste management program for the indefinite, but very long term, future.

The amount of liquid waste leaking from old tanks into the ground would be proportional to the length of time the completion of liquid transfer would extend beyond the mid-FY-1976 completion date scheduled for current waste solidification. Leakage during this period could be thousands of gallons and a few tens of thousands of curies annually. Adoption of this alternative would not reduce the essentially zero population dose resulting from the liquid waste management program, but would terminate contamination of underground soil from leaking tanks.

V.2.4.2 Calcine Waste

An alternative to salt cake formation is calcining of the Hanford high-level liquid waste. Several different techniques have been studied including pot, spray, and fluidized bed calcination.

Pot calcination has the advantage of being a relatively simple process that can handle a broad range of waste feed compositions. However, stainless steel pots are required for both product formation and storage, the batch wise process capacity is inherently low, heat conductivity through the calcine is low and the calcine can be dissolved in waste as readily as salt cake.

The spray calcination is a continuous process with good capacity and low hold-up volume. It produces a wide range of good quality solids, but is relatively complicated and difficult to operate, and may require use of expensive materials. When combined with a continuous melter for the calcine, it produces a monolithic, microcrystalline solid with three to five orders of magnitude less leachability than the pot calcine.

The fluidized bed calcination is a high-capacity continuous process extensively developed and currently in use at the National Reactor Testing Station in Idaho. The process is moderately complicated to operate. The product is a dry, granular solid easily transportable by pneumatic means.

Little development work has been done on the application of a calcination process to the Hanford-type of waste, but what has been done indicates that spray calciner would probably be the most successful of the calcination techniques for Purex-type waste. The product from a spray calcine process would be at least five orders of magnitude less leachable than salt cake.

All three of the above calcining processes would convert the high sodium content of the current liquid waste to sodium oxide. This compound is hygroscopic and will absorb sufficient moisture to create an unstable condition. In this sodium oxide form, the calcine product is quite similar to salt cake in stability and leachability. The chemical addition required to convert to a more stable form, e.g., sodium sulfate, significantly increases the final volume of the waste to be stored.

An estimated five years would be required for the research, designing, building, and placing a calciner into operation for processing Hanford waste. A calciner for Hanford waste should have a capacity of 15 million gallons of high-level liquid waste per year. It would have to operate for five years to reach current (equilibrium) status with the liquid inventory. Operating costs of the calciner would be \$6 to \$8 million per year. Capital investments of approximately \$200 million would be

required to construct the calciner, its auxiliaries and calcine storage facilities. Underground calcine storage bins would require extensive procurement lead time. Not included in the above cost are the \$5 million per double-wall tank needed for storage of the millions of gallons of waste being generated during the 10 years before the calciner would have processed the high-level liquid waste.

Also, adoption of this alternative would probably need to be coupled with the building of some new double-wall tanks to provide improved liquid waste containment for the existing inventory prior to calcination. Holding the existing liquid inventory for some 8 to 10 years beyond when it might have been converted to salt cake would lead to leaks from the single-wall tanks and consequently more soil contamination than expected by pursuing the salt cake formation program. Adoption of this alternative would not reduce the essentially zero population dose resulting from the liquid waste management program.

V.2.4.3 High Temperature Melt Formations

Another alternative to salt cake formation is converting the high-level liquid waste to a stable insoluble solid by a high temperature melt treatment.^{2, 3, 4,}

Numerous chemical formulations plus related process equipment and operations are being studied relating to the conversion of liquid waste to various types of glasses, glass-ceramics, devitrified phosphate glasses and others. Such formations could provide long-term storage stability and leach resistance. Silicate melt technology is the most advanced waste fixation technology on a world-wide basis. It is a leading near-term contender for producing an acceptable waste form.

This alternative would propose the use of an aluminosilicate formulation (basalt rock). The process would include an evaporative operation to concentrate the dilute liquors. The product material is a dense silicate glass resembling obsidian. This particular process should work well with

the existing highly basic waste. About 8 years would be required to design and build the facility. The costs for the "glass plant" would be about 100 million dollars, exclusive of storage facilities for the containers of "product". The final volume of glass would be approximately equal to the volume of calcine for an equivalent amount of liquid waste.

The adoption of this alternative would probably need to be coupled with the building of some new double-wall tanks to provide improved liquid waste containment for the existing inventory prior to processing. Holding the existing liquid inventory for some 8 to 10 years beyond when it might have been converted to salt cake would lead to leaks from the single-wall tanks and consequently more soil contamination than expected by pursuing the salt cake formation program. Adoption of this alternative would not reduce the essentially zero population dose resulting from the liquid waste management program. It would produce a product of good stability and low leachability.

V.2.4.4 Insoluble Formation

In this alternative,^{5,6} concentrated liquid waste would be mixed with clays at low temperatures (less than 100°C). Reaction products--solid brick-like, insoluble minerals such as cancrinite--would be formed which would be suitable for long-term storage. Liquid waste would be drawn up out of the storage tanks, mixed with the reagents in an in-line type of operation, extruded and cured in a selected geometric form, then returned to storage bins. Future retrievability would be accomplished by pneumatic or mechanical means.

Although considerable definitive work has been done on the technology of this process, operating plans and costs are viewed as tentative. The research, development, design, and implementation would require a minimum of 5 years. Costs are estimated at approximately \$30 million for the plant and 100 million dollars for the storage bin facility.

Liquid waste would be converted to solid, more rapidly and starting earlier (within 5 years) than would be the case with either the fluid-bed calciner or the glass plant, thus reducing the potential risk and amount of waste leakage into the soil. Some construction of new double-wall tanks would be needed. This alternative requires storing the waste in liquid form until implemented. The process essentially doubles the volume of the waste material so larger areas are required for waste storage. Adoption of this alternative would not reduce the essentially zero population dose resulting from the liquid waste management program.

V.2.5 Ultimate Disposal

The final plan for ultimate disposal of the high-level radioactive waste will emerge only after technology is developed. The processes being developed for commercial waste include a calcine, glass, microcrystalline, and bitumen-dispersed forms. Storage in engineered vaults and in geologic formations is being studied. These processes are being followed for possible application to Hanford waste. Currently, four ultimate disposal alternatives are being investigated. All four are in the research and development stage with primary emphasis currently on alternatives 1 and 2.

Alternative #1 is to leave the high-level radioactive salt waste in the tanks where they are formed. The required investigation includes waste characterization, tank failure effects, waste-sediment reactions, radionuclide transport, radionuclide resuspension, potential water pathways, seismic effects, potential biological pathways, acts of man, and waste retrievability. The technology for this alternative will be developed and the necessary demonstration performed by FY-1981. Research and development cost will be \$18 million. No implementation costs are known at this time.

Alternative #2 is to leave the salt waste in the tanks but add various engineered improvements to the storage system to increase the assurance of containment. This alternative could be selected at any time when it

became apparent that alternative #1 did not provide the required safety. The required investigations for alternative #2 include those listed for alternative #1. In addition, studies would be made of engineered facility improvements, groundwater level control, and of increased chemical immobilization of the waste in situ. Technology for this course can be available in FY-1982 for a cost of \$25 million. The implementation cost of this alternative cannot be estimated until the engineering studies are complete, but is expected to be over a 100 million dollars.

Alternative #3 is to remove the salt waste from the tanks, convert it to a highly immobile form, and store in an engineered onsite repository. In addition to many of the above listed tasks, this alternative requires investigations of site characterization, volume reduction of waste, and increased immobilization. The latter study aims at conversion to a hard, insoluble complex aluminosilicate. Technology for this alternative could be developed by FY-1986 at a cost of \$63 million. This alternative could be undertaken as early as FY-1977 following an adverse decision on Alternative #2. The cost of implementing this plan, following development, is expected to be up to 200 million dollars.

Alternative #4 is to remove the salt waste from the tanks, reduce volume, convert to an immobile form, package and ship to an offsite repository. In addition to the tasks required for Alternative #3, investigations are required in packaging and transport. The technology could be available by FY-1986 at a cost of \$47 million. This alternative could become the selected route by a negative decision on Alternative #3 as early as FY-1979. The cost of implementing this path is highly uncertain at this time, but is believed to approach a billion dollars.

V.3 OTHER RADIOACTIVE LIQUID WASTE

V.3.1 Current Program

In addition to the high-level liquid waste from fuel processing plants, large volumes of waste water both with and without low concentrations of radioactive materials are produced during operations. For some of this waste, it is practical to reduce the radioactivity to levels within established standards for release to uncontrolled areas by treatment methods such as ion exchange, evaporation, or retention to allow for the decay of radionuclides.

The effluents discharged to the ground contain levels of radioactivity which, while unacceptable for release to uncontrolled areas, are at a level where they may be safely released to controlled areas with suitable natural characteristics. Present practice is to use soil columns, seepage basins, evaporative ponds or retention ponds to retain radioisotopes. Wherever such practices are followed, there is a continuing program of extensive monitoring to maintain knowledge of the locations of the radionuclides.

The practice of using the favorable ion exchange properties of some soils to remove radioactivity from liquid waste and confine it in soil columns is a well established procedure. However, there is an implicit assumption that favorable environmental conditions will exist until the radioactivity in the soil columns decays to innocuous levels. Because of the long-term burden of control and surveillance inherent in the use of a technique that results in local accumulations of radioactivity in soil columns, the AEC program at Hanford is based on the goal of reducing the concentration of radionuclides in effluent streams to the lowest technically and economically practical levels. Alternative waste treatment techniques are being employed and further improved treatments planned to decontaminate the bulk of the liquid waste to the extent that it can be released to uncontrolled areas.

The largest current environmental impact from liquid waste is the release of liquid waste to 100-N crib and subsequently to the Columbia River. The radionuclides that enter the Columbia River from the N Reactor operations result in a population dose of about 1.0 man-rem/yr. The normal background dose is about 27,400 man-rems/yr. The dose to the public from the radionuclides released to the ground in the 200 and 300 Areas is less than 0.1 man-rem/yr.

Table V-4 summarizes the programs planned and budgeted through FY-1975 for liquid effluent waste cleanup. All of these programs are designed to reduce radionuclide discharges or to provide increased control over radionuclides during both normal operations and potential accident conditions.

TABLE V-4
WASTE MANAGEMENT FACILITIES AND ACTIVITIES PLANNED
AND UNDER CONSTRUCTION FY-1973 THROUGH FY-1975

<u>100 AREAS</u>	<u>Cost</u>
N Reactor Gravity Drain and Disposal Basin	\$ 445,000
N Reactor Control Rod Coolant Dump System	75,000
<u>200 AREAS</u>	
Waste Management Effluent Control (B Plant)	1,000,000
Contaminated Soil Removal Facility	1,000,000
Purex Condensate Recycle	405,000
Waste Management Effluent Control	410,000
<u>300 AREA</u>	
300 Area Liquid Waste Disposal	190,000
Replace and Upgrade 300 Area Contaminated Waste Line	<u>400,000</u>
Total - - - - -	<u>\$3,925,000</u>

A summary description of each of these programs is provided in Table V-5.

TABLE V-5

DESCRIPTION OF WASTE MANAGEMENT FACILITIES AND ACTIVITIES PLANNED
AND UNDER CONSTRUCTION FY-1973 THROUGH FY-1975

100 Areas

N Reactor Gravity Drain and Disposal Basin \$445,000

An Emergency Disposal Basin will be installed east of the existing 1301-N crib. The purpose is to provide an adequate emergency cooling water disposal capacity in case of 1) an emergency dump of the N Reactor primary loop to the dump tank followed by once-through cooling, and/or 2) a cooling system break inside the 105-N or 109-N Buildings and a concurrent drain pump failure. Emergency drainage sufficient to prevent direct overflow of contaminated water to the Columbia River and to prevent possible water damage to the 105-N and 109-N Buildings will be provided. The Basin will provide a soil column 25 to 30 feet deep between the bottom of the basin and the average groundwater level for absorption of radioactivity.

N Reactor Control Rod Coolant Dump System \$75,000

Valves and piping will be provided in the N Reactor Control Rod Coolant System to provide a positive way to discharge this stream to the 1301-N crib, thus further reducing the potential for discharging small amounts of radioactivity to the river.

200 Areas

Waste Management Effluent Control (B Plant) \$1,000,000

Four waste effluent streams, 1) 244-AR cooling water, 2) B Plant cooling water, 3) B Plant steam condensate and 4) B Plant process condensate will be provided with lined trenches, monitoring, and automatic diversion facilities such that in event of accidental contamination of these streams, the waste will be contained and recycled rather than released.

Contaminated Soil Removal Facility \$1,000,000

This project will remove plutonium containing soil from the underground disposal crib 216 Z-9 for packaging and restorage in facilities affording retrievability provisions.

TABLE V-5

(continued)

200 Areas (continued)

Purex Ammonia Scrubber Waste Concentration Facilities \$405,000

The amount of radioactivity in the Purex Ammonia Scrubber waste which is discharged to a covered trench will be reduced significantly by providing for routing of all of this stream to an existing concentrator system. The decontaminated condensate will be routed to a crib and the concentrated radioactivity will be routed to underground tanks.

Purex Condensate Recycle \$405,000

This project provides for recycling condensates from the 1) backcycle concentrator as extractant for the first uranium cycle and as the scrub solution for the first decontamination cycle, and 2) first uranium cycle concentrator as the final uranium cycle extractant.

With the proposed facilities, all process condensates except the final uranium concentrator condensate, which is well within release limits established by the AEC, would be recycled within the Purex plant. This provides for a significant reduction in the amount of radioactive material discharged to the ground. The total population dose from all 200 Area pond and crib discharges is about 1×10^{-6} man-rem/yr. This project prevents some discharge of radioactive material to the soil but makes no change in the essentially zero population dose resulting from past pond and crib disposal practices.

Waste Management Effluent Control \$410,000

This project provides diversion facilities to detect contamination which may accidentally enter normally nonradioactive cooling water streams and stream condensate from the Purex plant and to divert such an affected stream to either a lined and covered reservoir or to existing waste tanks for decontamination.

300 Area

300 Area Liquid Waste Disposal \$190,000

The existing process waste system will be provided with new leaching trenches, a sampling station and two monitoring wells. The new leaching trenches will replace the existing process ponds, thus eliminating the possibility of leaching the minerals which have accumulated over the years to the river. The total population dose estimated from use of present process ponds is about 0.04 man-rem/yr. This dose will be reduced by construction and use of the new leaching trenches.

TABLE V-5

(continued)

300 Area (continued)

Replace and Upgrade 300 Area Contaminated Waste Line \$400,000

The existing entire radioactive contaminated sewer system consisting of a 6-inch trunk line fed by smaller 3- and 4-inch lines will be replaced and upgraded to eliminate the possibility of line deterioration resulting in the release of radioactivity to the ground.

V.3.2 Liquid Waste Treatment Alternatives

V.3.2.1 100 Areas

In addition to the facilities and activities planned and under construction for FY-1973 through FY-1975, several alternatives exist.

Treatment facilities for reduction of the amount of radionuclides released to the cribs could treat all of the waste stream or only that portion that is the bleed from the reactor primary loop. In either case, the treatment probably would consist of evaporation of the liquid, filtration, and/or ion exchange processes to remove the suspended and dissolved solids. Such processes currently are used at commercial power reactors to separate most of the radionuclides from waste liquid streams with the results that, except for tritium, the amount of radionuclides remaining in the liquid streams can be below 5 Ci/yr. A preliminary estimate for the cost of such treatment facilities is \$15,000,000. This would reduce the radiation dose to the public by about 0.5 man-rem/yr. The facility could be installed about 3 years after funding is authorized.

Transporting the waste to another crib further from the Columbia River would require installation of the new crib, a pump station and a pipeline to the crib. This would increase the travel time from the crib to the river and increase the amount of earth that could absorb and hold the

radionuclides. The quantity of ground and groundwater contaminated by radioactive waste would be increased.

Transportation of the waste to the 200 Areas for storage and evaporation is not considered desirable because of the large volume of waste that would have to be evaporated. New evaporators of much larger size than the current ones would have to be installed at a cost expected to be much larger than the \$15,000,000 cost for treatment facilities at the reactor. Adoption of either of these alternatives would reduce the current population dose of about 0.5 man-rem/yr to near zero.

The only apparent alternatives to release of liquid waste to the 100-F leaching trenches are to 1) collect the waste and transfer it to the 200 Areas for appropriate treatment and disposal, 2) install waste treatment facilities that separate the radioisotopes, or 3) transfer the entire research program to another location with other liquid waste facilities. Transferring the waste to the 200 Areas would require about twelve 5000-gal truck shipments per day at an estimated cost of about \$600 per day. In addition, an investment of about \$100,000 for trucking facilities would be needed.

Transfer of the entire 100-F operation to the Pacific Northwest Laboratory currently is planned for late in CY-1975. From this location the waste will be contained, collected and transported to the 200 Areas for storage with similar waste.

V.3.2.2. 200 Areas

The primary alternatives to release of liquid waste to the 200 Area ponds are 1) installation of double heat exchange systems in the 200 Area facilities, 2) installation of closed cycle cooling systems with diversion tanks and treatment systems for the water that becomes radioactive, and 3) recirculation or reuse of these streams.

Installation of double heat exchange systems is visualized as the installation of a second heat exchanger in with each heat exchanger

now used. The process heat would flow through the current heat exchanger into an intermediate water stream that would be circulated between the two heat exchangers. The heat would then flow from the intermediate water streams through the second heat exchanger into the cooling water which would flow into the cooling ponds. Any radionuclides that would leak from the process into the intermediate water stream would be detected and diverted into a treatment facility for separation and storage. The radionuclides would not enter the second heat exchanger's water system and, hence, would not be discharged to any cooling or waste water ponds. Water discharge to ponds usually contains no radioactive materials and is suitable for uncontrolled discharge. The discharges to ponds that do contain some low-levels of radioactivity are usually the result of cooling coil failures in the single heat exchanger system. The pressurized water flowing in the cooling coils is effective in preventing nearly all radioactive materials from entering the cooling coil water system. The bulk of the liquid flow is from the pressurized water in the cooling coil into the process vessel.

Installation of double heat exchange systems has been studied for some systems and some cost estimates are available. The high costs developed in those studies are an indication that the cost for installation of such systems in all cooling systems would be in the tens of millions of dollars because many of the current heat exchangers probably would have to be replaced in order to operate properly with the higher cooling water temperatures that would result from use of intermediate heat exchangers.

Installation of closed cycle cooling systems would consist of installing cooling towers or lined ponds for transferring the heat to the air. The tower and ponds would be designed so that no water would enter the ground. If radionuclides leaked through the heat exchangers, the water in the closed system would be diverted to treatment facilities to remove the radionuclides for storage. These systems also would be quite costly

(in millions of dollars) because of the cooling tower or pond costs and the need to replace many heat exchangers to accommodate the higher cooling water temperatures.

Two major alternatives to the present program are being considered: 1) a 5 million dollar effluent treatment plan and 2) a 50 million dollar effluent treatment plan.

V.3.2.2.1 5 Million Dollar Effluent Treatment Plan

This alternative provides for routing B Plant process condensate and Purex ammonia condensate to the 242-A evaporator, and providing accidental release protection at Z Plant. The flow scheme to the evaporator and to the waste disposal sites is detailed in Figure V-1. The concentrations of the major radionuclides of concern and the relationship between the discharge concentrations and the guide discharge limits from AECM 0511 as related to AECM 0524 Table 2 for release to uncontrolled areas are given in Table V-6. Adoption of this alternative would limit yearly releases to soil column (for Purex processing 900 tons/yr of N Reactor fuel) to less than 4 grams of plutonium and to about 60 Ci of mixed fission products. The program could be in place about mid CY-1977. It would result in a reduction of about 9 grams of plutonium and 40 Ci of mixed fission products released to soil columns per year compared to the present program.

This alternative could be operational about 2 years after funding is authorized. There would be no reduction in the essentially zero population dose ($\sim 1 \times 10^{-6}$ man-rem/yr) resulting from the discharge of liquid waste to ponds and cribs.

V.3.2.2.2 50 Million Dollar Effluent Treatment Plan

This alternative requires additional equipment, facilities, and modifications to reduce the amount of radioactive releases to cribs and ponds from the Hanford 200 Area operations by providing capability to monitor, control, or treat all process waste streams and by providing

FIGURE V-1 5 MILLION DOLLAR EFFLUENT TREATMENT ALTERNATIVE

TABLE V-6

PRESENT RELEASES TO CRIBS UNDER CURRENTLY FUNDED PROGRAM

Stream	Flow Rate (gpm)	Isotope of Concern	Normal Conditions	
			Concentration ($\mu\text{Ci/ml}$)	Factor of Guide ⁷
Purex				
Process Condensate	20	^{90}Sr	1×10^{-7}	<1
Steam Condensate	400	^{90}Sr	2×10^{-6}	7
NH ₃ Condensate	35	^{90}Sr	5×10^{-6}	17
B Plant				
Process Condensate	40	^{90}Sr	4×10^{-4}	1300
Steam Condensate	120	^{90}Sr	1×10^{-5}	30
Tank Farms				
242-S Process Condensate	40	^{106}Ru	1×10^{-6}	<0.1
242-A Process Condensate	40	^{106}Ru	1×10^{-6}	<0.1
241-A-AX-AY-AZ				
Process Condensate	10	^{90}Sr	1.8×10^{-5}	60

additional contamination confinement barriers. Radioactivity content of effluents would be reduced to below the guidelines of AECM 0524 for releases to uncontrolled areas.

This alternative would include:

- a multiple-effect evaporator sized for a 500 gallon-per-minute (gpm) boil-off for streams which are potentially acidic
- a multiple-effect evaporator sized for 75 gpm boil-off for streams containing dissolved ammonia
- an evaporator building to house all of the components of the evaporator system and to provide personnel and support facilities
- a 150,000-pound-per-hour addition to the existing 400,000-pound-per-hour steam plant
- a 16,000 gpm cooling tower with basin and circulating pumps
- three 1,000,000-gallon, three 60,000-gallon, nine 500,000-gallon, three 200,000-gallon, and six 100,000-gallon retention basins for control, monitoring, and sampling of process streams before discharge to surface disposal
- closed circuit secondary cooling systems
- contamination confinement barriers
- a low-level laboratory for radiochemistry analysis of process streams
- a central control system for complete supervision of all operations.

This project would 1) reduce the amount of radioactivity released to cribs and ponds from the 200 East and 200 West Area processes, 2) increase capability for monitoring effluents, 3) provide for early warning of increases in radioactivity in the effluents, 4) increase the number of barriers between the process material and the environment, and 5) generally strengthen control of process confinement systems.

The population dose of about 1×10^{-6} man-rem/yr would be reduced. The proposed facilities, integrated with improvements funded in prior years, would provide capability to process, monitor, control, and dispose of process liquid streams which 1) routinely exceed disposal limits, 2) have a high risk potential of exceeding disposal limits, and 3) have a low but credible risk potential of exceeding disposal limits. Additional contamination barriers would be provided to protect the environment from radioactivity during both normal operations and maintenance activities. The low-level laboratory would provide the capacity required to conduct the extensive sampling and monitoring programs essential to total control of low-level radioactivity releases.

The flow scheme for this effluent treatment plan and the waste disposal sites is detailed in Figure V-2. The concentrations of all effluent streams would be below AECM 0524 Table 2 limits for release to uncontrolled areas.

Adoption of this alternative would limit yearly releases to soil columns (for Purex processing 900 ton/yr of N Reactor fuel) to essentially zero for both plutonium and fission products.

FIGURE V-2 50 MILLION DOLLAR EFFLUENT TREATMENT ALTERNATIVE

V.4 GASEOUS EFFLUENTS

V.4.1 Current Program

Gaseous radioactive waste is released to the air at four general locations on the Hanford Reservation as summarized in Table V-7. That table considers each of the production areas on the Reservation as being a single source since each of those areas is far enough from the closest residents that the radioactive gases from the numerous sources in an area are mixed enough to be treated as a single source by the time they reach nearby residents. This approach was used during the calculations of the radiation doses.

Most gaseous waste is treated by passing through one or more high efficient particulate filters. No treatment or delay equipment is used for gaseous waste such as tritium, argon, krypton and similar gases. Iodine is collected on silver reactors to avoid direct release to the atmosphere.

The current treatment facility design and the remoteness of the facilities result in the low radiation doses shown in Table V-7. The incentive for reducing the amount of radionuclides released is the elimination of a maximum of 1.3 man-rem/yr resulting from N Reactor operations.

No sealed containers on the site are used for storing radioactive waste gases either as gases or liquids. The only storage locations for significant quantities of gaseous waste are the charcoal filters in the ventilation systems of the N Reactor. These filters separate iodine and noble gases and retain them long enough to obtain a significant amount of radioactive decay.

The objective of the current program is the reduction of radioactive material release in gaseous effluents to the lowest technically and economically practical levels. Table V-8, summarizes the programs planned and budgeted through FY-1975.

TABLE V-7

GASEOUS RADIOACTIVE WASTE RELEASED TO THE AIR

<u>Location</u>	<u>Composition</u>	<u>Quantity/yr</u>	<u>Summarized Significant Environmental Impact</u>
105-N Ventilation	^{41}Ar , ^3H , ^{131}I , ^{133}I	100,000 Ci	1.3 man-rem/yr
144-F Ventilation Stack	^{239}Pu , ^{90}Sr	<5 μCi	<10 ⁻³ man-rem/yr
200 Areas	Pu, U, f.p.	1.1 Ci	<10 ⁻² man-rem/yr
300 Area	Th, U, Pu, f.p.	<0.02 Ci	<10 ⁻⁴ man-rem/yr

TABLE V-8WASTE MANAGEMENT FACILITIES AND ACTIVITIES
PLANNED AND UNDER CONSTRUCTION FY-1973 THROUGH FY-1975

<u>100 Areas</u>	
N Reactor Ventilation Loop Seal Improvement	\$ 325,000
<u>200 Areas</u>	
B Plant Vent System Ventilation Improvements	70,000
242-T Evaporator Effluent Improvements	200,000
Exhaust Ventilation Improvements- 222-S Laboratory - Purex	445,000
Waste Management Effluent Control	2,875,000
<u>300 Areas</u>	
Laboratory Ventilations Exhaust Addition - 325 Building	<u>485,000</u>
Total	\$4,400,000

A summary description of each of these programs is provided in Table V-9.

TABLE V-9

DESCRIPTION OF WASTE MANAGEMENT FACILITIES
AND ACTIVITIES PLANNED AND UNDER
CONSTRUCTION FY-1973 THROUGH FY-1975

100 Area

N Reactor Ventilation Loop Seal Improvement \$325,000

A redundant confinement valving system will be installed in the N Reactor building ventilation system to provide positive reliable secondary closures in the vent openings and thus assure containment of vapors and gases which would only be generated under unlikely conditions.

200 Areas

B Plant Gallery and Vessel Vent System Ventilation Improvements \$70,000

This project will provide new ventilation exhaust fans and single-stage, high-efficiency filters for the ventilation exhaust from the B Plant operating, pipe and electrical galleries and sampling facilities for the filtered vessel vent exhaust.

These additions will reduce the potential risk of releasing radioactive materials from the operating areas to the environment. The vessel vent exhaust sampling system will provide for detecting filter failure. The gallery ventilation filters will protect the environment from potential release of contamination from the operating areas.

242-T Evaporator Effluent Improvements \$200,000

In order to reduce the risk of releasing radioactive materials to the environment, the project provides the 242-T Building process cells (feed, evaporator, and condensate) with filtered supply and exhaust ventilation systems consisting of 1) supply air: preheater, two stages of roughing filters, and ductwork, and associated service piping, instrumentation and controls; and 2) exhaust air: preheater, prefilter, parallel two-stage, high-efficiency particulate air (HEPA) filters, parallel exhaust fans, stack, ductwork and associated service piping, instrumentation and controls.

Exhaust Ventilation Improvements 222-S Laboratory - Purex \$445,000

A new bank of HEPA filters will be installed in a new enclosure to further protect the environment by providing additional filtration of the exhaust air ventilation from contaminated and potentially contaminated zones of the 222-S Laboratory Building. New ductwork, fans, stack and accessories will also be provided.

TABLE V-9

(continued)

200 Areas (continued)

<u>Waste Management Effluent Control</u>	\$2,875,000
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This project provides facilities to maintain and to extend protection against the accidental release of radioactivity in certain effluent streams from the Waste Fractionization Facility (B Plant) and the Chemical Processing Facility (Purex Plant). The facilities include: 1) a replacement ventilation filter for B Plant, including an underground concrete filter cell equipped with replaceable prefilters and two stages of HEPA filter banks and a corrugated metal instrument building above the cell; 2) improvements, including prefilters and HEPA filters for treating ventilation air from the sample gallery, and the organic treatment and acid fractionization cells of the Purex Plant; and 3) replacement of Purex canyon ventilation air filter design for a flow rate of 125,000 cubic feet per minute and consisting of a prefilter and secondary high-efficiency filters in a concrete cell with a corrugated metal instrument building above the cell.

300 Areas

<u>Laboratory Ventilation Exhaust Addition, 325 Building</u>	\$485,000
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The 325 Building Laboratory will be provided with new local exhaust filter plenums containing HEPA filters, fire detection sensors and fire suppression equipment, thus adding a second stage of filtration to the existing single stage system. Improved reliability will result and the potential for release of radioactivity via the ventilation system will be correspondingly reduced.

V.4.2 Gaseous Waste Treatment Alternatives

In addition to the facilities and activities planned and under construction for FY-1973 through FY-1975, several alternatives exist. The alternatives to release of the gaseous waste are to 1) install additional filters to remove particulates, 2) install additional chemical scrubbers to remove reactive gaseous radioisotopes such as iodine, and 3) add cryogenic systems for removing nonreactive gaseous radioisotopes such as xenon and krypton. Diversion of some exhaust air through existing, more effective systems also may be possible.

Selection of the optimum amount of gas treatment facilities requires a balance of: 1) the costs for installing and operating the treatment facilities, and 2) the effect of those gases on the general population. The cost of existing gas treatment facilities on the Hanford site is quite high because of the large volume of ventilation air (over 10^{12} ft³/yr) that is handled and because the treatment facilities are designed to assure a low radiation dose to the general public. The remoteness of the 100 and 200 Areas also results in significant dilution of the gases and settling of particulate material before it leaves the site.

Reduction of the ⁴¹Ar releases from N Reactor has not been studied in detail and a cost estimate for the necessary plant modifications has not been made. The cost probably would be in the tens of millions of dollars because of the difficulty of removing a dilute noble gas from a large air stream. A cryogenic separation system requiring refrigeration of a large fraction of the ventilation air probably would be necessary. The high cost has not appeared justified by the resultant small reduction in radiation dose to the general public (a maximum reduction of 1.3 man-rem/yr).

Gaseous radionuclides (e.g., ³H, ⁸⁵Kr, ¹²⁹I, ¹³¹I) released during fuel element dissolution operations are discharged from the main Purex Plant stack. Radioiodine (¹²⁹I and ¹³¹I) can be removed as necessary from dissolver off-gases by use of a silver reactor, which is capable of removing 99.95% of the radioiodine present. Much of the radioiodine escaping the silver reactors is trapped in the acid recovery system and retained. Fuel elements presently scheduled for dissolution and processing in the Purex Plant will have been discharged from the reactor at least 6 months prior to dissolution. With an 8-day half-life, essentially all ¹³¹I will have decayed away by the start of processing.

During dissolution of these fuels, emission of ¹²⁹I can be controlled at concentrations well below allowable limits for release to uncontrolled areas, even if silver reactors are not regenerated or

efficiencies are well below 99.95%. Regeneration of silver reactors is a routine operational alternative immediately available if needed. Alternatives for off-gas treatment which have been used elsewhere in the nuclear industry for iodine include caustic scrubbers, charcoal absorbers, gas collection and storage. Based on Purex iodine release data, these would neither be needed nor justified from standpoints of high cost and the small impact of current operation, <0.01 man-rem/yr total-body dose and about 0.5 man-rem/yr thyroid dose. The most effective alternative is that of storing the fuels until the 8-day half-life ^{131}I has decayed away before processing is begun.

Currently, Purex has no capability for removing tritium (^3H) or krypton (^{85}Kr) from the dissolver off-gas waste stream. Approximately 5% of the tritium content of the fuel elements is discharged to the atmosphere via the dissolver off-gases. This means that at the maximum tritium content of the fuel elements dissolved at the maximum conceivable rate, approximately 10 Ci/day of tritium would be discharged to the atmosphere via the 200-ft tall Purex main stack. This would result in an average concentration in the offsite atmosphere of 3×10^{-12} $\mu\text{Ci/ml}$, which is a factor of more than 65,000 below the AECM 0524⁷ guide concentration of tritium for release to uncontrolled areas (2×10^{-7} $\mu\text{Ci/ml}$).

At the maximum krypton content of the fuel elements dissolved at the maximum achievable dissolution rate, approximately 8400 Ci/day of krypton would be discharged to the atmosphere via the 200-ft tall Purex main stack, resulting in an average krypton concentration of 4×10^{-9} $\mu\text{Ci/ml}$ in the offsite atmosphere. The guide concentration limit for uncontrolled areas in AECM 0524⁷ is 3×10^{-7} $\mu\text{Ci/ml}$.

Alternatives such as cryogenic gas recovery, selective absorption and membrane separation, could possibly be adapted for Purex use in the collection and retention of the noble gases. However, these would be very expensive (probably greater than 10 million dollars) and would take from

3 to 5 years to design and install. Recovery efficiencies for krypton would probably range from 90 to 99%, depending on the process, thus giving offsite atmospheric concentrations from 4×10^{-10} to 4×10^{-11} $\mu\text{Ci/ml}$, compared to the guide concentration 3×10^{-7} $\mu\text{Ci/ml}$.

V.5 SOLID RADIOACTIVE WASTE

V.5.1 Current Practice

Solid radioactive waste is placed into the ground at several locations in the 200 Areas from sources described in Table V-10. This waste is a miscellaneous mixture of solid materials ranging from floor sweepings to contaminated equipment and contains all ranges of radioactivity from essentially none to induced activity from reactor neutron irradiation.

Beta-gamma contaminated solids are packaged, sealed and buried in shallow trenches. The transuranics are segregated in special sealed containers to be retrievable contamination-free for 20 years and buried in controlled facilities. Large items of process equipment, too radioactive and too bulky for either transfer to 200 West Area (for decontamination) or burial, go into the railroad tunnel. Continued emphasis will be placed on reducing the amount of contaminated waste generated, and on packing more waste into each burial package to reduce the amount of trench usage needed.

V.5.2 Solid Waste Treatment Alternatives

Several alternatives relating to disposal of solid waste have been studied.

Compaction

Compaction of solid waste could reduce the total volume of the initial package. Compaction would not reduce, of course, the total radionuclides to be disposed of, and the corresponding reduction in the size of burial grounds would not appear to justify the cost of compaction units in view of the lack of environmental impact of current waste burial practices.

TABLE V-10

SOLID RADIOACTIVE WASTE RELEASES TO THE GROUND

Location	Composition	Quantity		Current Disposition Location	Primary Environmental Impacts
		Currently Stored (ft ³)	Future Storage (ft ³ /yr)		
100 Areas	Miscellaneous Solid Waste	(a)	40,000	200 Areas	Total of 4 acres land use/yr; essentially zero population dose ↓
200 Areas	Miscellaneous Solid Waste	5.5×10^6	93,000	200 Areas	
300 Area	Miscellaneous Solid Waste from fuel element manufacturing containing uranium and thorium and from research and development	7.5×10^5	56,000	200 Areas	
600 Area	Miscellaneous Solid Waste	(a)	0	200 Areas	

(a) Volume not known

Storage in Deactivated Plants

Deactivated plants could be converted to waste storage "vaults." Modification of old plants to provide fire protection, ventilation and monitoring would be required and would probably cost many millions of dollars. The benefit would be a reduction of the commitment of additional land for storing solid waste. No changes in population dose would result.

Sorting and Classifying

A sorting and classification system for solid waste handling would develop instrumentation to nondestructively analyze the contents of packaged solid waste to assist in sorting. Identification and measurement of the radioactive content of waste is essential before determining its disposition. The measurements would determine whether the package could be treated as fission product-contaminated waste or would have to be handled as transuranic element-contaminated waste (alpha waste).

A centralized data reduction system has been developed, the Automatic Radioactive Inventory System (ARIS), which can identify 34 nuclides from one spectrum. Further efforts would be needed to develop the satellite package counting system and the in-plant measurement system using the central data reduction equipment. The satellite counting equipment would have to function under a wide variety of plant conditions. An estimated \$400,000 would be needed to provide in-plant capability of sorting according to type of scrap or waste and level of radioactivity. If adopted, use of this nondestructive assay equipment would probably start in Z plant about 2 years after funding was available. The equipment would provide good segregation of transuranic waste from fission product waste.

Transuranic Waste Storage

Pad storage for transuranic waste retrievable burial is currently being tested. This alternative provides protection of the metal containers from contact with the soil and allows sampling of the storage facility

atmosphere for radioactivity and combustible gases, either of which would indicate container failure. Final evaluation of a retrievable burial system is expected in FY-1975 with routine use of the selected concept to follow.

The alternatives to storage of transuranic waste in V trenches, transuranic storage slabs, and caissons are 1) to store the waste in burial trenches or 2) to treat it to remove transuranics and then store the residual. Storage in burial trenches is not desirable because retrieval of the waste is difficult and costly. Such a practice would not maintain positive containment control for transuranics as does the current program.

Treating the waste to remove the transuranics generally would be quite costly because of the low concentrations of those radionuclides and because in some cases the waste already is being treated to remove as much of the transuranics as can be removed without excessive costs.

Equipment Reclamation

An equipment reclamation alternative would involve the recovery, i.e., the cleaning and repairing, of all contaminated process equipment for reuse, thus eliminating the need for burial. This type of work is current practice, but it is neither technologically nor economically feasible to recover all such equipment since, in many cases, costs in time, chemicals and radiation dose to employees would far exceed the value of the equipment and the costs of burial. Such extra cleanup would also produce significantly larger volumes of liquid waste to be disposed of.

Equipment Disposal

An equipment disposal alternative would involve one or more methods of consolidating large, bulky items, such as process equipment, hoods, structural members, etc., into forms which could be readily dealt with. Items could be cut, melted, burned, disassembled, compacted, or they

could be completely converted to liquid waste which could then be handled as part of the existing liquid waste inventory.

Currently, large items of failed equipment are placed in concrete boxes and buried. This volume would be expected to increase significantly under the long-range facilities decommissioning program. A study is under way to establish the technologies for converting the large items to consolidated forms and determine subsequent treatments. Cost estimates and schedules for possible alternatives have not been made.

Wet Oxidation

Two wet oxidation alternatives to incineration for waste volume reduction are being studied: 1) a wet oxidation process for disposing of spent solvent, solid waste and scrap, and 2) the sulfuric acid oxidation process. The goal of this development effort is to provide a plutonium-bearing oxidation product (ash). If this technology is attained, design of the proposed solid waste incinerator would be based on one of the above oxidation processes.

Burial Ground Selection

Evaluation of solid waste burial alternatives for long-term versus short-term burials may be considered. The study would be conducted over a 3-year period (FY-1975 to FY-1979) at a cost of \$500,000. Criteria for long-term burial would be developed and existing burial sites would be evaluated using these criteria. The evaluations would be expected to determine which burial grounds need stabilization, which need relocation, and which potential new sites would be acceptable for long-term storage.

An additional 3-year study to develop the technology for acceptably relocating burial grounds has been proposed for FY-1977 to FY-1979 at a cost of \$300,000. Should relocation of a burial ground be judged necessary, the technology or equipment would probably not be available prior to FY-1980.

Conclusions

Radioactive solid waste burials in the dry soil of the 200 East and 200 West Area plateau do not and are not expected to have an offsite environmental impact. Alternatives to present practices are being studied to determine a practical plan for long-term treatment, disposal and surveillance of this solid radioactive waste.

V.6 NONRADIOACTIVE WASTE

V.6.1 Chemical Releases to the Columbia River

Chemicals are released to the Columbia River in significant quantities at three locations: 1) the 100-N Area, 2) the 100-K Area, and 3) the 300 Area. The quantities of chemicals released are shown in Table V-11. The current primary source of chemicals released to the river is the 100-N Reactor operations. In addition to these chemicals, the impurities removed from the river by the water treatment plants also are returned to the river. The effect of returning those impurities to the river can be considered to be negligible because essentially all of the purified water is returned to the river either in process sewers or as groundwater. As a result, the average chemical content of the river is essentially unchanged.

The alternatives to release of the chemicals to the river are 1) evaporation of the water to dryness and storage or reuse of the chemicals, and 2) release of the waste streams to ponds in which part of the chemicals would remain as a precipitate in the bottom of the ponds or be absorbed on the soil column below the pond surface. The disadvantages of these alternatives are the additional cost and the solid waste disposal problem, which requires use of additional land. Such releases might also have an adverse effect on the water table.

Because the current practice of releasing the chemicals to the river has no detectable environmental impact, adoption of more costly land disposal does not appear justified.

TABLE V-11

CHEMICAL RELEASES TO THE COLUMBIA RIVER

Materials	Quantity Discharged per Year (lb)			
	100-K	100-N	300 Area	Total
Aluminum sulfate,	17,500	337,000		
Chlorine,	4,000	28,000		
Polyacrylamide,	100	900	not	
Sodium Dichromate,	0	200		
Sulfuric Acid,	0	1,410,000	measured	
Ammonium Hydroxide,	0	266,000		
Hydrazine,	0	14,000		
Morpholine,	0	2,800		
Sodium Hydroxide,	0	463,000		
Total, lb	21,600	2,521,900	~960,000 ^(a)	3,500,000

or

1,750 ton/yr

Quantity of dissolved solids in Columbia River = 13,000,000 tons/year.

(a) Assuming that all materials entering process pond eventually enter the river.

V.6.2 Chemical Releases to the Land

This category of waste includes only those chemicals released in liquid streams. Solid chemicals placed in sanitary land fills and specific burial trenches are included below in the discussion of nonradioactive solids released to land.

Chemicals are released to the land at several locations. The primary release points are summarized in Table V-12.

The primary reasons for release of chemicals to land are 1) to reduce pollution of the Columbia River and 2) to minimize the disposal cost of these chemicals. Because of the highly absorptive characteristics of the Hanford soils, the chemicals are generally retained in the ground above the water table and do not enter the water table or eventually the Columbia River. It should be noted in evaluation of chemical releases to the land that part of those chemicals do not actually enter the land. In some cases, the chemicals remain in the disposal pond either dissolved in the liquid in the pond or as a layer on the bottom of the pond.

The primary alternatives to release of these chemicals to the land are 1) release to the Columbia River and 2) separation of the chemicals from the liquid streams and storage in sealed containers. Release to the river is not desirable because of the additional pollutant burden to the river.

Separation of the chemicals from the liquid streams probably would require large, costly evaporation plants or ponds. Many of the chemicals are highly soluble and cannot be readily removed by chemical treatment or ion-exchange processes. Detailed analysis of use of separation systems has not been made because of the low incentive for using such systems. The primary impact from ground disposal is the use of desert land for disposal ponds and ditches. This impact results in an insignificant loss of desert land in the western states. In particular,

most releases to the land are into ponds and cribs, which also contain radionuclides. The additional impact due to the chemicals can be considered to be negligible.

TABLE V-12

CHEMICAL RELEASES TO THE LAND

<u>Project Region</u>	<u>Release Location</u>	<u>Primary Constituents</u>	<u>Annual Releases (Tons)</u>
100-N	1301-N Crib	Calcium Magnesium Ammonia Sulfate	120
200 Areas	Cribs and Ponds	Salt Aluminum Sulfate	330
300 Area	Process Ponds	Chlorine Nitrates Sulphates	480

V.6.3 Chemicals Released to the Air

The three primary sources of chemical releases to the air are: 1) gases in fossil fuel plant exhaust gases, 2) gases in process stacks, and 3) gases in laboratory and experimental facility exhaust streams. A summary of the major annual releases is presented in Table V-13.

At present, no standards for release of nitrogen oxide from individual plants have been established. Discussion of alternatives does not appear justified because no adverse environmental impact is apparent for releases of nitrogen oxide in the sparsely populated Hanford region.

Sulfur dioxide released from all power plants is below the current standard of 2000 ppm SO₂ in the stack gas. As shown on Table V-13, the releases from the coal and oil-fired power plants are at about 25 and 40%, respectively, of the standards. When the standard decreases to

TABLE V-13

MAJOR CHEMICAL RELEASES TO THE AIR IN 1972

Chemical	Project Region	Release Source	Fuel Type	Annual Release (tons)	Percent of Standard (a)	
					Current	7/1/75
NO _x	100-N	Power Plant	#6 Oil	172	N.S.	N.S.
	200-E	Power Plant	Coal	428	N.S.	N.S.
	200-W	Power Plant	Coal	260	N.S.	N.S.
	300 Area	Power Plant	Coal	210	N.S.	N.S.
			#6 Oil		N.S.	N.S.
		333 Building	...	14	N.S.	N.S.
	100-D,F,K, and 200-E	Package Steam Plants	#2 Oil	29	N.S.	N.S.
			TOTAL	1113		
SO ₂	100-N	Power Plant	#6 Oil	1002	40 to 50	80 to 100
	200-E	Power Plant	Coal	6500	25	50
	200-W	Power Plant	Coal	3990	25	50
	300 Area	Power Plant	Coal	120	25	50
			#6 Oil	269	20 to 40	40 to 80
	100-D,F,K, and 200-E	Package Steam Plants	#2 Oil	10	~10	~20
			TOTAL	2450		

(a) N.S. means no standard. SO₂ standard is 2000 ppm until 6/30/75, and 1000 ppm thereafter.

1000 ppm in 1975, these releases still are expected to be within the standards. The releases from the package steam plants currently are at about 10% of the standards because of the low sulfur content (0.2%) in the light fuel oil used in those plants.

Since the sulfur dioxide releases are well within standards and probably will remain within the future lower standards, detailed discussion of alternatives does not appear justified. All of the normal alternatives, namely 1) conversion to oil with a lower sulfur content, 2) conversion to natural gas, or 3) installation of sulfur dioxide removal equipment, result in higher costs. Use of other oils or natural gas is undesirable because of the current shortage of petroleum and natural gas. Since the current SO_2 and NO_x releases from the Hanford power plants have no apparent adverse environmental impact on the surrounding vegetation or life forms, no apparent incentive exists for expenditures to reduce the release rates.

Currently, obtaining heavy fuel oil with less than the desirable maximum of 1.5% sulfur is difficult. Because of the current petroleum shortage, some recent shipments have had sulfur contents as high as 1.8% sulfur. Although these high sulfur contents do not cause operation above the current standards, they may make operation within the 1000 ppm standard difficult after July 1, 1975.

V.6.4 Chemical Waste Stored in Special Repositories

At Hanford, significant quantities of waste chemicals are stored in the radioactive waste storage tanks in the 200 Area.

The chemicals in the 200 Area storage tanks are primarily fuel reprocessing chemicals in the radioactive waste streams from the 200 Area operations. Also included are any chemicals from 100 Area and 300 Area operations and from research and development activities that accompanied radioactive waste sent to the 200 Area for storage. These chemicals were not separated from the radioactive waste because the separation

and subsequent storage or disposal costs were larger than the extra cost for storage with the radioactive waste.

The typical composition of these chemicals is common sodium salts, because sodium is the primary cation or metallic constituent of the process chemicals. The other metallic components generally are fission products or corrosion products from the process equipment.

No acceptable alternatives to the storage of the chemicals in the 200 Area waste tanks are known. Waste tank storage provides isolation from the environment while control measures to assure radionuclide containment also provide chemical containment. The alternatives discussed earlier to improve radionuclide containment would also improve chemical containment.

The 100-H Area storage basins are to be used for interim storage of process chemicals from the 300 Area fuel fabrication facilities. While the waste is stored in these basins, the water will evaporate producing a sludge which could subsequently be processed to recover the uranium and copper.

The alternatives to this storage are to either release the material to waste ponds or install evaporators or other processing equipment to concentrate the solutions more rapidly before recovering the uranium and copper. Release to ponds would result in creation of additional undesirable release of radioactivity to the environment and loss of the uranium and copper values. Installation of concentration equipment would increase the cost of the uranium and copper recovery, probably enough to make the recovery uneconomical.

The primary environmental impacts that might result from storing these chemicals in the 100-H Area would be from spills of the chemicals during transportation and leakage out of the basins. Entry of the chemicals into the environment in these manners is not considered a significant impact because these chemicals have innocuous effects and can be easily cleaned up.

V.6.5 Sanitary Waste

Sanitary waste is created throughout the Reservation wherever there are facilities occupied by personnel more than a few minutes at a time. Two methods are used for disposing of this waste: 1) septic tank systems, and 2) chemical toilets. The material in the chemical toilets is disposed of periodically in the septic tank system. A summary of the locations and amount of waste handled in the septic tank systems is presented in Table V-14.

Septic tank systems operate quite satisfactorily. The arid climate and porous ground result in satisfactory drainage without surfacing of the waste because of ground saturation or plugging. Proper design of the tile fields results in ample disinfection before the liquids enter the water table and eventually the Columbia River. Much of the liquid does not enter the water table because the moisture in the ground at the shallow depths of the leach lines moves toward the surface due to evaporation and evapotranspiration.

The normal alternatives to septic tanks are connection to a municipal sewage system or installation of an extended aeration system. Connection to a municipal system would be quite expensive for most of the Reservation because of the long distance (up to 40 miles) to the nearest municipal system at Richland. This alternative might be feasible for the 300 Area, although even then the distance to the Richland sewer plant is about 7 miles.

In the extended aeration process, raw sewage continuously flows into an aeration tank where it is continuously air sparged to provide oxygen for the biological degradation of the organic components of the waste. The aeration tank is sized to provide approximately a 24 hour retention time for the sewage. The contents of the aeration tank continuously overflow into a settling tank that provides a minimum of 4 hours retention time. The scum and settled solids are returned to the aeration tank for further treatment, while the

clarified effluent flows into a chlorine contactor for chlorination to kill any remaining pathogenic bacteria prior to release to the environment. Periodically, the excess sludge is removed to a landfill site.

TABLE V-14

SANITARY WASTE FLOWS TO SEPTIC TANKS

<u>Project Region</u>	<u>Gallons Per Day</u>
100 B	180
100 D	2,400
100 F	2,700
100 K	2,700
100 H	0
100 N	22,500
200 E }	99,000
200 W }	
300 Area	491,000
Other (a)	<u>9,000</u>
TOTAL	692,000 (a)
	= 440 gpm

(a) Does not include 60,000 GPD at the FFTF site or 10,000 GPD at the WPPSS Hanford generating station.

Evidence indicates that the current septic tank systems are operating satisfactorily and in accordance with the state of Washington sanitation regulations. Hence, no apparent justification exists for the extra expenditures for either of the alternatives.

V.6.6 Nonradioactive Solids Released to the Land

Large quantities of normal industrial trash and used equipment are generated on the Reservation. Materials of value, such as relatively pure metals and excess equipment, are sent to salvage yards, sorted and sold. The other materials are collected, compacted and transported to a central landfill site to be buried. The total volume of this waste is about 360,000 ft³/yr requiring about 2 1/2 acres of land/yr.

The alternatives to disposal in the central landfill site are 1) disposal at scattered landfill sites, and 2) greater compaction and/or incineration prior to disposal in order to reduce the volume and noxious nature of the waste.

Disposal, with burning, at scattered landfill sites was the standard practice until 1972. Burning was stopped in accordance with an executive order. The current procedure of disposing of all material at one central landfill location was adopted in 1972 because a study of the costs for the various methods for waste disposal showed that transportation of all waste to one central site by use of a modern compactor truck would cost less than the existing system, and a landfill operation would cost much less than incineration.⁸

The waste is not compacted to greater density or incinerated because 1) ample land is available for disposal, 2) a considerable amount of compaction occurs at present during collection and covering of the waste, 3) degradation of the waste probably occurs more rapidly if it is not compacted to a greater amount, and 4) installation plus operation of incinerators designed in accordance with current air pollution regulations is more costly than the current practice.

V.6.7 Other Environmental Pollutants

The other environmental pollutants for which alternatives might need to be considered are heat, odor, and noise.

V.6.7.1 Heat to the Columbia River

The one significant source of heat releases to the Columbia River is the N Reactor operations. All other heat releases to the river are much smaller and contain only about 1% of the total releases to the river. The total heat input is about 470 megawatts.

At the minimum permissible river flow rate of 36,000 cfs, the routine release rate of about 500 MW increases the average river temperature by only 0.25°F. At the average river flow rate of 120,000 cfs, the average increase in river temperature is only about 0.08°F.

The primary alternatives to the current release of heat to the river are 1) installation of an open-cycle cooling system utilizing a cooling tower or lake for dissipating part of the heat to the atmosphere before the water is released to the river, or 2) installation of a closed-cycle cooling system using a cooling tower or pond. Although these alternatives have not been studied for the N Reactor, experience with other power reactors can be used to illustrate the costs.

The four most common designs for cooling towers and lakes are 1) mechanical draft towers, 2) natural draft towers, 3) large quiescent ponds and 4) spray ponds. Natural draft towers are not technically feasible at Hanford because an adequate draft does not occur during periods of low relative humidity. Data developed during investigations of cooling systems for the proposed adjacent WPPSS power reactor indicate that the installation costs for WPPSS would be from 20 to 30 million dollars. Since the cooling water flow at N Reactor is only about 40% of the flow for the proposed plant, such a cooling system for N Reactor probably would cost between 11 and 17 million dollars.

Since the effect of the N Reactor heat releases on the Columbia River are considered insignificant (Section III.1), installation of a cooling tower or pond to eliminate these releases to the Columbia River cannot be justified.

V.6.7.2 Heat Released to Land

Heat is released to land whenever a water stream flows into a pond or a well or through a buried pipeline at a temperature higher than the temperature of the ground. It also may flow into the ground from buildings, tanks, and other facilities which are at a higher temperature than the ground.

Flow of heat into the ground is of concern from an environmental standpoint only if the higher ground temperatures create a measurable change in habitat condition for plants or animals. Excessive temperatures can sterilize the ground or dehydrate it, making plant survival difficult.

All heat releases to the ground at Hanford are at relatively low temperatures and have no apparent effect on the vegetation or aquatic life. Therefore, discussion of alternatives does not appear justified.

V.6.7.3 Heat Released to the Air

Heat is released to the air primarily from cooling ponds, process facilities, and buildings. The primary effects on the environment are climatic through creation of heat islands and occasional local fogging.

The four primary sources of heat releases to the air at Hanford are 1) combustion of fossil fuels, 2) consumption of electricity, 3) decay of radionuclides, and 4) release of heat from N Reactor to the Columbia River. The heat released to the river eventually is transferred to the air at downstream locations.

The total quantity of heat released directly to the air at Hanford is estimated in Table V-15.

TABLE V-15

TYPICAL HEAT RELEASES TO THE AIR AT HANFORD (1972)

<u>Source of Heat</u>	<u>Annual Quantity</u>	<u>Average Heat Generation (MW)</u>	<u>Heat Content (Btu/yr)</u>
Fossil Fuels			
Coal	103,000 tons	93	2.8×10^{12}
Oil	12,740,000 gallons	63	1.9×10^{12}
Electricity	3.2×10^8 kW-hr	37	1.1×10^{12}
Radionuclides	$\sim 3.0 \times 10^7$ kW-hr	<u>~4</u>	<u>1.2×10^{11}</u>
TOTAL		197	5.9×10^{12}

Because of the large area of the Reservation and the wide dispersion of these heat releases, a significant climatic effect has not been observed. A small increase in local fog probably occurs in the vicinity of the 200 Area cooling ponds and the Columbia River during the winter months, but this fog has an insignificant effect on the general public. The only location where this fog might affect the public is on Highway 240, which passes about one mile from the S-17 pond. An analysis of automobile accidents on Highway 240 between the Yakima Barricade and the Prosser Barricade roads reveals that none of the 68 accidents from January 1, 1967, to September 30, 1973, occurred during fog conditions.

V.6.7.4 Odors

No odor sources are on the Reservation that are noticeable at the boundaries. All of the chemicals used in large quantities either are odorless or are contained such that the odors are not noticeable except in the immediate vicinity.

V.6.7.5 Noise

No noise sources are on the Reservation that create a noticeable increase in noise levels at the boundaries in comparison to a normal urban environment. The only noticeable noises usually are traffic noises due to trucks, trains, and automobiles. No construction activities are scheduled at locations close enough to the boundaries to cause a significant impact.

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VI RELATIONSHIP BETWEEN LOCAL SHORT-TERM USES OF MAN'S ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

VI.1 BACKGROUND

Continued waste management operations according to present AEC policies and standards will protect the offsite environment and will contaminate a small fraction of the onsite environment for the long-term. Hanford Waste Management Operations to date have resulted in the establishment of certain areas on the Hanford site for continued use in waste disposal or storage. Additional areas of contamination will be small compared to those well-defined areas that are already contaminated from past waste management operations.

The areas that contain radioactive materials will remain contaminated for the foreseeable future even after operations cease. Most of the Reservation and all of the land, water, and air surrounding the plant are protected for possible long-term uses because the waste disposal and storage sites are few in number and are centrally located.

Large portions of the land on the Hanford site are being put to other productive uses:

- Arid Land Ecology Reserve
- Washington State Game Reserve
- Commercial Nuclear Power Plants
- Research and Development Facilities for Energy.

The changes within the dedicated portion of the Reservation are both slight and major. Installations of fences, telephone lines, and transmission lines are regarded as slight changes wherein construction effects were minor. The longer-term effects occurred only on the small

portions of the rights-of-way actually occupied by the present structures that, in most cases, could be removed at moderate cost, allowing the land to revert naturally over a decade or two to its original state. Major changes include the erection of massive concrete buildings and, as a part of waste management operations, the installation of underground storage tanks and the discharge of radioactive materials to the ground. Restoration of the land thus occupied to its original condition would be extremely expensive and, for some portions, practically impossible. Intermediate changes over the past 30 years include the erection of buildings, the construction of paved roads (about 0.5% of the Reservation), and the laying of road beds for rail traffic (about 0.25% of the Reservation).

To place in perspective the changes on the 30 square miles of Reservation land requires a summary view of the use of Reservation land prior to 1942. Historically, the unmodified steppe ecosystem provided little food to man (although the Columbia River was an important food source). A minor but significant part of the Reservation was altered by irrigation, yielding agriculturally productive land, particularly near the river.

Considering all effects on man's environment, a small positive long-term effect is forecasted for the productivity of man's environment. Primarily the direct effects, while occasionally adverse, are not large. The total human population radiological dose from Hanford Waste Management Operations Program is only about 0.01% of the natural background dose sustained by the same population. The figure will drop substantially when N Reactor operations are completed. The loss of habitat for wildlife is not expected to be significant for a long time, if ever, in view of the preponderance of similar habitat on the Reservation and on adjacent lands. Man-made fires make an insignificant impact. Although metals and fluoride may to a small degree be incorporated by some waterfowl, no serious threat is made to higher terrestrial biota. Some

biological uptake and dispersion of radioactive materials occur in waste management zones, but only at a low level. The release of small amounts of radioactive materials to the open terrestrial environment does not manifest an obvious impact on local biota.

Life in the Columbia River sustains no significant effects due to the discharge of heat. Impingement losses at the various intakes are small; no significant entrainment losses occur. Springs draining into the river at 100-N and 300 Area contain some chemicals. Aquatic populations in the river sustain no observed deleterious effects caused by Hanford radioactive effluents. The extent of genetic effects, if any, is unknown. Aquatic biota existing in other surface waters such as ditches and ponds are unlikely to involve offsite ecosystems in any important way. Consumptive use of Columbia River water is inconsequential at 550 cfs, about 0.4% of the average flow rate. The quantity of groundwater withdrawal is inconsequential in view of the total supply.

VI.2 EFFECTS OF PROPOSED ACTIONS

Future plans for the Hanford Reservation call for the continuation of its present use as an area dedicated primarily to nuclear energy activities. Thus, the use of man's environment will be long-term; there will be no short-term use. The relationship to be considered is that of long-term productivity of the environment.

Current use of the land has probably barred major irrigation projects from the Reservation because of their potential impact on the water table levels. Also, an inventory of mostly tritium and $^{106}\text{Ru-Rh}$ will remain in the groundwater under the Reservation and fission products in the soil columns under cribs, trenches and ponds for many centuries.

In the future, additional Reservation land may be dedicated to nuclear energy activities. On the other hand, some current activities will cease, therefore encroaching no further on man's environment. The direct net effect will probably be a slightly increased encroachment upon man's environment.

Assuming that the primary activities on the Reservation do meet their objective of benefiting man's social-economic environment, the Waste Management Operations program will continue to be of benefit by reducing substantially the potentially inimical environmental effects that would result from unprogrammed releases of waste materials to man's environment.

VII RELATIONSHIP OF PROPOSED ACTION TO LAND USE PLANS, POLICIES, AND CONTROLS

The continued operation of the Hanford waste management facilities will not conflict with national, state, or local plans and programs. Implementation of the action proposed herein, i.e., a continuation of effluent and waste management practices at Hanford, calls for land use as described in Sections II and III. All land is and will be managed consistently with federal regulations to assure the safety and well-being of the public. Specifically, as paraphrased from Wash. 1202(73), "Plan for Management of AEC-Generated Radioactive Wastes," and applicable to land use:

- Operate in such a manner as to ensure radiation exposures do not exceed established standards.
- Continue to reduce the amount of radioactivity released to the environment to the lowest level below established standards that is technically and economically practical.
- Continue to minimize radioactive contamination of real property and facilities for the purposes of protecting public health and safety.
- Discontinue the use of natural soil columns for storing intermediate-level waste as soon as technically and economically practical.
- Maintain records of locations of radioactive burial sites and the amount of radioactivity contained at each site.

Site use dictates the type of control necessary to ensure the safety and well-being of the public. Access to radioactive waste storage areas, for example, will be controlled. Standards and requirements for the management of radioactive waste at Hanford are set forth in AEC Manual Chapter 0510 "Prevention, Control, and Abatement of Air and Water Pollution," AEC Manual Chapter 0511 "Radioactive Waste Management,"

AEC Manual Chapter 0513 "Effluent and Environmental Monitoring and Reporting," and AEC Manual Chapter 0524 "Standards for Radiation Protection."

Continued land use in addition to effluent and waste management on the Hanford Reservation includes 1) research and development associated with the Arid Land Ecology (ALE) Program, and various laboratory facilities in the 100, 200, and 300 Areas, 2) N Reactor and plutonium production facilities in the 200 Areas, and 3) the Fast Flux Test Facility. Some land north of the Columbia River will continue to be administered by the U.S. Bureau of Sport Fisheries and Wildlife, the U.S. Bureau of Reclamation, and the Washington State Department of Game. The State of Washington leases land on the 200 Area plateau for radioactive waste burial. Private leases of land include the Washington Public Power Supply System (WPPSS) steam plant operating at 100-N Area and the WPPSS Power Reactor now under construction.

Many future uses of Hanford Reservation land have been suggested, but no definite plans exist. Some of the suggested projects include a nuclear energy park, Liquid Metal Fast Breeder Reactor demonstration facility, waste handling and storage facilities for public power reactors, a uranium enrichment facility, Ben Franklin Dam, Columbia River navigation upstream to Wenatchee, and irrigated farmland. Although the proposed construction of Ben Franklin Dam received attention, the Corps of Engineers stated that completion of feasibility studies were delayed pending further consideration of environmental matters. A date for completion of the studies was not set, nor was a decision made as to whether or not the Corps will recommend authorization and construction of the project.

The potential environmental consequences and relationships of all specific proposed projects to the Hanford Effluent and Waste Management Operations Program are studied and considered. Environmental impact

statements for future individual projects will be prepared, as appropriate. The impact and feasibility of each individually proposed program will be evaluated, including any potential impact on the Hanford Waste Management Operations.

 

VIII IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

VIII.1 PERMANENT COMMITMENTS

The resources that are considered to be committed in an irretrievable and irreversible manner by the Hanford Waste Management Operations are 1) land and materials containing or used for storing radionuclides with a half-life longer than 10 years, 2) labor expended by construction and operating personnel, and 3) materials, such as fuels and chemicals, that are burned, diluted, or consumed during use.

Most land containing fission product radionuclides with long half-lives can be considered unusable for agricultural purposes for centuries.

Although most of these radionuclides probably could be separated from the land, reduction of the concentration to a level which would permit unrestricted use undoubtedly would cost more than the value associated with normally expected uses. This land will require a commitment of both people and surveillance equipment until the radioactivity is essentially removed by processing or decay.

Land containing transuranic materials, particularly plutonium can be considered unusable for any purpose for hundreds of thousands of years. Until any recovery program for the transuranic materials would be completed, this land will require a commitment of both people and surveillance equipment.

About half a million tons of fossil fuels and 50,000 tons of chemicals are expected to be irreversibly consumed by the Hanford Waste Management Operation. Some components of the concrete structures and equipment as well as about 6,000 acres of desert land are in essence irretrievable due to the practical aspects of reclamation and/or radioactive decontamination.

VIII.2 TEMPORARY COMMITMENTS

Other resources and land are temporarily committed by the Waste Management Operations, but cannot be considered to be irreversibly and

irretrievably committed. As an example, some land currently is occupied by buildings, roads, and waste sites. As a general rule, that land could be retrieved by demolition of the buildings and roads, retrieval of the waste, dispersing the nonradioactive component materials to their original sources and storing radionuclides at locations where they have no effect on humans or the usefulness of the storage location. No land is considered to be irretrievably committed by use or disposal of pesticides, oils, and chemicals.

The use of the mobile portions of the environment (air and water) by the Waste Management Operations does not represent an irreversible or irretrievable resource commitment, but rather a relatively short-term investment. The water and air above the surface of the earth are rapidly restored to essentially their original conditions by natural processes and dilution. The groundwater contains only a few isolated locations where the concentrations of radionuclides and chemicals are above the current concentration guides for drinking water. Dilution and radioactive decay will restore that water to a useful form.

Irretrievable damage or loss to the biota of the region is not expected to occur.

IX COMPARISON OF COSTS AND BENEFITS

This cost-benefit analysis is concerned only with the future costs and environmental impacts of the Hanford Waste Management Operations. The overall program objective is to accomplish waste management operations in a manner resulting in the best balance of costs and benefits.

IX.1 EVALUATION OF BENEFITS FOR THE WASTE MANAGEMENT OPERATIONS

IX.1.1 Minimum Radiation Dose

The current total radiation dose to the general public as a result of the Waste Management Operations activities is estimated to be about 2.4 man-rem/yr. When N Reactor operations are complete, this dose is expected to decrease to less than 0.01 man-rem/yr. These doses are low when compared to the naturally-occurring background dose of about 27,400 man-rem/yr for the persons living within 50 miles of the Hanford Project.

The maximum total-body dose received by an individual from Hanford operations during 1972 was estimated to be about 0.6 mrem/yr. The average individual total-body dose was about 0.01 mrem/yr. These individual doses are low when compared to the naturally occurring background dose to individuals of about 110 mrem/yr.

No attempt was made to estimate the reduction in radiation dose to the general public that resulted from having the present Waste Management Operations Program. The alternative of not having some program for managing waste has always been considered an unrealistic case.

IX.1.2 Minimum Chemical Pollution

Land and water pollution due to release of chemical waste is kept to a minimum by storing the waste in the high-level radioactivity waste tanks or by releasing the chemicals to controlled disposal sites. Only

relatively small amounts of chemicals in comparison to the normal content of the river are released into the Columbia River.

IX.1.3 Increased Technical Knowledge

Research and development efforts are providing improved methods for handling radioactive waste and extending knowledge of the effects of radionuclides on terrestrial and aquatic biota. This knowledge helps establish the best balance between costs and environmental impacts for radioactive waste management programs.

IX.1.4 Employment

The Hanford Waste Management Operations requires continuing employment for about 700 to 1200 persons.

IX.2 EVALUATION OF COSTS FOR THE WASTE MANAGEMENT OPERATIONS

IX.2.1 Capital Cost

Future construction costs for the planned waste management facilities through 1975 are estimated to be about \$42,000,000 as outlined in Table IX-1. (Costs for the various major alternatives are given in Table IX-3.)

IX.2.2 Operating Costs

The operating costs for the waste management facilities are estimated to be about 35 million dollars per year.

IX.2.3 Land Use

Continuation of the Hanford Waste Management Operations Program will result in 1) occupancy of land by structures containing radionuclides and 2) restricted use of land containing radionuclides. The quantity of land committed will remain essentially constant for about 300 years because of the presence of ^{137}Cs , ^{90}Sr , and transuranium materials in the burial grounds and crib sites. After 300 years, the quantity of

TABLE IX-1

WASTE MANAGEMENT FACILITIES AND ACTIVITIES PLANNED
AND UNDER CONSTRUCTION FY-1973 THROUGH FY-1975

<u>100 AREAS</u>	<u>Cost</u>
N Reactor Ventilation Loop Seal Improvements	\$ 325,000
N Reactor Gravity Drain and Disposal Basin	445,000
N Reactor Control Rod Coolant Dump System	75,000
 <u>200 AREAS</u>	
In-Tank Solidification Systems, Auxiliaries	2,500,000
Waste Management Effluent Control (B Plant)	1,000,000
Contaminated Soil Removal Facility	1,000,000
B Plant Vent System Ventilation Improvements	70,000
242-T Evaporator Effluent Improvements	200,000
222-S Laboratory Exhaust Ventilation Improvements	445,000
Additional Waste Concentration and Salt Cake Storage Facilities	30,000,000
Tank 241-C-106 Sluicing Facilities	400,000
Purex Condensate Recycle	405,000
Waste Tank Leak Detection Laterals	330,000
Groundwater Monitoring Wells	100,000
Encased Waste Lines 232-Z and 241-Z	50,000
Waste Management Effluent Control	3,500,000
 <u>300 AREA</u>	
300 Area Liquid Waste Disposal	190,000
325 Building Ventilation Exhaust Addition	485,000
Replace and Upgrade 300 Area Contaminated Waste Line	400,000
Total - - - - -	<u>~\$42,000,000</u>

land required for such purposes will decrease to the lands which contain plutonium or other long-lived transuranics.

A summary description of the committed lands is presented in Table IX-2. The areas on that table include appropriate buffer zones for surveillance and prevention of disturbance of the radionuclides by nearby activities such as irrigation agriculture.

Commitment of some of the Hanford lands to waste management makes that land unavailable for other uses. Because there are tens of thousands of acres of similar desert land available throughout the Western United States, the dedicated land cannot be considered to have rare characteristics that result in a premium value, such as for residential or industrial use. Ample similar land is available nearby for any such uses foreseen.

IX.3 COST-BENEFIT ANALYSIS

The planned and budgeted changes for FY-1973 through FY-1975 are summarized in Table IX-1.

When implemented, these programs will reduce the quantities of radionuclides released to air, water, and soils during both routine operations and potential abnormal operations. The changes to the 300 Area Liquid Waste Disposal System (\$190,000) and the N Reactor Control Rod Coolant Dump System (\$75,000) will essentially eliminate the population dose contributions from these waste systems (about 0.1 man-rem/yr). All other facilities where changes are being made to improve radionuclide containment (\$41,435,000) are already contributing essentially zero population dose.

In Section V, alternatives were discussed for several categories of waste with special emphasis placed on alternatives for the high-level radioactive waste. Study of these various categories of waste reveals that none of the waste is currently causing a significant environmental impact on either the biota on or near the Hanford Reservation or on the

TABLE IX-2

DEDICATED WASTE MANAGEMENT LANDS

<u>General Location</u>	<u>Content^(a)</u>	<u>Approximate Area (acres)</u>
100 Areas	Burial Grounds	70
200 Areas	Burial Grounds, Process Buildings, Tank Farms, Cribs, and Ponds	5,100
300 Area	Burial Grounds and Process Ponds	50
600 Area	Burial Grounds	10
TOTAL		5,230 ^(b)

(a) Excludes standby facilities

(b) This is 1.4% of the total Hanford Reservation land area

The existence of the current inventory of radioactive waste requires that the Waste Management Operations Program be continued. The waste management program alternatives presented are being considered and could be adopted within the limits of current technology and availability of federal funds. The radiation dose to the population and consequently the health effects are essentially independent of the alternative chosen.

The existence of the current inventory of radioactive waste requires that the Waste Management Operations Program be continued. After weighing the cost and benefits of the alternatives to the high level liquid waste program, it is concluded that the current program of solidification to salt cake should proceed. This program will include the replacement of some or all of the single wall tanks with improved double-walled tanks as required. However, research and development should continue on methods for solidification of residual liquors as well as alternative insoluble formations.

It has concluded that the alternatives for further reducing the amount of effluents to the ground are not economically practical at this time. These multi-million dollar facilities would have little, if any, effect on the radiation dose from the Hanford Project (see Table IX-3), which is already substantially below established standards. Further, these effluent control projects could not be installed and in operation before the primary operations are scheduled to be shut down. Consideration of possible extended use of either of these facilities has been suggested; however, deliberations on their extension are only in a preliminary stage. Although, as noted above, the operation of N Reactor or Purex has a minimal environmental effect, the economic practicality of alternatives for further effluent reductions will be reconsidered if these facilities operate beyond current projections. Studies should continue on effluent control projects that are technically feasible and could be placed in service in the interim period.