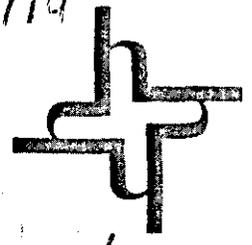


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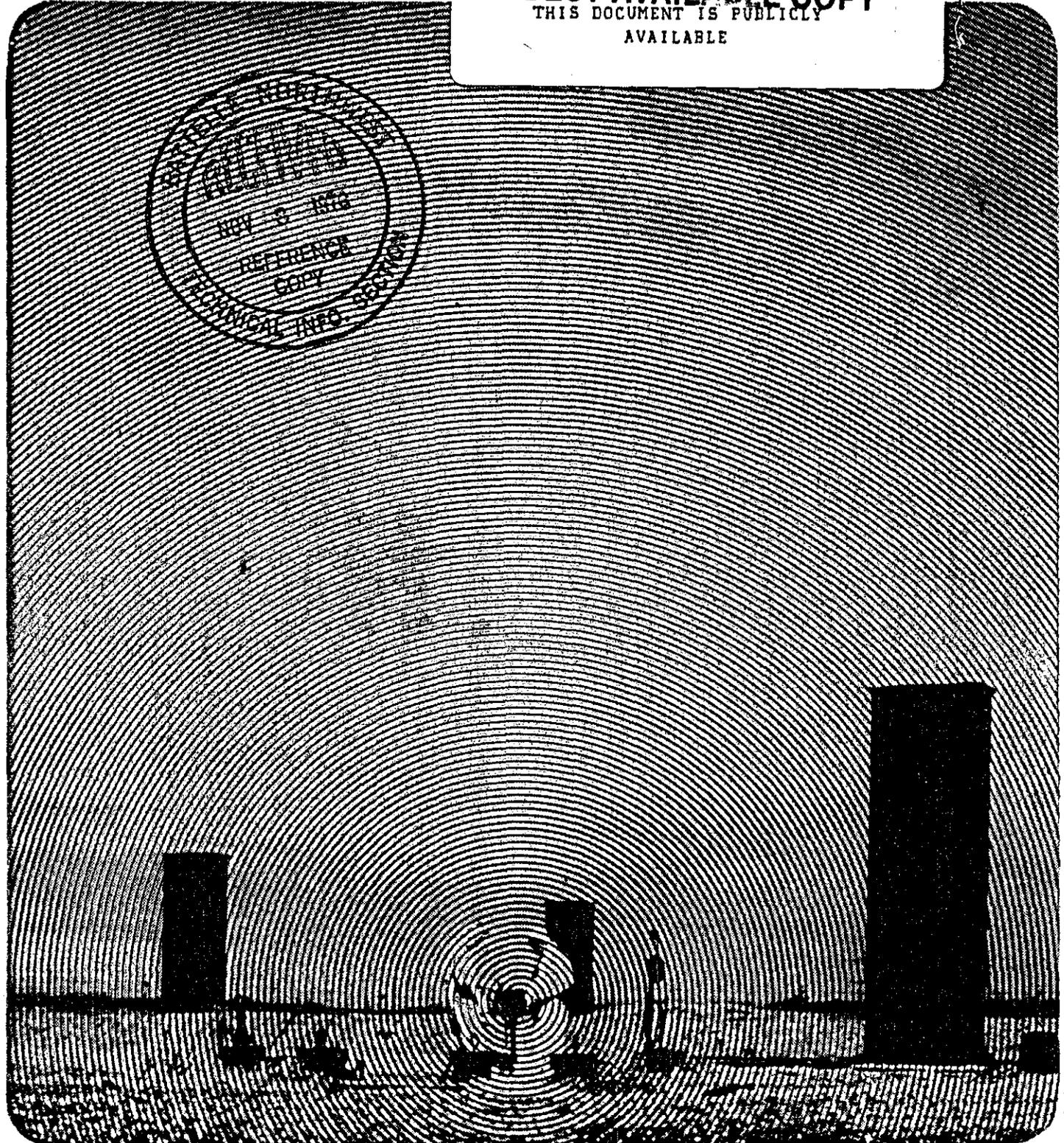
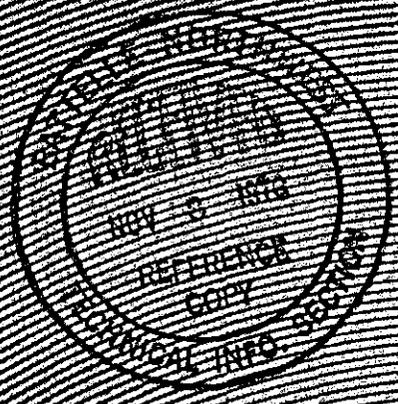
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MANAGEMENT of RADIOACTIVE WASTES at the HANFORD PLANT

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Presentations Made to the Committee on Radioactive Waste Management of the National Academy of Sciences at Richland, Washington
June 23 and 24, 1969.

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ERRATA

- Page 3 - Last paragraph, seven lines up from bottom: change word "uranium" to "ruthenium."
- Page 17 - Immediately following first paragraph, the following excerpt should be included:
- PROGRAM BASES
- The following considerations are the bases for the formulation of the Hanford Waste Management Program:
- Underground storage tanks near the end of being reliable containment vessels
 - Storage space needed to maintain production continuity
 - Mobility of cesium in stored solutions
 - About 7×10^6 Btu/hr decay heat to be safely dissipated
 - More than 90% of the long-lived heat emitters contained in one-sixth stored waste volume
- Page 19 - In Table III-5, reverse the numbers 1.1 and 1.2 as shown opposite "solidified."
- Page 34 - In Figure IV-5, dimension 100' should be 70', and dimension 140' should be 110'.
- Page 36 - In Figure IV-6, coordinate in upper right corner should read "S 75° E" instead of "575° E."
- Page 37 - In Table IV-2, insert a horizontal line in the WT% column above the number "100." To the left of the number "100," insert word "TOTAL."

MANAGEMENT of RADIOACTIVE WASTES at the HANFORD PLANT



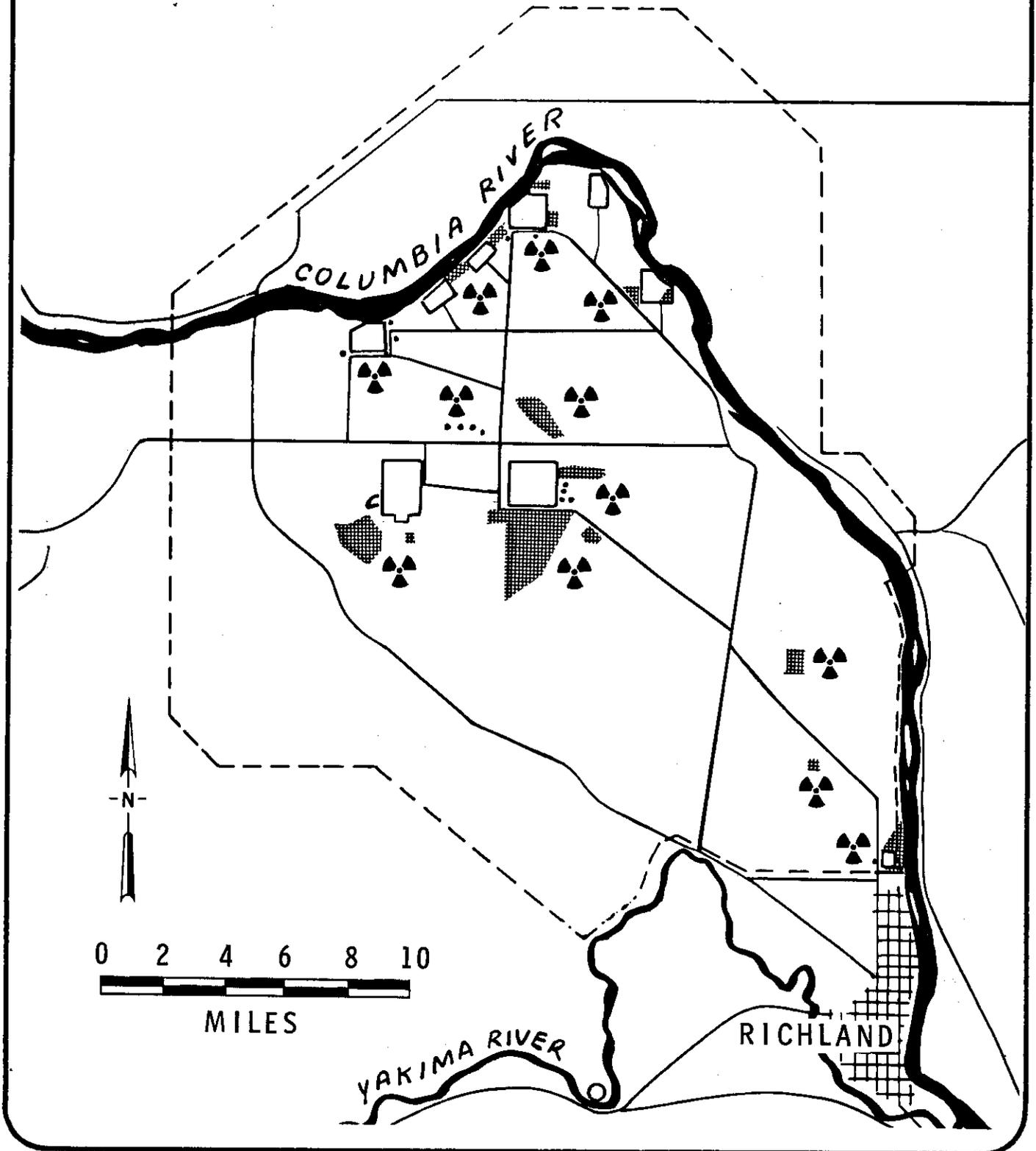
Presentations Made to the Committee on Radioactive Waste Management
of the National Academy of Sciences at Richland, Washington/June 23 and 24, 1969.

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FIGURE I-1

RADIOACTIVE WASTE STORAGE SITES OUTSIDE LIMITED AREAS



I HANFORD WASTE MANAGEMENT POLICY and PHILOSOPHY

O. J. Elgert — U. S. Atomic Energy Commission

Hanford waste management policies and philosophies have developed from the many years of experience in handling radionuclides at Hanford, consideration of unique site characteristics, analyses of environmental surveillance data, and information from outside sources. RL (Richland Operation—AEC) Appendix 0510 to the AEC Manual Chapters provides release guides for radioactive wastes. AEC and RL Manual Chapters 0524 set forth limits and guides for radionuclide exposure to people both onsite and offsite.

New facilities and operations must be reviewed by RL to assess adequacy of safety features, including waste management requirements. The RL Division responsible for a particular facility or operation is also responsible for reviewing and approving the safety features. In practice, the RL Health and Safety Division provides the major staff review. Major projects are also submitted to AEC Headquarters' Program Division and Division of Operational Safety for review. The individual contractors also provide safety review through committees established for this purpose as well as by their respective safety groups. Recently, RL has established a Waste Management Advisory Board composed of both RL and contractor personnel to develop common waste management goals for Hanford. An offsite emergency disaster plan has been developed by RL Health and Safety Division. The plan is described in the appendix attached.

In the following presentations, we have excluded consideration of reactor coolant water effluent, which does contain radionuclides, except to the extent of its effect on environmental surveillance. The once-through flow of coolant water creates a special problem at the Hanford reactors and is normally not a consideration elsewhere. Omission of this subject is in accord with your expressed desire.

Historically, we have categorized liquid radioactive wastes as follows:

- | | |
|-----------------------|---|
| 1. Low level | $< 5 \times 10^{-5} \mu \text{ Ci/ml}$ |
| 2. Intermediate level | $5 \times 10^{-5} \text{ — } 100 \mu \text{ Ci/ml}$ |
| 3. High level | $> 100 \mu \text{ Ci/ml}$ |

The high level wastes have been further categorized into boiling and nonboiling types. We are moving toward only two general classifications of liquid wastes: 1) Those which can be discharged to the soil (very low level) and 2) those which will be further processed.

Because of the unique site characteristics (semiarid climate, excellent soil ion exchange properties, high specific retention capacity and low moisture content of the soil, a long soil column to normal groundwater level, and site isolation), low level and intermediate level liquid wastes have been discharged directly to the ground via ponds or underground structures called cribs. Nearly all of the long-lived radionuclides are held by the soil within a short distance of the point of discharge.

Detection of long-lived radionuclides ($< 0.1 \text{ MPC}_w$) at groundwater level is a guide to deactivate that immediate site for further waste storage. Solid wastes are buried directly in the soil, packaged to the extent necessary to prevent spread of contamination during the burial operation. Presently, all plutonium and fission product bearing wastes (liquid and solids) are sent to the 200 Areas for storage. This centralizes storage of long-lived radionuclides in an area which provides maximum separation from groundwater (200-300 feet).

I would like to emphasize that storage of radionuclides directly in the soil has been a practice at Hanford only because of unique soil and site characteristics. The amount of radionuclides so discharged has been reduced drastically over the last decade, and plans have been and are being developed to further reduce their discharge. These plans include the installation of facilities as funds are provided to reduce total beta activity discharged to about 400 Ci/yr and plutonium to less than 10 g/yr. Figure I-1 shows the extent to which the soil has been used to hold radionuclides outside "limited areas." The major radionuclide deposits in soil are within "limited areas." These areas are shown in the following detailed discussions. While some radionuclides (tritium, ²³⁸uranium) from liquid waste effluents (other than from coolant water streams) no doubt have migrated offsite into the Columbia River, we have been unable to detect them because of their very low concentrations in respect to weapon test fallout, dissolved uranium from natural sources, and reactor coolant water activity discharge. This is covered in greater detail in Section VII.

The present Hanford high level waste management policy calls for in-tank evaporation of all liquid wastes as rapidly as possible after strontium and cesium removal. We expect to have converted our stored liquid wastes, exclusive of a current working inventory, to solids before the end of 1975. The solid residue will be stored in existing tanks for the foreseeable future, but capability to remove the solids is being developed. The strontium and cesium which have been separated from the wastes to the extent required for safety reasons (high temperature) will be solidified, packaged in high integrity containers, and stored onsite. This approach leads us to the safest form (solids) for our high level radioactive liquid wastes. It is essential that we move as rapidly as possible in the direction of solidifying wastes because we have recently experienced a significant increase in tank leakage. We believe, furthermore, that the high level wastes solidified in tanks can be safely stored with minimal surveillance for the time required for the fission products, primarily ^{90}Sr and ^{137}Cs , to decay to innocuous level (~ 500 years). Our development program is directed to show that radioactive wastes can be stored safely near the surface for the foreseeable future, at least as long as some surveillance can be provided. Surveillance is to assure that the ground surface remains undisturbed either by erosion or digging operations and that ground-water is not permitted to rise into the stored wastes.

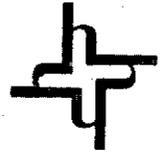
It may be desirable to relocate the wastes, perhaps after decay of fission products at a point in time when direct radiation is not a significant factor, in order to provide isolation of residual plutonium for about 500,000 years without the need for continuous surveillance. Technology to assure this degree of isolation could be expected to be developed in the next several decades, most probably within a century. Because of the low water solubility of the plutonium in the salt cakes, water leaching should not be a problem after sufficient decay of the fission products. However, geological formations must be found for deposition of plutonium bearing wastes into which man is not likely to dig after the wastes have been placed there.

We must also consider that national policy may dictate a change in storage criteria in the relatively near future, or we may deem that other storage methods are preferable for the next several centuries. We are, therefore, developing methods to remove and relocate the high level wastes as well as investigating alternative storage methods. Costs will be considered in evaluating alternatives for which no overriding safety factor dictates a specific choice. Safety problems associated with removing and transporting very large quantities of soluble radioactive salts from the waste tanks must of course be considered. These alternatives are covered in more detail in Section IV.

AEC and RL Manual Chapters 0510 and 0524 also provide limits and guides for radioactive gas or particulate release. No significant change in our present practices are envisioned with the exception of possibly reducing discharges of oxides of nitrogen.

II GENERAL SITE DESCRIPTION and WASTE MANAGEMENT SUMMARY

J. H. Warren — Atlantic Richfield Hanford Company



DEVELOPMENT OF THE SITE

General Location

As illustrated in Figure II-1 the Hanford Plant occupies 585 square miles in the south central portion of the State of Washington bounded on the north and east by the Columbia River. This particular view is looking south. The area is characterized by a semiarid climate. Rainfall averages 6.1 inches per year, occurring mostly in the December through February period. (1) Temperatures in an average year exceed 90°F on about 60 days and are below 32°F on about 116 days. During a three-year period the average wind velocity at 200 feet above the ground was equal to or greater than five miles per hour 87% of the time. Moderate to high winds are frequent throughout the year. Temperature

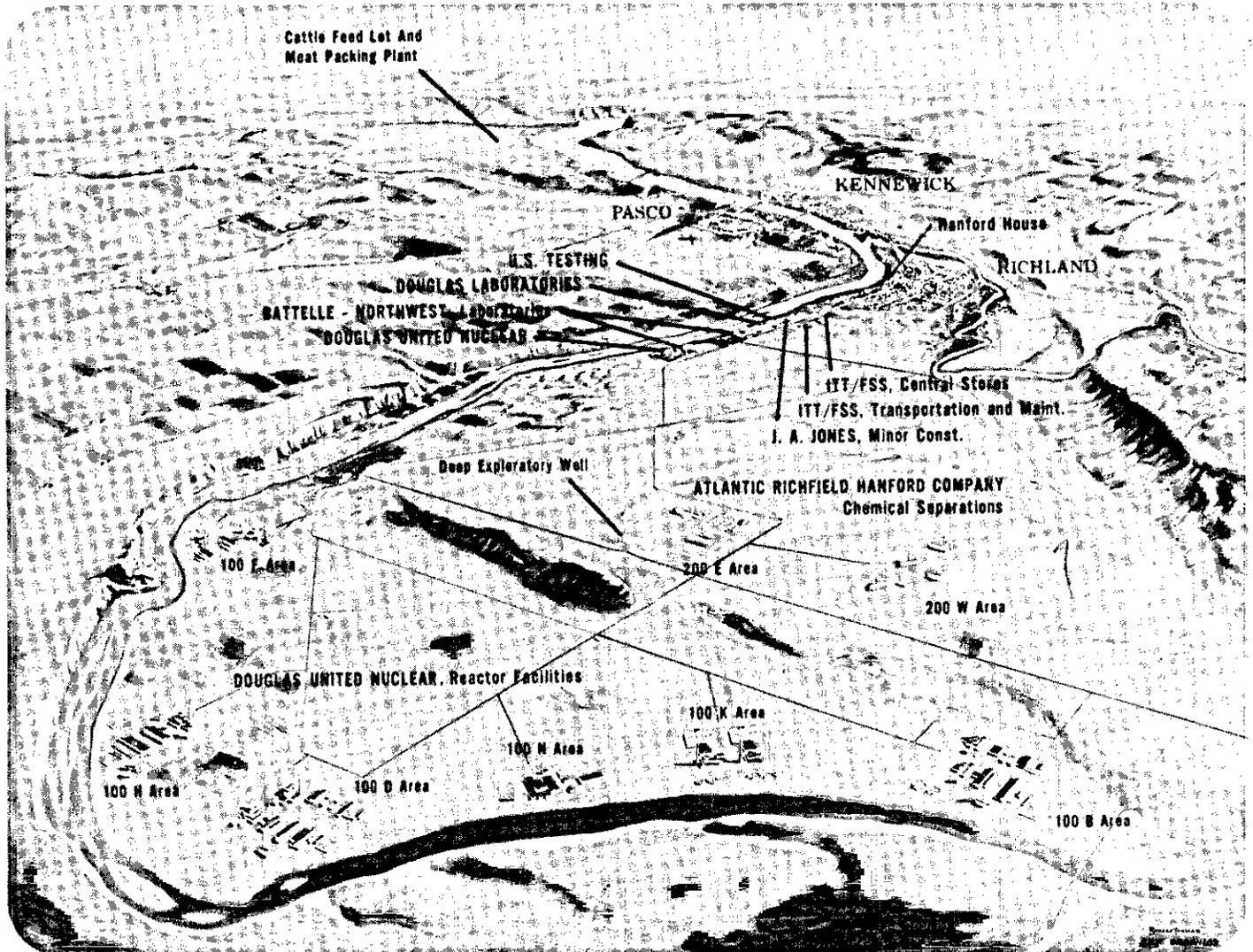
inversions, or atmospheric stagnation, are encountered only occasionally, usually in the winter months.

The principal water courses in the area are the Columbia River, and the Yakima River on the south edge of the project. Average flows of these two streams are 90,000 cubic feet per second for the Columbia and 4,500 cubic feet per second for the Yakima.

Selection Factors

The principal factors which led to the selection of this site were 1) the availability of a large and continuing quantity of cool and relatively pure water plus an ample power supply, and 2) its isolation from high density population areas. These considerations were paramount because of the

FIGURE II-1. Artist's conception of Hanford Plant, looking south



need to dissipate large quantities of heat from the reactors, to supply the electrical needs of the plants, and to minimize human exposure to radioactivity in event of an accidental gross release of radioisotopes in any form.

The geology of the Hanford Plant area is characterized by numerous layers of tertiary basaltic volcanic rocks (Figure II-2) several thousand feet in thickness. Upon these rocks rest locally thick sections of tertiary and quaternary sedimentary strata. Hanford is considered to be a region of moderate seismicity, verging on minor seismicity. The area has not been subjected to more than weak ground shaking during historical times.

Location of Operating Complexes

The principal operating or manufacturing complexes on the plant site are illustrated in Figure II-3. The fuel fabrication location is designated as the 300 Area, the reactor plants as the 100 Areas, and the fuel reprocessing plants as the 200 Areas.

The fuel fabrication area, where there are also extensive research and development facilities supporting all Hanford operations, is located about five miles north of the city of Richland directly on the Columbia River. The nature of operations in the 300 Area does not require extreme isolation from population centers as large quantities of fission products or other unstable isotopes are not being produced at this location.

Three reactor areas (B, D, and F) were completed on the Columbia River between 1942 and 1944 at distances varying from 25-40 miles from the nearest population center.

The fuel reprocessing plants were isolated from population centers and removed as far as possible from both surface and subsurface water courses because of the accumulation of radioactive materials. The plateau-like area about seven miles from the Columbia River was selected as the most suitable site for the 200 Areas. The operating plants within these areas are about 200-300 feet above the water table. No other site on the Hanford Plant enjoyed simultaneously as great a distance both from the Columbia River and above the natural water table level. The travel time of the groundwater underlying the 200 Areas to the river was at that time believed to be a matter of at least 10 years. Considerable protection was offered by this time span and by the normal dilution which any undesirable waste would receive if it reached the water table and/or either of the rivers.

Variations in Physical Plant and Land Use

Production capacity at Hanford was expanded on numerous occasions between 1948 and 1962. Fuel fabrication facilities in the 300 Area were enlarged. Six additional reactors (H, C, DR, KE, KW, and N) were added to the original three. Three reactors are being operated today (KE, KW and N). In the 200 Areas (Figures II-4 and II-5) the two original batch-type plants for the separation of ^{239}Pu were made obsolete by advances in technology, and shut down between 1950 and 1956. Two higher throughput continuous solvent extraction plants were provided, one of which still operates today. Uranium previously stored in the waste tanks from the batch-type plants was recovered in a modified third batch facility previously held in standby. Original provision for the isolation and purification of plutonium was followed by facilities to convert it to the metallic state, then for a period fabrication of weapons components was carried out locally. There is no local fabrication activity at this time.

FIGURE II-2

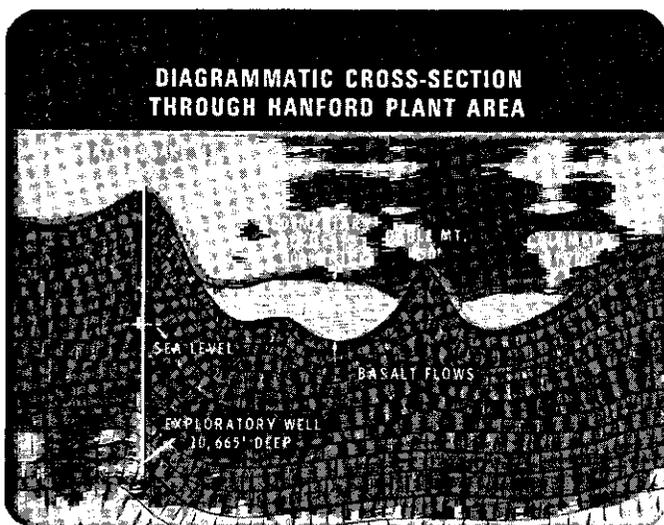


FIGURE II-3 Hanford Plant.

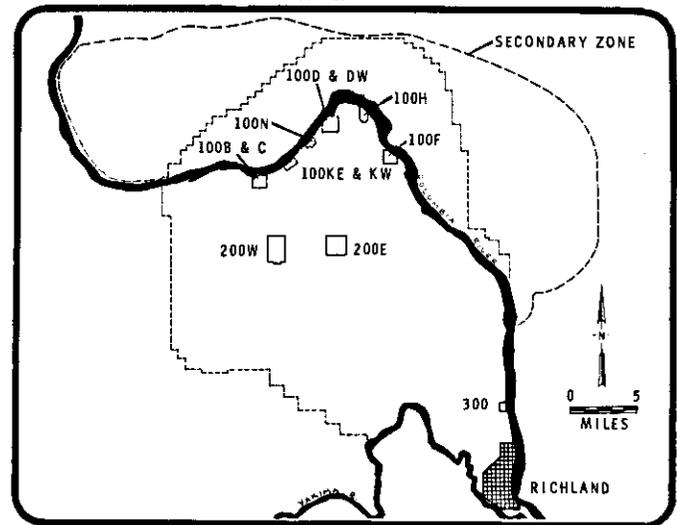


FIGURE II-4 200 East Area facilities

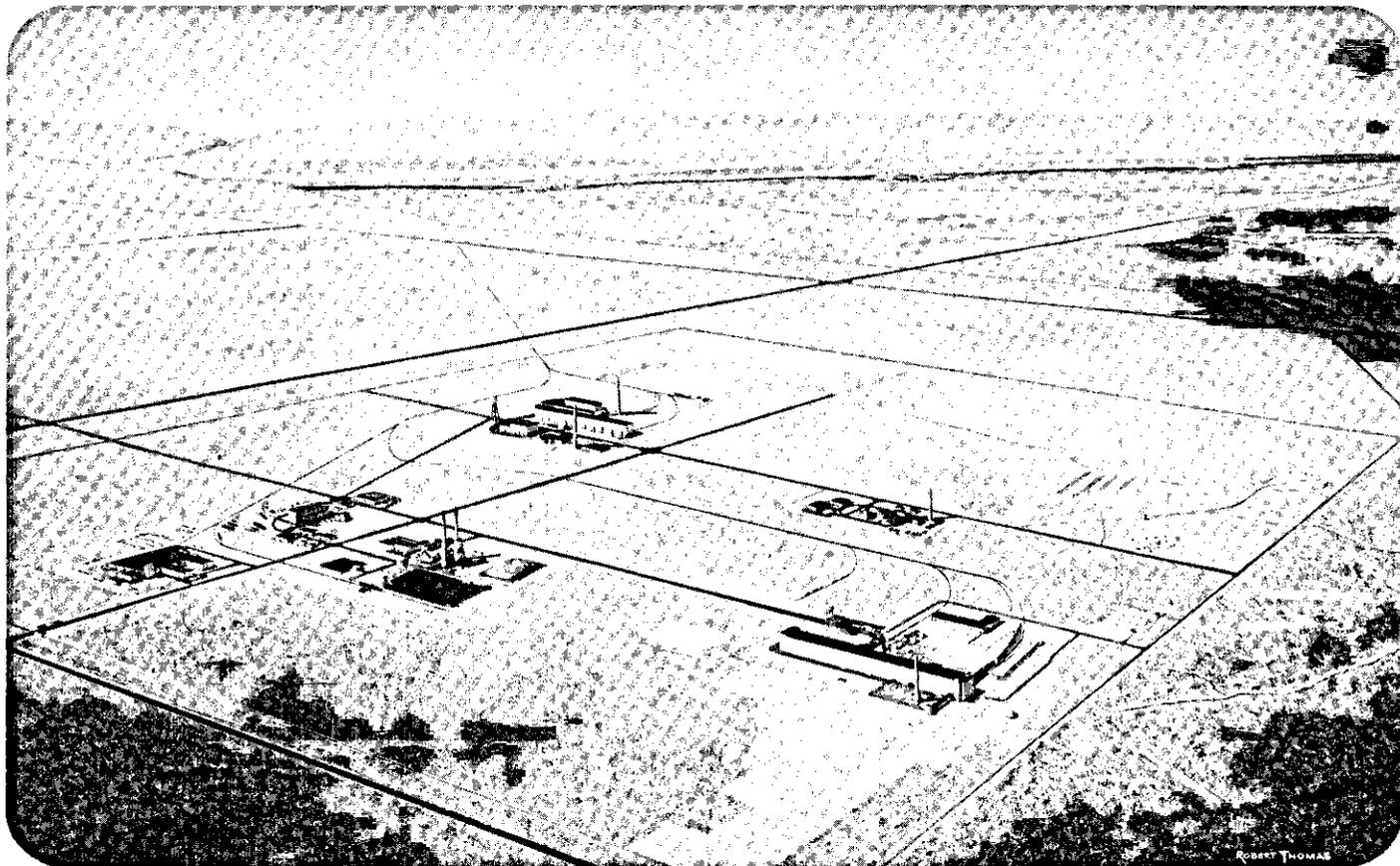
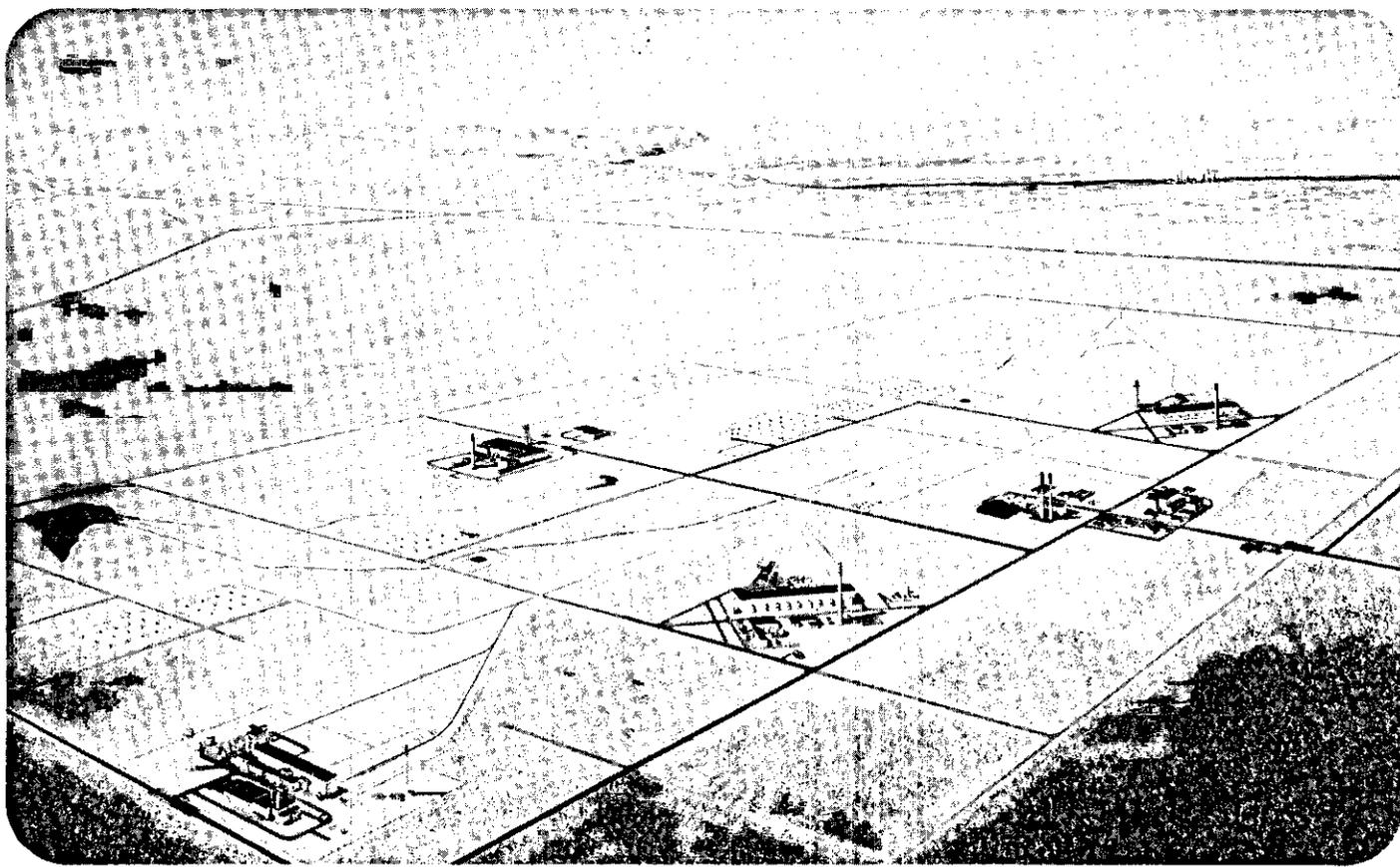


FIGURE II-5 200 West Area facilities



Aside from the operating complexes, land use within the Hanford Plant area and public access to it has changed as security limitations have been relaxed progressively over the 25-year project operating life as shown in Figure II-6. Land controlled by the Atomic Energy Commission north of the Columbia River has been released to the public on two occasions, 87,000 acres in 1953 and 105,000 acres in 1958. The Commission still owns 85,000 acres north of the river not available for public use. This is essentially a buffer zone north of the reactor areas. In 1964 the Commission leased 1,000 acres of land on the 200 Area plateau to the State of Washington. Under state auspices utilization of this land for nuclear related businesses has been promoted. Solid radioactive waste burial is carried on there at this time by the Nuclear Engineering Company serving firms from various locations throughout the country. Another major change in land use has been the building of a public road, Washington State Highway 240, across the southern portion of the project in 1967, connecting Richland more directly with the west gate of

FIGURE II-6 Changes in land use.

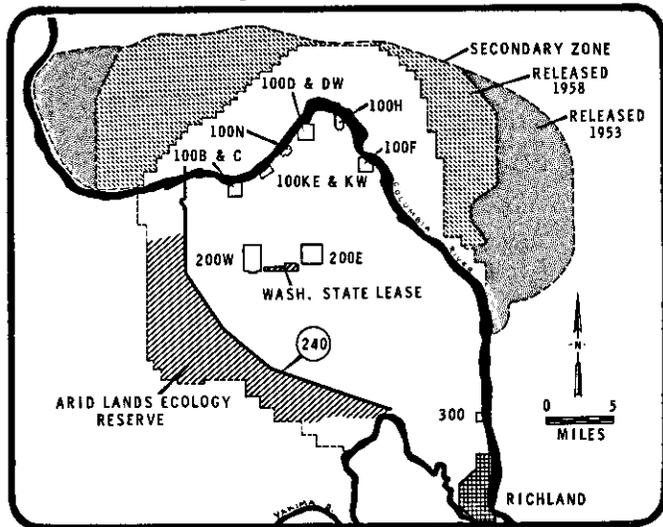
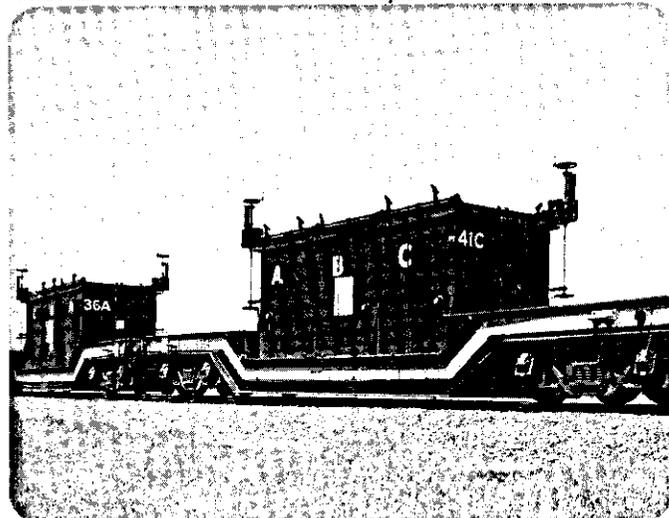


FIGURE II-7 Fuel element transport.



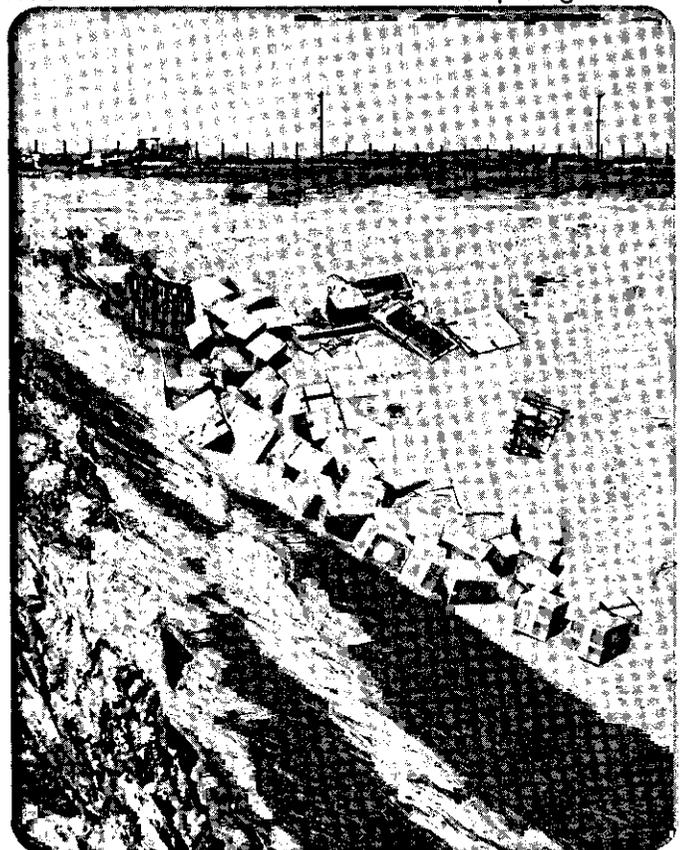
the project and routes west to Yakima and northwest to Seattle. South of this public road and extending to the top of the Rattlesnake Mountain is a 110 square mile ecology reserve where Battelle-Northwest conducts studies for the AEC.

Radioactive Waste Disposal History

Both natural and enriched uranium metal fuel elements clad with aluminum or zirconium are produced in the 300 Area, and irradiated for varying periods in one of the three reactors operating today to produce ^{239}Pu . Following discharge from the reactors, they are held in interim water-cooled storage to permit decay for approximately four months. All wastes from these operations will be described in a later section of this presentation.

Water-cooled heavily shielded casks (Figure II-7) are used in the rail transfer of the fuel elements to the fuel reprocessing plants. The valuable products which the fuel elements contain are separated from the fission products by solvent extraction or ion exchange in nitric acid solutions. This reprocessing is concerned only with fuel elements irradiated for government production.

FIGURE II-8 Burial of small solid waste packages.



Types of Waste

The types of waste produced in the fuel reprocessing plants may be categorized generally as 1) gaseous effluents, 2) stored solids, 3) released liquids, or 4) stored liquids. The general origin, composition, and past disposal practices for each of the categories is described briefly below.

● **Gaseous Effluents** These are typically discharged from each fuel reprocessing facility at 50,000-300,000 cfm. The composition of the gas streams varies from plant to plant. Most of the nitrogen oxides which are contained in the gaseous wastes from plutonium separation and uranium recovery operations have been removed by absorption; radioiodine in the plutonium separation operation is reduced by decay and the remaining fraction has been absorbed in silver reactors. Particulate material in the gaseous waste streams has been removed by scrubbing and filtration through sand, fiber-glass and/or high efficiency media. No control of tritium has been exercised. Less than five percent is discharged through the stacks.

● **Stored Solids** Solid wastes (Figure II-8) from all plant and laboratory operations in the 200 and 300 Areas (failed equipment, protective paper covering, construction debris, rags) have been sealed in cardboard, wooden or concrete boxes to prevent spread of contamination to the environs. These have been transported to the 200 Area burial trenches which are up to 25 feet in depth. They have been covered with

up to 10 feet of earth. The burial sites are marked. An underground tunnel at the Purex Plant has also been used for the interim storage of large radioactively contaminated equipment.

● **Released Liquids** These effluents have been classified arbitrarily into two groups by management definition. Those which have radionuclides in concentrations below 5×10^{-5} microcuries per milliliter are referred to as "low level" wastes. A typical example is cooling water used in condensers and some vessel cooling coils. These wastes have been routed to open ponds (Figure II-9) where the water percolates to the water table.

Contamination of these wastes is possible only through equipment failure, which has occurred infrequently. In such a situation diversion to specific retention sites is possible in some instances. Any radionuclides which have arrived at these open ponds have been partially sorbed on the underlying soil as the water percolates downward. The ground sorption delays the migration rate and reduces peak concentrations but does not prevent migration of contaminants to and with the groundwater. The pond levels are maintained to prevent exposing and drying of contaminated bottom dirt at the shoreline.

FIGURE II-9 Purex cooling water pond



Effluents at greater radionuclide concentrations but less than 100 microcuries per milliliter are referred to as "intermediate level" wastes. Typical examples are drainage and other high-risk utility wastes. Preliminary research as early as 1944⁽²⁾ established a basis for direct ground disposal of these wastes through cribs (Figure II-10). As more advanced flowsheets developed, process and steam condensates fell into this group. Liquid wastes from the 300 Area laboratories, in the high range of this "intermediate" classification, have been transported to evaporators in the 200 Areas where they have been concentrated and the bottoms stored in underground tanks.

Wastes have been discharged to cribs until long-lived radionuclides of concern in the water table beneath them reach AEC guide concentrations. The wastes are then directed to new crib areas. This disposal technique relies on the sorptive capacity of the soil to retain essentially all of these long-lived radionuclides and prevent their further migration to the water table upon retirement of the crib.

FIGURE II-10

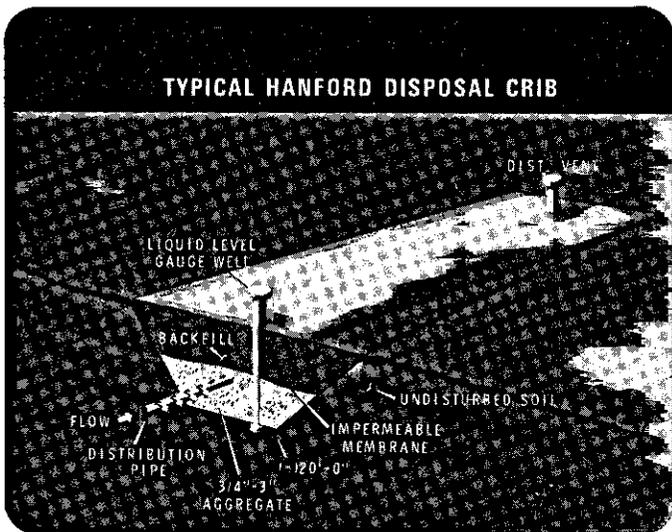
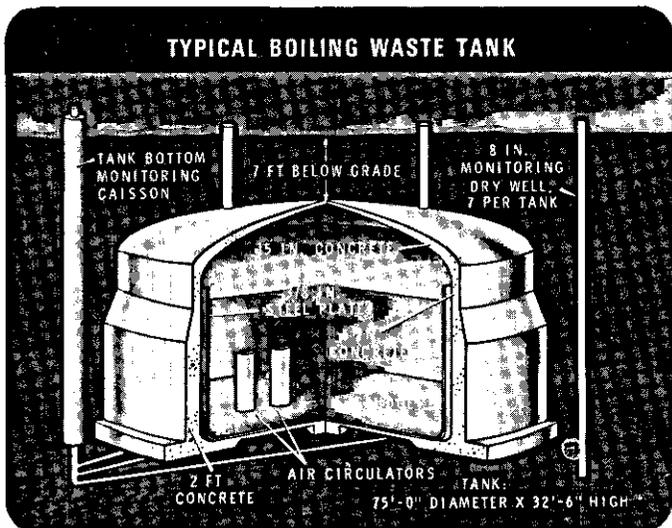


FIGURE II-11

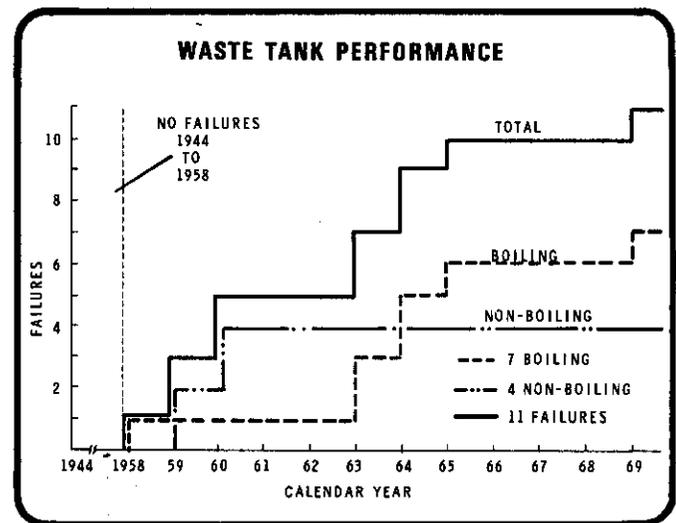


Also, the low rainfall in the Hanford area avoids long-term leaching effects. Some radionuclides with low soil sorption do percolate to the water table during crib operation. As an example, greater than 95% of the tritium in the process leaves in these liquid wastes. Their concentrations, after 25 years of operation, have never exceeded the AEC guide concentrations in the groundwater at distances of more than three miles from the disposal area. The decay rates for these radionuclides presage their reduction to innocuous levels before they arrive by normal groundwater migration paths at points of potential uptake some nine miles further to the southeast.

Some wastes are released on a specific retention basis. This method depends on wastes being held in place by capillarity, thereby avoiding the necessity of relying solely on the sorptive capacity of the soil to remove the radionuclides. The soil above the water table at Hanford is capable of retaining additional moisture up to 10% of its total volume. Typical examples of wastes having been disposed to specific retention sites include organic solvents and aqueous solutions not chemically conducive to ion exchange.

● **Stored Liquids** Nearly all of the radioactive wastes from the aqueous process streams contain a mixture of numerous radionuclides in concentrations exceeding 100 microcuries per milliliter, and are referred to as "high level" wastes. Those wastes generated in the 25-year history of the Hanford Plant have been stored in 149 carbon steel-lined, reinforced concrete underground tanks ranging in capacity from 50,000 to 1,000,000 gallons (Figure II-11). The wastes were introduced to the tanks as alkaline slurries, with suspended solids setting to form sludges of hydrous metal oxides and radioactive materials such as ⁹⁰Sr and plutonium. The supernatants contain sodium nitrate and nitrite and essentially all of the ¹³⁷Cs.

FIGURE II-12



In summary, the radioactive waste disposal practices employed in the fuel reprocessing plants have had small contribution to offsite personnel dose — — — essentially insignificant.

Problem Areas

Radioactive waste management in the fuel reprocessing areas at Hanford has its most pressing problems when container integrity has been violated and aqueous wastes escape, or when a fissile material concentration buildup in the soil reaches substantial proportions.

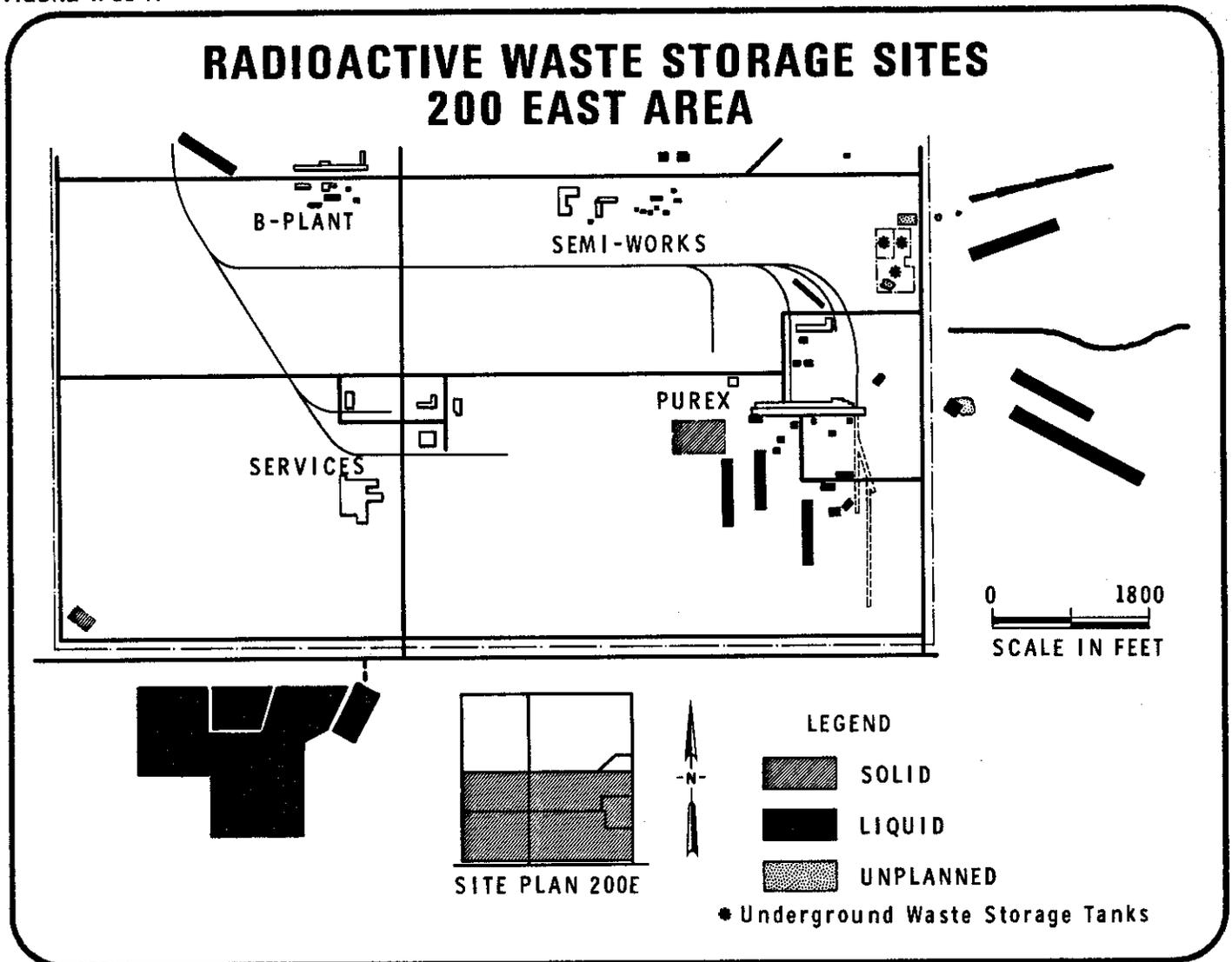
Nearly 15 years of continuous underground storage of alkaline wastes, some self-boiling, had transpired before the first tank leak was experienced. In the last 10 years, leaks have been confirmed in 11 of 149 such tanks (Figure II-12). The supernatant which has escaped from these tanks into the surrounding soil has contained an estimated 140 kilocuries of ¹³⁷Cs as well as other fission products.

In some cases, these leaks self-sealed by salt crystallization; in other cases they were controlled by pumping the contents to spare tanks. Once a leak has been stopped, movement of radionuclides towards the water table is negligible. From soil samples and radiation measurements, it has been determined that the activity remains in the 10-20 feet of soil directly beneath the waste tank⁽³⁾

Occasionally there have been accidental spills of aqueous or solid wastes. Such spills require either immediate stabilization of the surface soil or its removal to a burial site, followed by many years of surveillance and controlled access at the spot of the accident.

The gradual accumulation of ²³⁹Pu in the soil in minute amounts in aqueous streams, or in solid form adhered to solid wastes or failed equipment, presents a long-range

FIGURE II-13-A



control problem. Wherever this material comes to rest in the final analysis, it demands assured long-term identification, and centuries long surveillance coupled with sustained communication of its hazard potential to the human race. This problem has been under evaluation and the search for the optimum solution is continuing. Meanwhile, the immobility of plutonium in the soil — its disinclination for migration — is certainly a favorable aspect.

Inventory of Wastes

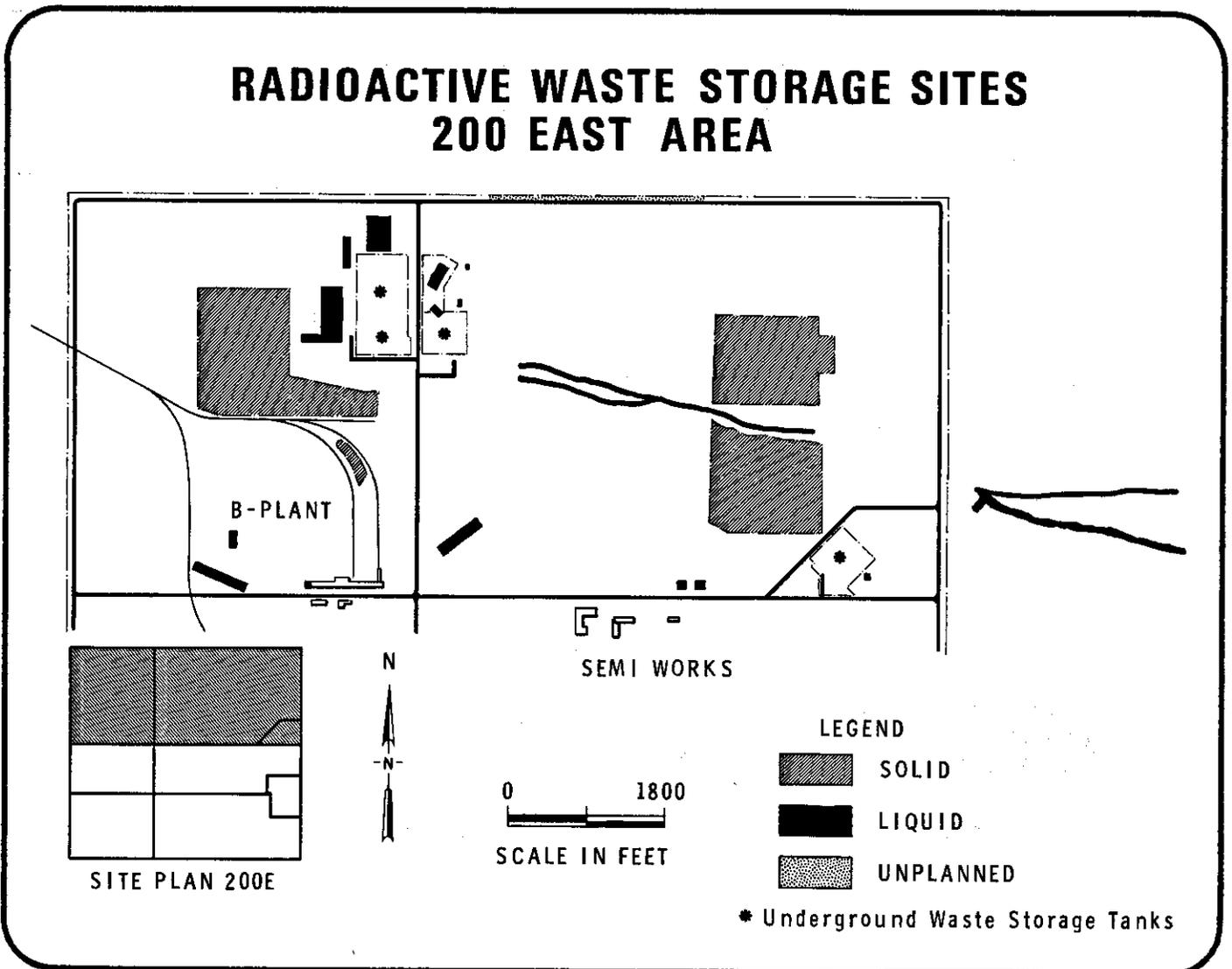
The many sites at which radioactive waste storage has been effected since 1944 in the fuel reprocessing areas are shown in Figures II-13 and II-14. Storage has been effected for about 700,000 kilograms of uranium, 600 kilograms of plutonium, and 3,700,000 curies of beta emitting isotopes through 1968. Allowing for decay, about 230,000 beta

curies remain in the ground. These figures do not include the tanked inventory, the radioisotopes held in the ground next to storage tanks which have leaked for temporary periods, nor that which is stored in the Purex tunnel.

Present and Long Range Plans

By the late 1950's, the inventory of wastes directly placed in the ground and that stored in underground tanks had reached proportions at Hanford at least fivefold greater than that of any other AEC site. The operations had capitalized on favorable climatological and soil characteristics peculiar to the Hanford area, aided and abetted by the impression that this area would be under governmental control with virtually no public access. Even these factors, however, could not dispel the sense of urgency which accompanied the onset of leaking underground tanks in repetitive instances, and the immediate recognition of additional provision needed for increased long-term safety to human population. In 1957, Hanford began the development of a long-range waste management program.

FIGURE II-13 -B



No guidelines for this needed program were available, hence many assumptions were made in its development to satisfy all aspects of the problem — technical, operational, social, moral, and political. This program, while very appropriate to Hanford's specific situation, is not recommended for other sites. Each site still must react in accordance with its own specific environment. The revised program provides a safer, long-term method for the storage of radioactive aqueous wastes, converting them to a solid, immobile form stored in locations permitting retrievability.

The specific program (Figure II-15) for the large Hanford inventory of stored sludges and supernatants, and for currently generated wastes of similar composition ("high level" wastes), features fractionization of the long-lived high heat producing radionuclides ^{90}Sr and ^{137}Cs , followed by their high integrity packaging and storage in mechanically cooled spaces. The waste volumes which remain after this separation contain the low heat producing radionuclides

and sodium salts. This volume is then converted to a solid salt cake in the storage tanks by direct heating and evaporating techniques. By 1980⁽⁴⁾ there will be about 40-45 million gallons of solid salt cake in underground tanks. Preliminary estimates of the shipping cost alone to move this salt cake to midcontinent abandoned salt mines approximates 250 million dollars. This estimate would more than double if mining costs, shipping casks, and reasonable contingency were included. If long-term storage of solid salt cake in underground tanks at Hanford is felt to be unreasonably hazardous for future generations, then the radioactive materials deposited in the soil from direct buried solids and aqueous percolations as described above must also be considered for removal. Billions of dollars would be required to complete this step.

FIGURE II-14-A

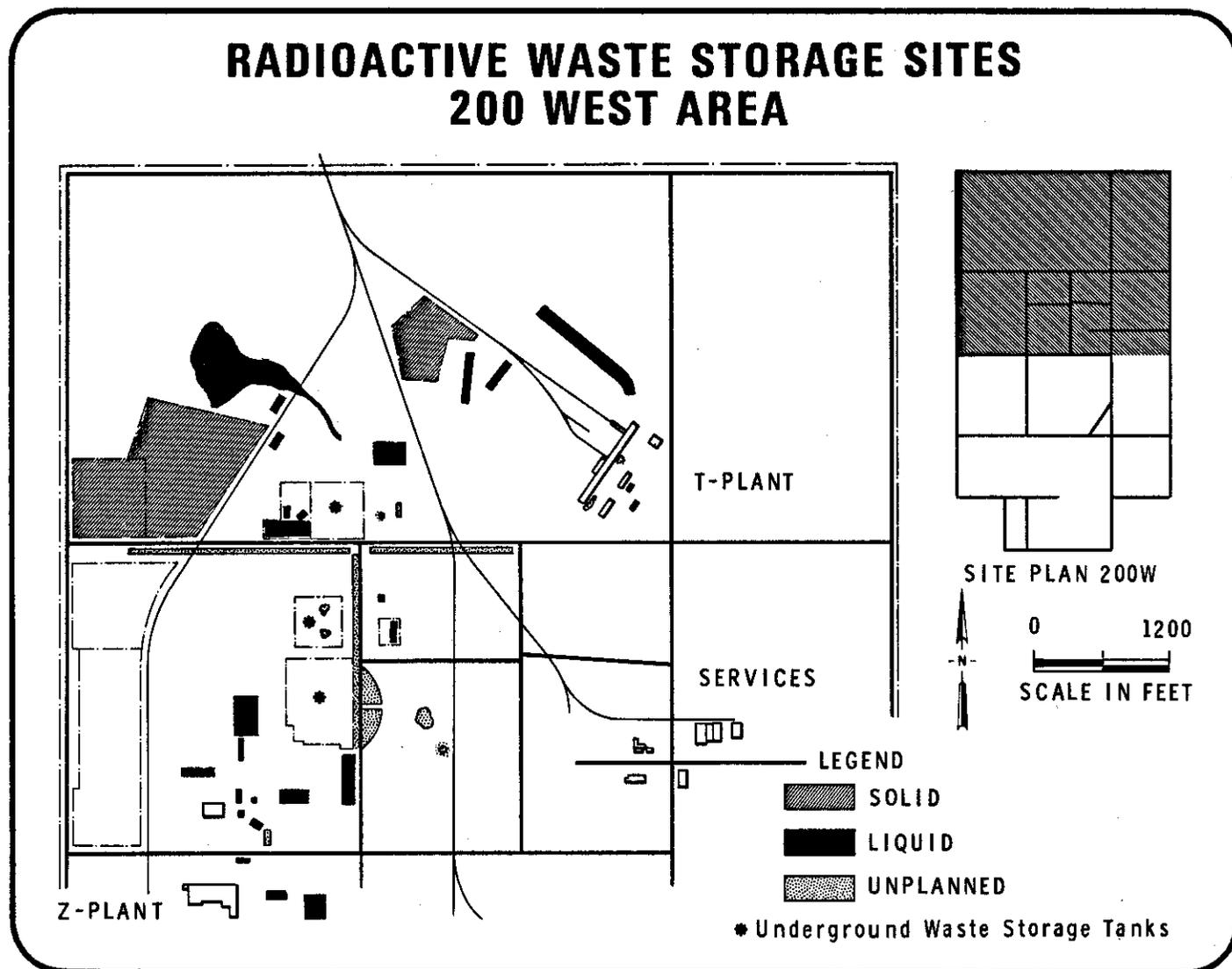
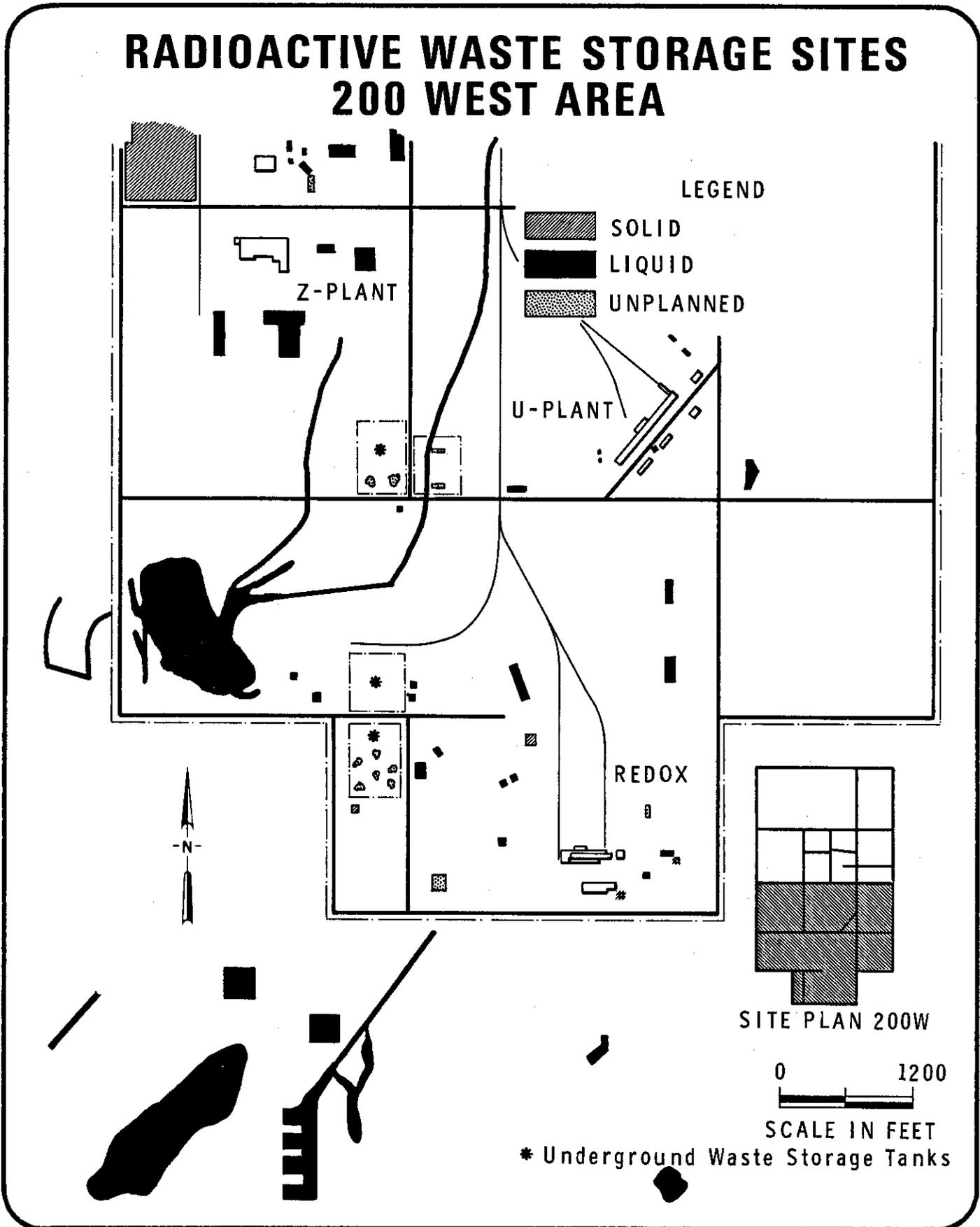


FIGURE II-14-B



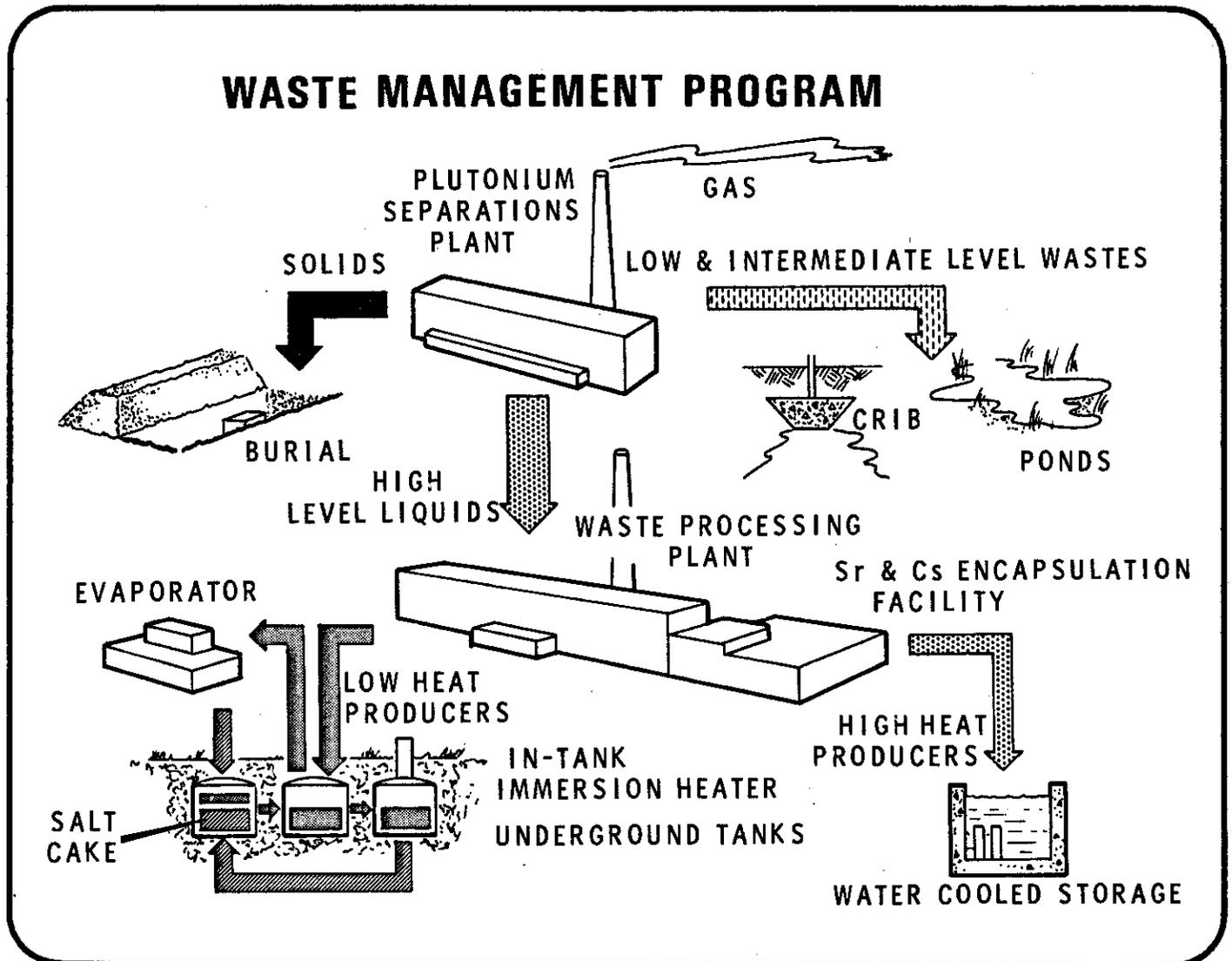
Concurrent with the reorientation of the "high level" waste program, increased national demand for pollution abatement on a comprehensive scale has developed. It is anticipated that standards for the disposal of gaseous, solid, and both "low level" and "intermediate level" radioactive liquids may become more stringent. Programs are being considered for reducing oxides of nitrogen released to the atmosphere, recovering virtually all plutonium in high salt waste streams now cribbed, and diverting condensates with high contamination risk to tanked storage for evaporation.

It is felt that when the Hanford situation is viewed in perspective, taking into account the total site inventory in the ground and in the tanks, it is likely the conclusion will be reached that, from a safety point of view, it is better to leave the solidified salt in the tanks rather than risk the hazards of mining these tremendous quantities of radioactivity and transporting them to a distant storage site.

References

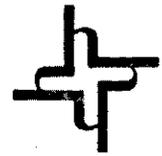
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4. Kirkman, MJ, GL Ritter and PW Smith "B Plant Production Schedule and In-Tank Solidification Alternatives," March 6, 1969, ARH-900 (Secret)

FIGURE II-15



III THE NATURE, PRESENT HANDLING, and STORAGE of CHEMICAL PROCESSING WASTES

P. W. Smith — Atlantic Richfield Hanford Company



Radioactive wastes have been accumulated at Hanford since 1944 when the first reactor fuel was processed for plutonium recovery. High level liquid wastes have been stored as neutralized slurries in 149 underground storage tanks of approximately 94 million gallons capacity. These wastes have fission product concentrations ranging from 100 $\mu\text{Ci/ml}$ to 20,000 Ci/gal. The corresponding heat generation rates are from negligible to 150 Btu/hr/gal. The wastes continue to be generated from uranium-plutonium separations processing in the Purex plant.

High level liquid wastes can be broadly categorized into high heat wastes and low heat wastes. High heat wastes consist of primarily Purex and Redox process solvent extraction wastes from fuels processing as shown in Table III-1. This material contains greater than 99% of the fission products in irradiated uranium fuels. It frequently

contains sufficient decay heat to self-boil until the short-lived fission products have decayed sufficiently so that the heat can be removed by other mechanisms. The Redox plant was shut down in 1966. Currently high heat wastes are being generated from the processing of aluminum and zirconium clad fuel in the Purex plant.

Low heat wastes contain relatively small quantities of fission products and associated decay heat. These wastes consist of stored bismuth phosphate and early Redox fuels processing waste, tributyl phosphate process wastes from an early uranium recovery program, process solvent wash wastes, and fuel cladding removal wastes, as indicated in Table III-2. Currently, only solvent wash wastes and fuel decladding wastes are being generated.

PROGRAM

Beginning in 1957 periodic progress and planning reports⁽¹⁾ were issued which traced the Hanford High Level Liquid Waste Management Program formulation. The following action plan was adopted:⁽²⁾

High Heat Wastes

- Remove long-lived heat emitters (⁹⁰Sr, ¹³⁷Cs)
- Package strontium and cesium for long-term storage as salts in capsules
- Treat residual salts as low heat wastes
- Store packaged isotopes onsite

Low Heat Wastes

- Evaporate to salt cake in existing tanks
- Remove or sorb free liquid
- Cap with sand, bentonite, or grout
- Stabilize ground surface

TABLE III-1

CHEMICAL	HIGH HEAT WASTES (CONCENTRATIONS IN MOLARITY)			
	CURRENT ACID WASTES		STORED NEUTRALIZED WASTES	
	PAW	ZAW	PUREX	REDOX
H	1.0	1.0	---	---
Na	0.7	0.4	3.5	7.0
Fe	0.25	0.26	0.35	---
Al	0.25	0.35	---	---
Zr	---	0.03	---	---
AlO ₂	---	---	0.2	1.2
NO ₂ -NO ₃	2.4	2.1	3.1	3.6
CO ₃	---	---	---	0.1
SO ₄	0.4	0.6	0.5	0.03
PO ₄	0.01	0.01	0.01	---
OH	---	---	pH 9 - 11	0.7
F	0.005	0.1	0.004	---
SiO ₃	0.1	0.01	0.1	---

TABLE III-2

CHEMICAL	LOW HEAT WASTES (CONCENTRATIONS IN MOLARITY)				
	NEUTRALIZED		COATING WASTE		PUREX ORGANIC WASH WASTE
	BIPO ₄	TBP	Al CLAD	Zr CLAD	
Na	7.0	8.0	5.0	3.0	0.15
Fe	0.1	0.06	---	---	---
Bi	0.03	---	---	---	---
Zr	---	---	---	0.4	---
AlO ₂	---	---	2.0	---	---
MnO ₂	---	---	---	---	0.02
NO ₂ -NO ₃	5.3	6.6	1.7	1.7	0.1
CO ₃	---	---	---	---	0.06
SO ₄	0.16	0.31	0.03	---	---
PO ₄	0.9	0.29	---	---	---
OH	---	0.18	1.2	---	0.03
F	0	0	0	2.9	---

This program provides a high degree of waste immobilization in a short time. The scheme assures reliable containment of the low heat wastes over a 50-100 year period and perhaps much longer. During this time additional technology and options can be developed for ultimate waste disposal if desired. The plutonium concentration in the immobilized low heat wastes will only be 100-5000 times the maximum permissible concentration in water.

- Necessity of keeping some sludges wet or cooled for safe heat dissipation
- 250,000 tons of contaminated salts in inventory
- Variety of waste chemical compositions to be treated
- Sodium salts are soluble and not readily converted to insoluble form
- Active interest in using long-lived isotopes that cause a long-term problem in heat dissipation
- Large volume of soil contaminated with plutonium and fission products
- Favorable site characteristics
- Availability of process facilities for modification
- Hazards of transporting large volumes of radioactive materials offsite
- Low cost for program implementation
- Lack of long-term acceptability consensus

ALTERNATIVES CONSIDERED

Based on program formulation guidelines, various alternatives were re-evaluated⁽²⁾ in August, 1967, and updated one year later to provide the best method of managing high level liquid wastes. Methods other than those described here were preliminarily reviewed but were not studied in detail due to apparent deficiencies in safety, technology, or economics.

High Heat Waste Treatment

Various schemes investigated for treating high heat and combinations of high and low heat wastes are summarized in Table III-3. Shown in the table is the time an alternative approach would begin operation if work

commenced immediately or has been initiated, and the date the program would end assuming the Purex plant would shut down in 1980. The status of process technology is also indicated. If the technology has not been satisfactorily established on a pilot plant basis, it would have to be demonstrated before detailed design and construction of facilities. Unique hazards are also noted. The indicated costs are total program processing costs through the year 2600. Costs include research and development, incremental operating costs in addition to existing programs, and capital costs. The funds are 1969 dollars at five percent discount rate. Long-term waste storage costs are not included. The alternatives are described below.

- **Fractionization—Cesium and Strontium Compacts**
Cesium and strontium would be removed from current and stored Purex wastes to reduce the waste heat content. The waste balance could be safely immobilized without compromising waste storage tank integrity. Cesium would be removed from selected stored Redox waste solutions and the associated high heat sludges would be air cooled in place. The waste balance would be concentrated and immobilized in existing underground waste storage tanks as a salt cake. The strontium and cesium would be converted to salts, doubly encapsulated, and stored onsite.
- **Solidification** B-Plant would operate as programmed in the fractionization case through FY-1976, processing all Purex wastes plus selected stored Redox process sludges and supernatant solutions.

TABLE III-3

HIGH HEAT	START FY	COMPLETE FY	TECHNOLOGY	UNIQUE HAZARDS	TOTAL COST THROUGH 2600 AT 5% DISCOUNT \$ MILLIONS
FRACTIONIZATION	68	81	ESTABLISHED	HIGH TEMPERATURE	78
COMPACT: Cs, Sr	74	81		HIGH TEMPERATURE	14
SOLIDIFICATION	78	82	PILOT PLANT	HIGH TEMPERATURE	97
HIGH AND LOW HEAT					
AIR COOLING DISPERSE AND SOLIDIFY	70	81	ESTABLISHED	LEAKS AND MINING	79
DECAY AND SOLIDIFY CS TANKS	69	2070	ESTABLISHED	LEAKS AND MINING	79
SS TANKS	69	2070			160
PERPETUAL TANK STORAGE CS TANKS	69	INDEFINITE	ESTABLISHED	LEAKS AND MINING	260
SS TANKS	69	INDEFINITE			480

Strontium and cesium products would be stored on an interim basis as solutions in B-Plant. A new calcination facility would begin operation in FY-1978 and continue operation through FY-1982 solidifying current acid wastes which would be blended with strontium and cesium product. Two stainless steel tanks would be provided for current acid waste storage during FY-1977 which would be used for fission product decay prior to processing the waste through the solidification plant.

- **Disperse and Solidify** Wastes would be dispersed into low heat content material and be evaporated to a salt cake in underground tanks with subsequent forced air cooling for salt cake temperature control as required. About 50 years of radioactivity decay would be required before air cooling could be eliminated.
- **Decay and Solidify** Wastes would be stored as a slurry until the heat of radioactive decay declines sufficiently, about 110 years, to permit evaporation to a salt cake in underground storage tanks without encountering excessive temperatures.
- **Perpetual Tank Storage** Wastes would be stored indefinitely as a slurry, transferring the wastes to a new tank as each tank nears the end of its useful life.

The deciding factors determining the choice of fractionization—Cesium and Strontium Compacts as the Hanford action plan were:

- Tank performance indicated prompt action required
- Technologies most compatible with available facilities
- Separated isotopes available for repackaging and storage at an alternate site

TABLE III-4

	START FY	COMPLETE FY	TECHNOLOGY	UNIQUE HAZARDS	TOTAL COST THROUGH 2600 AT 5% DISCOUNT \$ MILLIONS
ITS	65	85	ESTABLISHED	- - -	20
SOLIDIFY IN VAULT	75	85	ESTABLISHED	- - -	63
ASPHALT MATRIX IN VAULT	78	87	ESTABLISHED	SELF OXI- DATION RADIONUCLIDE MIGRATION	67
CALCINATION					
a) CALCINATION	78	87	PILOT PLANT	LARGE SCALE EQUIPMENT	78
b) CALCINATION- MELT	78	87	PILOT PLANT	HIGH TEMPERATURE	79

Low Heat Waste Treatment

The alternatives studied for low heat wastes are summarized in Table III-4, similar to the high heat wastes.

- **In-Tank Solidification** Wastes would be concentrated and solidified in existing underground storage tanks by evaporating water from the stored salt wastes to form a salt cake for long-term storage in place. Any supernatant liquid not crystalizing would be slowly evaporated with an air flow, sorbed in a solid used as tank filler, or pumped back to the concentrator for reconcentration.
- **Solidify in Vault** Wastes would be slurried from the tanks to an evaporator constructed at the site of a new vault so that the concentrate could discharge directly into the vault for crystallization. Any residual mother liquor would be immobilized as in the previous case.
- **Asphalt Matrix in Vault** Wastes would be slurried from the tanks combined with an asphalt emulsion and the liquid evaporated to form blocks of asphalt which would incorporate the salts and radioisotopes. This operation could be conducted in modified separations processing facilities.
- **Calcination** Wastes would be slurried from the tanks to a new calcination facility, possibly located in a modified separations plant, and converted to a dried sulfate cake at about 400°C. The calcine would be packaged in carbon steel containers for transfer to storage.

The deciding factors in determining the choice of In-Tank Solidification were:

- Safety promptly improved
- Advantages of alternatives not quantifiable
- Future actions not precluded
- Prompt action avoided need for new tanks
- Alternatives more costly
- Compatibility with evolving criteria not yet established

Long-Term Waste Storage Alternatives

Different methods were reviewed for long-term storage of high and low heat wastes generated up to Purex shutdown, Table III-5. Costs are total program costs in 1969 dollars at a five percent discount rate through the year 2600 and contain required research and development, incremental operating, and capital funds.

● **Existing Tanks** Solid wastes from the In-Tank Solidification Program stored as dry salt cakes in underground onsite tanks would be prepared for long-term storage by:

- Adding sand or grout to fill the tank dome
- Capping the structure with rock and gravel to resist wind erosion.

The completed structure would be about 10 feet below grade and about 150 feet above the water table.

● **Salt Mine** Solid wastes would be transported to a salt mine for long-term storage. It is assumed that an organization would be actively engaged in storing radioactive wastes in a salt mine. The estimated costs are those required to mine, package, ship, and accept the postulated waste packages as required from Hanford.

● **Onsite Vault** A monolithic structure about 60 feet below grade would be used. A location about two miles south of 200 East Area was selected as the best site for the vault. The soil in that vicinity has very low permeability, and current data indicate that the groundwater in the vicinity will take about 10,000 years to reach the Columbia River.

● **Deep Underground** The basalt layers extending at least 10,000 feet below the Hanford site are being considered as a potential storage site for radioactive materials. The solid or liquid wastes would be transported to and stored in a deep underground cavern. An active research and development program is being undertaken to determine the technical feasibility and safety of disposing of liquid or solid wastes in the basalt. The integrity and permeability of the basalt and interbeds will be investigated.

Long-term waste disposal methods for wastes have not been finally decided. It is presently planned to in-tank solidify low heat wastes and leave them in existing tanks. This method of waste storage does not preclude the possibility of waste relocation and provides rapid and safe waste immobilization.

WASTE STORAGE IN UNDERGROUND TANKS AND OPERATIONAL CONTROLS

High level liquid wastes from the chemical processing plants at Hanford have been stored as alkaline slurries in underground tanks since startup. Currently, liquid wastes in-process are being stored on an interim basis. The complex of waste storage tanks includes 149 tanks, ranging in capacity from 50,000 to 1,000,000 gallons. The sixteen 50,000-gallon tanks are 20 feet in diameter by 19 feet high carbon and stainless steel tanks in concrete structures. These tanks were used in the past for processing activities. The other storage tanks are underground reinforced concrete with carbon steel liners. The liners are 75 feet in diameter and vary from 18 to 32 feet high. The liners are from one-fourth to three-eighths-inch thick and not bonded or anchored to the concrete. There are no columns to support the concrete dome which is exposed to the tank vapors.

Nonboiling Waste Tanks

The first tanks were built for low-heat wastes as shown in Figure III-1. All of these tanks are vented to the atmosphere, some through air-cooled reflux condensers. Instrumentation is provided to measure the sludge and supernatant temperature, as well as the liquid and sludge levels in the tanks. A grid of dry wells in each tank farm is used to monitor the soil for radioactivity.

The primary control for preventing leakage from a non-boiling tank is to maintain the integrity of the tank liner. Thermal stresses in a tank concrete support shell are minimized by limiting the rate of temperature change allowed. Pressure stresses are prevented by the open venting to the atmosphere. The pH of the waste is controlled to keep corrosion to a minimum. Those leaks which have occurred have been at relatively slow rates and were detected by loss of liquid level in the tanks and/or radiation

TABLE III-5

LONG-TERM STORAGE ALTERNATIVES AT 5% DISCOUNT TOTAL COSTS THROUGH 2600				
MILLIONS OF DOLLARS				
	SALT MINE	ON-SITE VAULT	DEEP UNDERGROUND	EXISTING TANKS
HIGH HEAT WASTES				
COMPACT: Cs, Sr	2.0	2.0	--	--
SOLIDIFIED	1.2	1.7	--	--
LOW HEAT WASTES				
ITS	250	--	75	5
SOLIDIFY IN VAULT	--	25	--	--
ASPHALT	250	45	--	--
CALCINE	300	45	--	--
CALCINE-MELT	300	30	--	--

measurements in the soil surrounding the tanks. Wastes from leaking tanks have been pumped to spare storage space in other tanks.

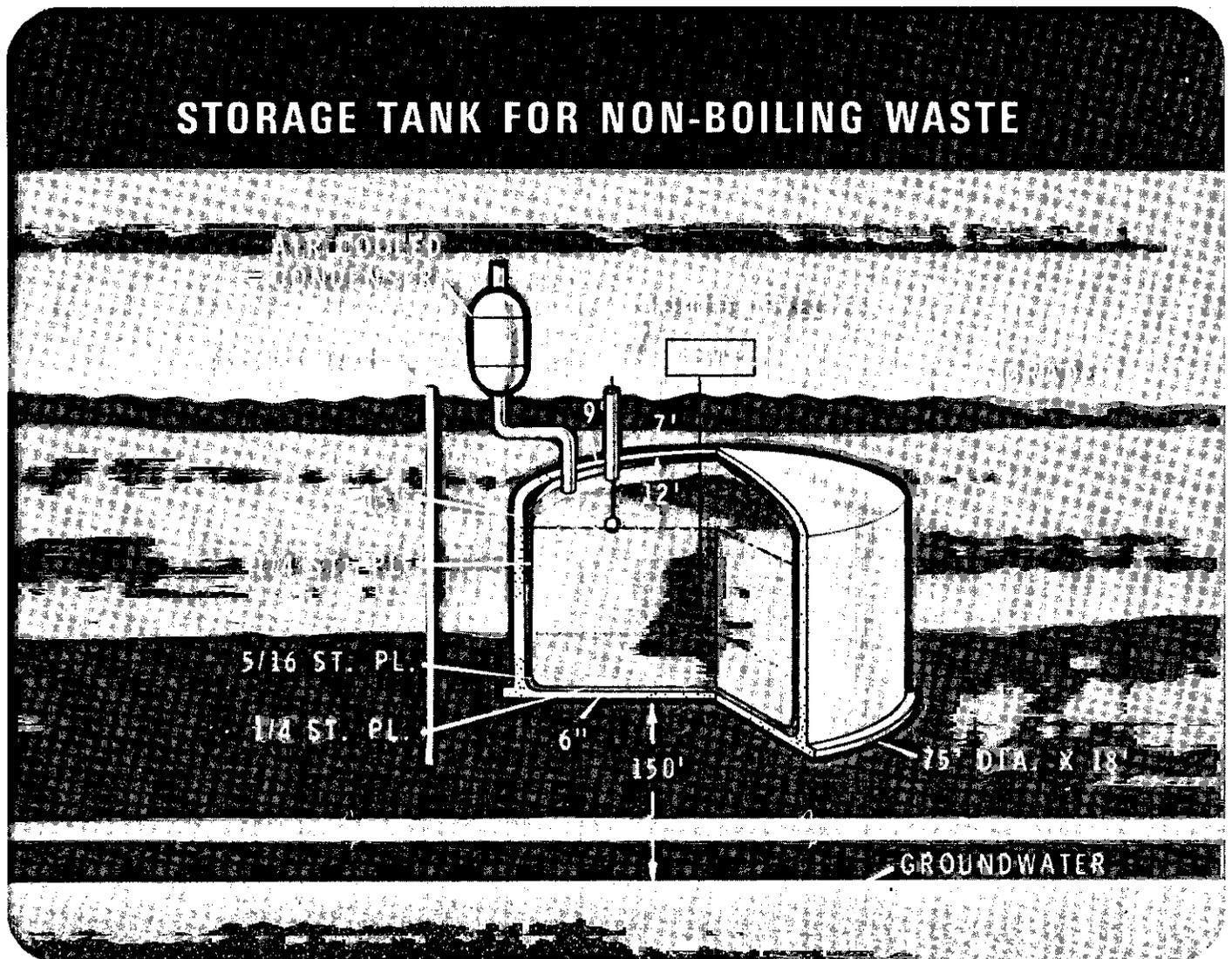
Boiling Waste Tanks

Later, tanks were built to contain wastes with greater heat generating characteristics as shown in Figure III-2. These tanks are of the same general construction as those described for nonboiling wastes. Additional features have been provided, however, to permit self-concentration of waste. Vapors from stored Purex wastes are routed through headers to a York demister, condenser, another York demister, heater, filter, and an exhauster. Condensate is routed to an underground crib or is returned to the waste tank to

prevent over-concentration. The tanks are provided with air-lift circulators to prevent superheat in the liquid which can cause bumps from sudden steam releases if not controlled. These air circulators also keep some sludge in suspension which helps minimize settled sludge temperatures. Each tank is closely encompassed by vertical and horizontal dry wells so that any leak may be detected by monitoring for radioactivity in the soil surrounding the tank. Some of the tanks have a drainage grid beneath the tank liner which connects to an associated leak-detection well. A temperature element, liquid level instrumentation, and a radiation detector may be located in each well.

The principal method for minimizing the possibility of leakage from a boiling waste tank, like the nonboiling waste tank, is to maintain the integrity of the tank liner. Tanks are heated at a controlled rate prior to receiving wastes. This controlled heatup at less than 5°F per day minimizes stresses in the concrete support shell and

FIGURE III-1



allows the gradual removal of water from the concrete which could vaporize and bulge the liner upward if trapped beneath the liner. A volume of 800 gallons of water was collected from runoff between the liner and concrete during tank 104-AX heatup. Temperatures in tanks receiving wastes are controlled by limiting the slurry salt concentration, total heat content and by agitating the stored solutions. Pressure stresses are limited by controlling the vapor space pressure. Corrosion effects are minimized by controlling the pH of the waste slurry. The possibility of atmospheric contamination is minimized by maintaining the tank vapor space under a slight negative pressure, filtering the noncondensable gases, and diluting the explosive gases, primarily hydrogen generated by radiolysis.

The few leaks that have been encountered in boiling waste tanks have been detected in the soil monitoring grid except

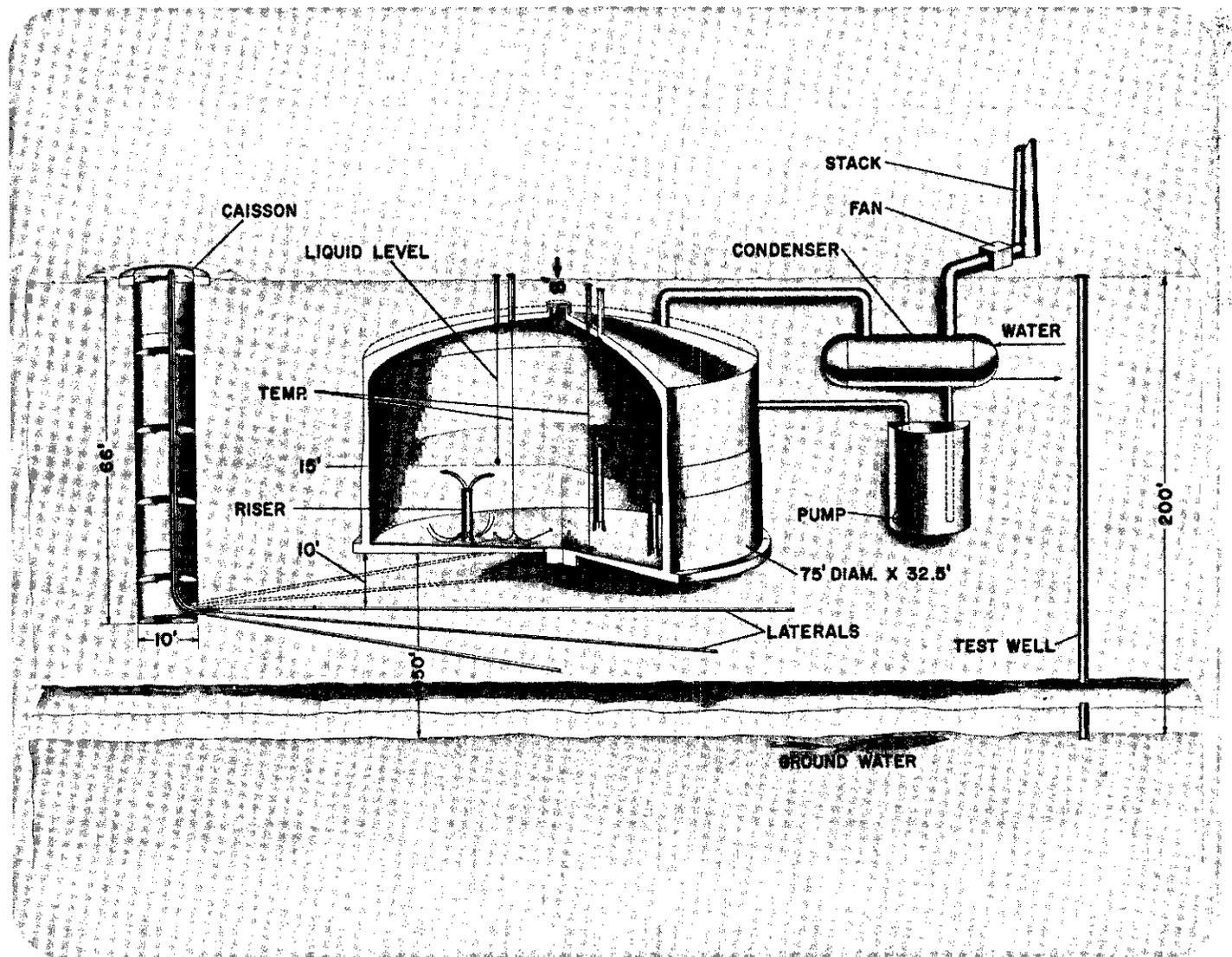
for one which was discovered by a liquid level decrease. The wastes were pumped from the leaking tanks to appropriate spares.

Future tanks to store high heat wastes will be of double shell (tank in tank) design to improve integrity, waste containment and leak detection.

Tank Storage Experience

Of the 149 waste storage tanks constructed at Hanford, 11 of them have leaked stored solution^(4,5). Seven of these tanks have been boiling waste storage tanks. The total amount of ¹³⁷Cs released to the ground is estimated to be about 140 KCi in 240,000 gallons of solution. The associated strontium and plutonium is estimated to be

FIGURE III-2 Storage tank for boiling waste.



small compared to the cesium released since 95% or greater of these elements is precipitated in the tank sludge. Waste tank leakage history is summarized in Table III-6.

Breaches in a tank liner generally allow solution to leak at a slow rate. There are two methods by which leaks can be detected, liquid level measurement and radiation monitoring in wells or laterals adjacent to the tanks. Once a leak is detected a pump is installed in the tank and the solution removed. Depending on the heating characteristics of the sludge, it may be left in place either uncooled, air cooled, or removed by hydraulic sluicing. Hanford experience has shown that a leak of high salt solution will normally self-seal after a small amount of waste has entered the soil due to formation of salt crystals in the tank liner cracks or concrete and/or in the soil surrounding the cracks. It is estimated that a 50,000-gallon leak could be safely retained by specific retention in the soil without approaching the regional groundwater. About 50,000 gallons leaked from a failed SX Farm tank and activity penetrated no more than about 15 feet below the tank.

An important tank failure history is that of tank 105-A. Tank 105-A was built in 1955 to receive neutralized Purex boiling wastes. From May, 1962, to January, 1963, the tank was used to store supernatant solutions from other A Farm tanks. These solutions were transferred to nonboiling waste and the tank began receiving wastes from Purex in February, 1963, with self-concentration starting shortly thereafter. Low intensity radiation was detected in one lateral beneath the tank when it was half filled. The leak became inactive after one week, and radiation readings

indicated the leak had been small. Use of the tank was continued because no spare tank was available at the time. After December, 1964, no further wastes were added to this tank. In January, 1965, a sudden steam release occurred while the airlift circulators were in operation. This release appeared more intense than previous tank incidents without circulator operation. Inspection did not reveal any major damage to the tank or equipment, and tank operation continued with additional surveillance. In March, 1965, the radiation level increased under the tank. Further tank inspection and mapping showed that the tank liner was bulged up to a maximum of 8.5 feet, creating a void space of about 80,000 gallons between the liner and the concrete shell. One of the airlift circulators on top of this bulge was skewed.

In April, 1967, a cyclic liquid level variation began. A typical cycle consisted of a 9-10 inch drop in liquid level in a matter of minutes followed by a relatively stable period of about 20 hours. The liquid level then returned to its original level in about a day. No significant liner movement could be detected. This liquid level variance is believed to be caused by vaporization and condensation of the liquid beneath the bulge in the liner. The possibility of heat producing solids being transferred under the bulge with the rapid liquid level variance which could result in local high temperatures became a new concern.

A program was initiated to remove the tank liquid and sludge. The solution was pumped from the tank and the remaining heel was diluted with cesium-denuded tank farm supernatant solutions. This pumping and dilution removed about 94% of the cesium and 30% of the strontium. Subsequent sluicing of the tank with dilute supernatant solution removed an additional 35% of the strontium from the tank which finally reduced the total-heat content tenfold. Additional sluicing was ineffective because the remaining sludge cakes have a one to two-inch hard layer on top. Tank inspection by photography showed the liner bulge, a breach in the liner, and the sludge cakes (Figures III-3 and III-4).

Laboratory data indicate that these sludge cakes could be softened with inhibited 1M sulfuric acid and the remaining sludge could then be removed. It is planned to add a portion of the required acid in the near future to evaluate the laboratory data on a plant size basis. If successful, the remainder of the sludge will be treated with the inhibited sulfuric acid and sluicing will be resumed to remove this sludge. The bulge will be vented and the area under the liner will be investigated to determine if sufficient sludge is deposited to require additional sluicing.

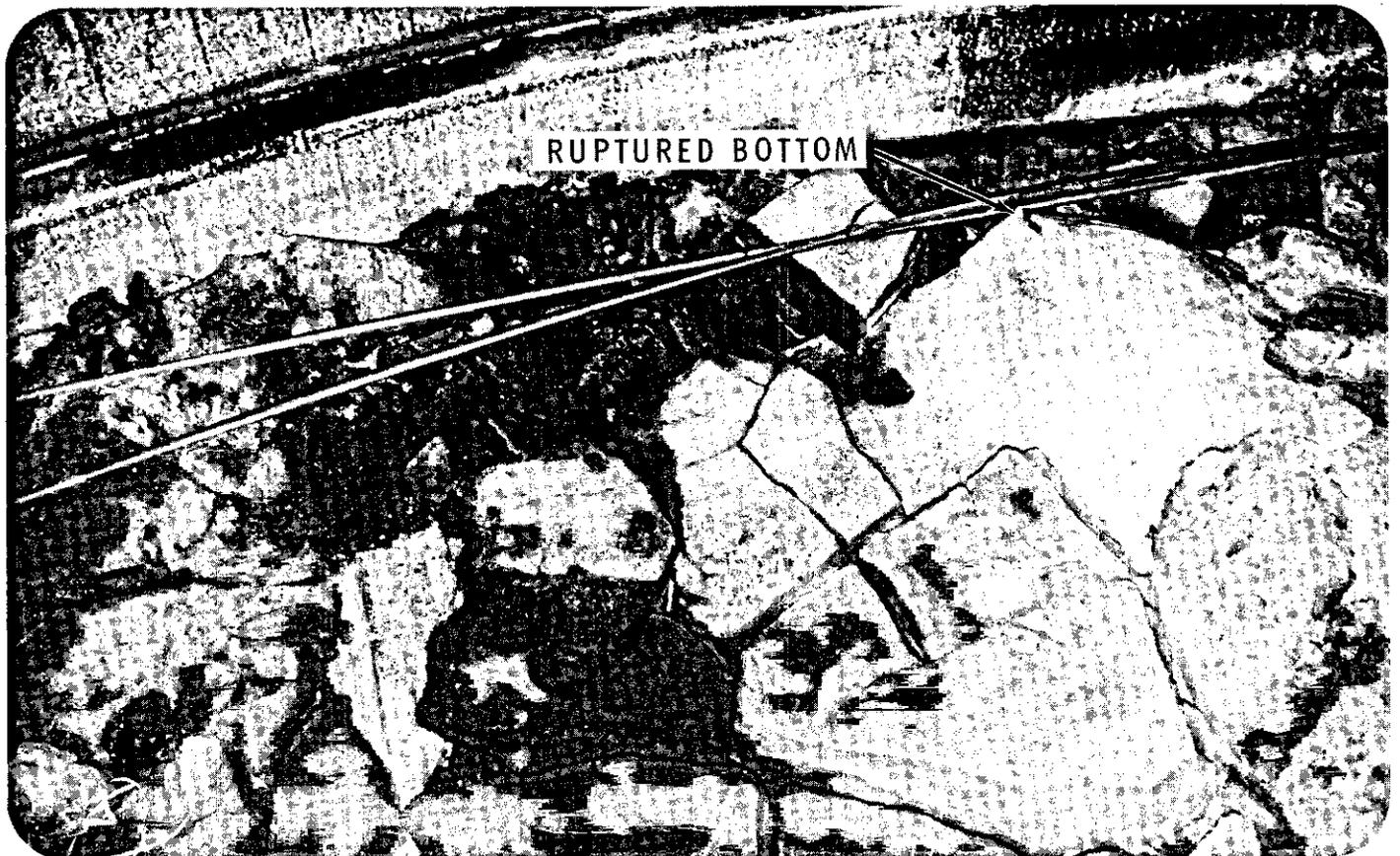
TABLE III-6

WASTE STORAGE TANK FAILURES						
	TANK	TYPE WASTE	TANK LIFE MONTHS	VOLUME LOST GALLONS	MATERIAL LOST KCI ¹³⁷ Cs	PRESENT STATUS
BOILING	105-A	PUREX	11	VERY SMALL	- -	EMPTIED
	107-SX	REDOX	83	VERY SMALL	- -	AIR COOLING
	108-SX	REDOX	73	2,400	17	AIR COOLING
	109-SX	REDOX	101	VERY SMALL	- -	FILLED
	112-SX	REDOX	155	30,000	45	AIR COOLING
	113-SX	REDOX	3	15,000	8	EMPTY
NON-BOILING	115-SX	REDOX	78	50,000	40	EMPTY
	105-TY	TBP	104	35,000	4	EMPTY
	106-TY	TBP	74	20,000	2	EMPTY
	101-U	REDOX TBP	153	30,000	23	EMPTY
	104-U	TBP	73	25,000	0.09	EMPTY
	11 TANKS			237,000	139	

FIGURE III-3 Tank 105-A bulged bottom.



FIGURE III-4 Tank 105-A liner breach.

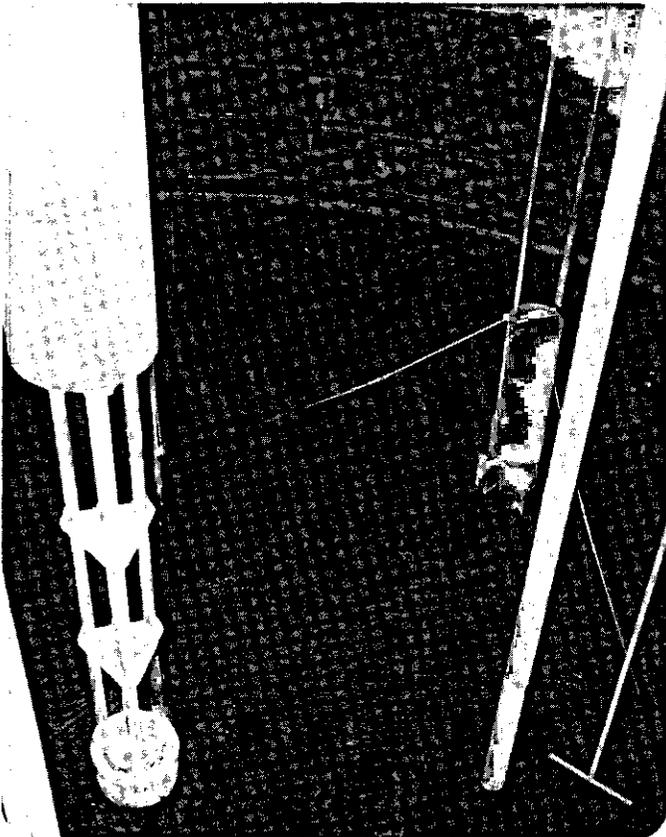


Sluicing experience in another boiling waste tank, TK-101-A, indicates that the tank 105-A sludge removal problem may be unique. Tank 101-A was prepared for use as a spare boiling waste tank by sluicing with dilute supernatant solution with the sludge being easily removed to another tank. During the final stages of sluicing, water was used to sluice two or three resistant sludge mound areas with good success. Figure III-5 shows the interior of tank 101-A with about seven inches of liquid remaining and essentially free of sludge.

Spare Tank Criteria

A sparing philosophy has been formulated⁽⁶⁾ to provide emergency storage reserve at all times. It may be summarized as requiring a minimum of two unoccupied tanks of the present single steel shell design in each boiling waste storage area or one tank of the double shell design currently under construction. Previously, one single steel shell tank had been considered an adequate spare for each boiling waste storage area. However, this sparing philosophy has been compromised in the past when only nonboiling waste tank space was available for emergencies (boiling wastes would have been diluted had an emergency developed) and at present when only one single shell tank is available as a spare for a few months.

FIGURE III-5 Tank 101-A sluiced.



For nonboiling waste, at least two million gallons of useful storage reserve is maintained at all times.

WASTE MANAGEMENT PROGRAM

A schematic diagram of the current high level liquid waste management program is presented in Figure III-6. Self-boiling liquid wastes which have been generated and stored in underground tanks since about 1951 are now being processed in B-Plant, an old separations plant modified for high level waste processing, for removal of ^{137}Cs and ^{90}Sr . The resulting wastes are then solidified by evaporation and crystallization of the residual bulk salts in tanks. Removal of the cesium and strontium from high heat wastes is necessary prior to solidification to prevent abnormally high temperatures in the salt cakes. Currently generated self-boiling wastes are being treated similarly except that an aging period of from five to seven years is required to permit short-lived fission products to decay, before the residual salt waste can be in-tank solidified. Low heat, nonboiling waste is being processed directly to salt cakes.

Waste Fractionization

Stored high-level liquid wastes and current Purex acid waste are processed in B-Plant for removal of ^{90}Sr and ^{137}Cs .^(7, 8) The supernatant solutions in the stored alkaline wastes are processed by ion exchange for removal of the cesium. The cesium product is concentrated and stored in B-Plant tanks prior to encapsulation. The alkaline sludges are sluiced from the tanks, acidified, and transferred to B-Plant for strontium removal. After a pretreatment using a lead-carrier sulfate precipitation flowsheet with a carbonate metathesis step to remove the bulk of the nonradioactive cations, the strontium is recovered by di(2-ethylhexyl)phosphoric acid (HDEHP) solvent extraction in four pulse columns. The strontium nitrate product is concentrated and stored in B-Plant tanks prior to encapsulation.

Currently generated Purex acid wastes are processed in B-Plant to remove both the strontium and cesium. 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 (PTA). The recovered cesium is further processed by ion exchange. Strontium is recovered by processing the acid waste through the solvent extraction system. All B-Plant wastes from treatment of current acid waste are sent to interim boiling waste storage for five to seven years to allow the short-lived fission products to decay prior to in-tank solidification.

Strontium and Cesium Encapsulation⁽⁹⁾

The strontium removed from current acid waste and stored sludge will be purified by a second solvent extraction cycle and doubly encapsulated as strontium fluoride in a new facility constructed adjacent to B-Plant. The cesium will be purified by a second ion exchange cycle and doubly encapsulated as cesium chloride. The encapsulated cesium and strontium will be cooled in water basins for several years prior to transfer to the long-term storage site.

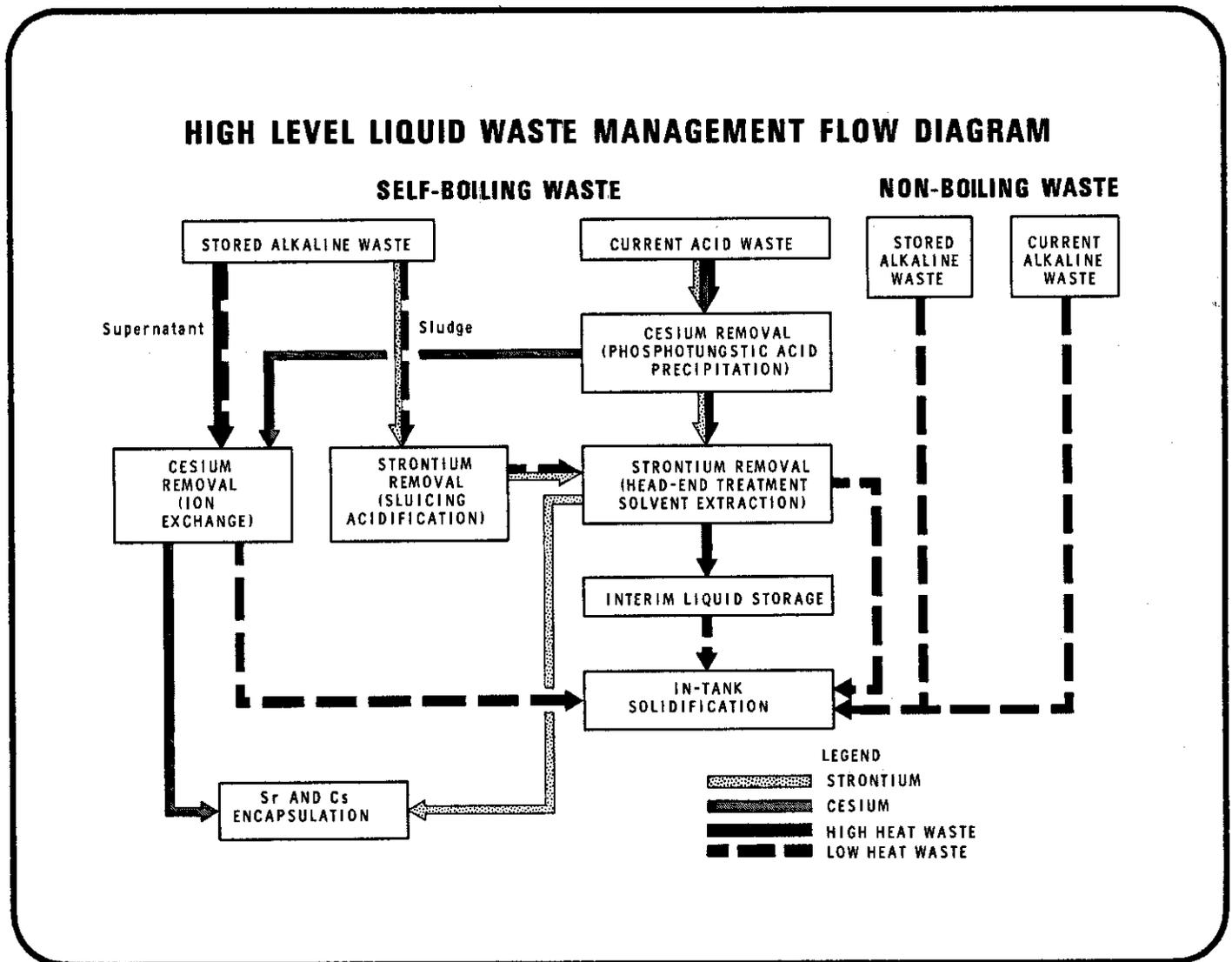
In-Tank Solidification

Nonboiling wastes are solidified in existing tanks by evaporation and crystallization upon cooling following removal of the ⁹⁰Sr and ¹³⁷Cs heat emitters where necessary. There are three types of evaporators in operation.^(6, 10) One unit is a heated air unit in which about 3000 cfm of air at 1200°F is supplied to an airlift circulator in a waste storage tank. A second unit is a large electric immersion heater (4000 KW) installed in an airlift circulator in a storage tank. The third

unit is a conventional steam heated tube bundle evaporator of about six million Btu/hr capacity. The evaporator units are operated on a recycle basis which permits solids to build up in air-cooled bottoms receiver tanks and the supernatant solution to be returned to the evaporator.

The electric immersion heater is shown in Figure III-7. The off-gas treatment facilities and operational mode are similar to the other units. The feed is pumped to the evaporator tank where it is concentrated to about 10% solids volume. The concentrate is pumped to a cascade of cooling tanks for further solids formation and deposition. The supernatant is recycled with fresh feed. The off-gas system includes a de-entrainer, a condenser, a cyclone separator, another de-entrainer, and high efficiency filters. The condensate is routed to a crib and the gases are vented to the atmosphere through a stack. The condensate's radioactivity is near low level waste concentrations and

FIGURE III-6



the gases are well within release guide considerations. A quadrant of the immersion heater is shown in Figure III-8. Figure III-9 illustrates salt cake forming in a concentrate receiver, and Figure III-10 shows dried salt cake.

Operational controls are exercised to ensure safe operation of an in-tank solidification system. Several steps are taken to minimize the possibility of breaching a tank liner. Thermal stress in the concrete support shell is limited by controlling the rate of temperature change during operation. The maximum temperature following solidification is limited by controlling the amount of fission product decay heat in a tank. Pressure stresses are limited by controlling the vapor space pressure. Liner corrosion is minimized by appropriate solution pH control. Condensate from the evaporator is routinely sampled and monitored for activity. Condensates may be recycled to the tank when required to prevent out-of-guides release to the ground. Activity releases to the atmosphere are minimized by filtering noncondensable gases, monitoring off-gas activity, and discontinuing operation if the activity reaches an unacceptable level. The equipment is protected by process composition limits, heater operation limits, and electrical

fail-safe devices. The feed composition for an evaporation unit is controlled to minimize the potential for an explosive hazard.

PROGRAM RESEARCH AND DEVELOPMENT

An active research and development⁽¹¹⁾ program is being maintained to support the high level liquid waste management program. Studies are being directed primarily at optimizing current program processes, reviewing other approaches to the program, and demonstrating strontium and cesium encapsulation technology. Some of the areas receiving emphasis in high heat waste processing are:

- B-Plant solvent degradation studies
- Mathematical model for B-Plant solvent extraction performance
- N-Reactor fuel crushing and leaching
- Investigation of alternative processes for solidifying Purex current acid wastes
- Alternative Purex process reductants to reduce materials undesirable in Purex acid wastes for waste processing.

FIGURE III-7

IN-TANK SOLIDIFICATION

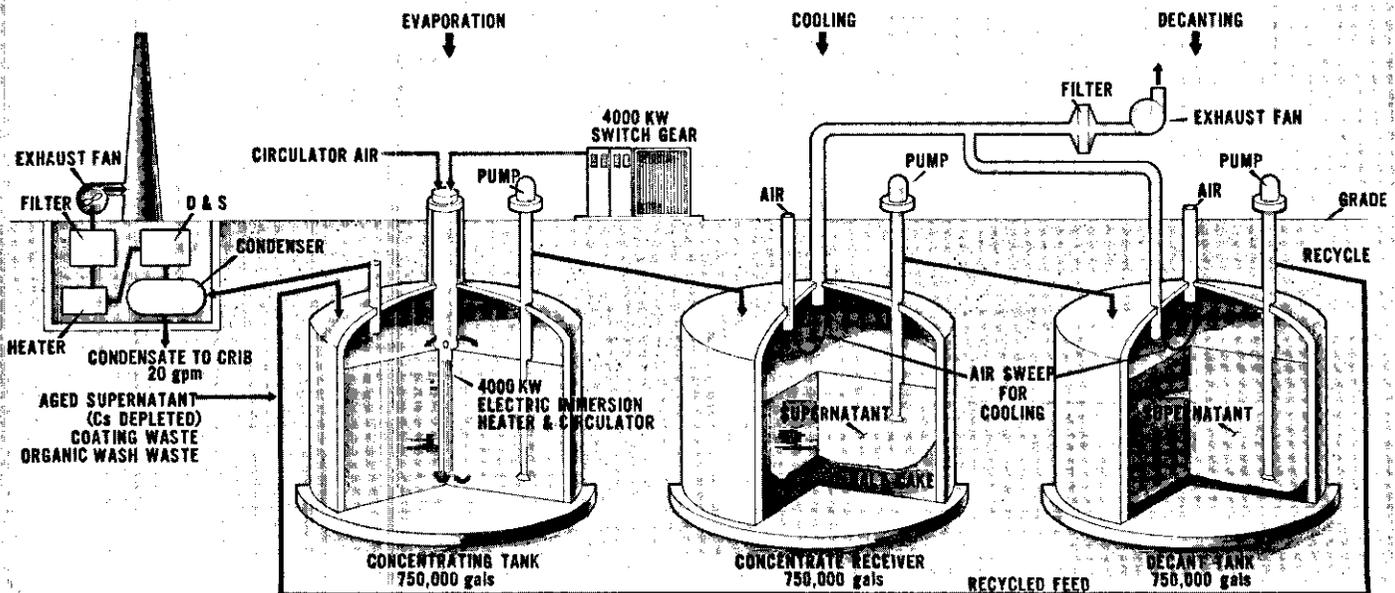
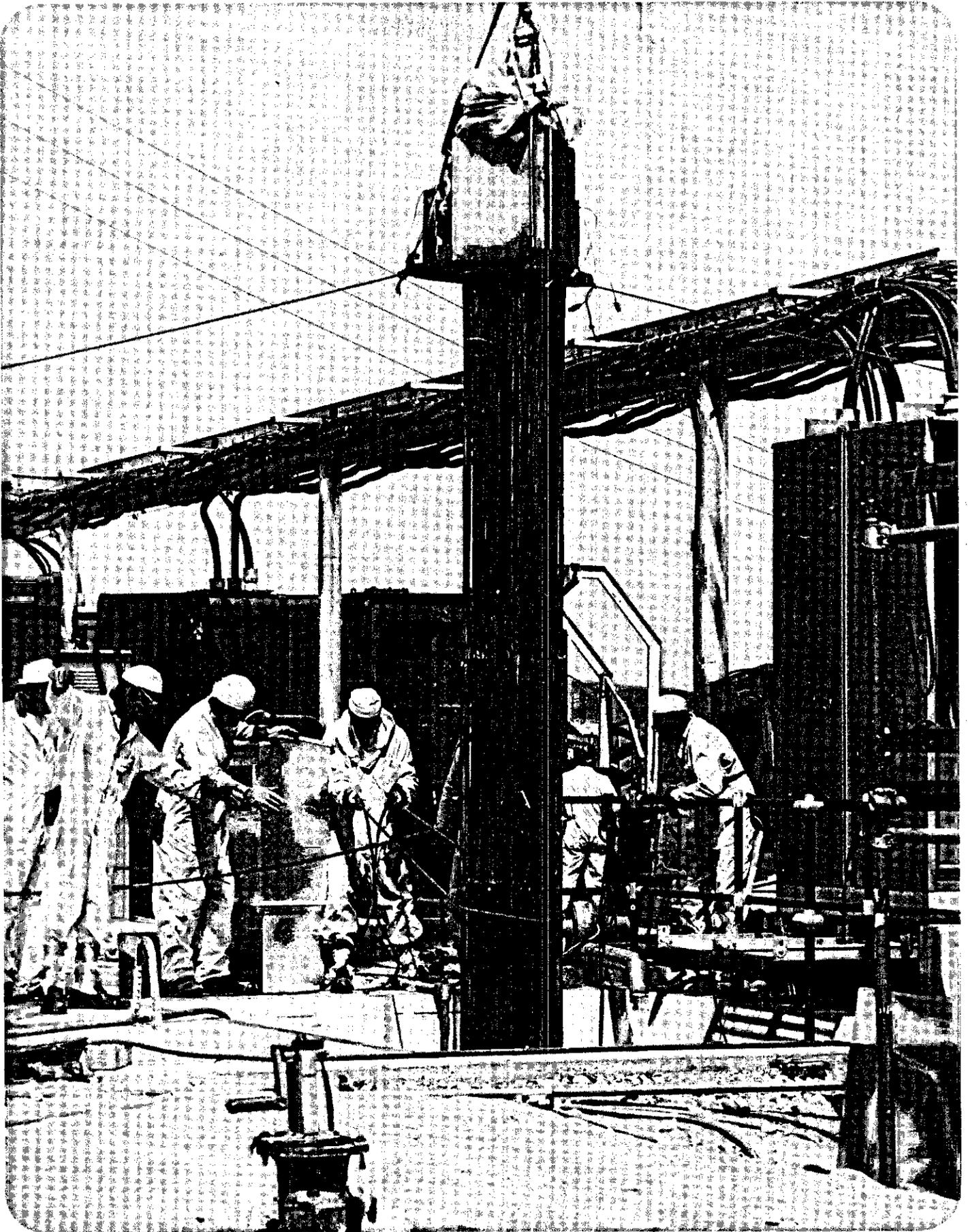


FIGURE III-8 ITS-2 Immersion heater quadrant.



Studies being carried out for strontium and cesium waste encapsulation include:

- Capsule-compound compatibility
- Flowsheet demonstration and optimization
- Compound compacting methods
- Thermal calculations — capsule sizing
- Process equipment materials and process compatibility.

References:

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2. ISO-981, P. W. Smith and R. E. Tomlinson, "Hanford High Level Waste Management Re-evaluation Study," August 31, 1967.
3. G. L. Ritter and P. W. Smith, "Attachment A—Discussion of DRDT Comments on the Hanford Waste Management Program," letter report.
4. RL-SEP-700, R. E. Tomlinson, "The Possible Need for New Waste Storage Tanks at Hanford," August 30, 1965.
5. BNWL-CC-701, J. R. Raymond and E. G. Shdo, "Characterization of Subsurface Contamination in the SX Tank Farm," June 13, 1966.
6. CPD-220, O. J. Elgert et al., "Hanford Radioactive Waste Management Plans," January 20, 1969.
7. ARH-564, D. E. Larson, "B-Plant Recovery of Cesium from Current Acid Wastes by Phosphotungstate Precipitation," April 22, 1968.
8. ISO-986, D. E. Larson, "B-Plant Phase III Flowsheets," August 31, 1967.
9. ARH-916, H. L. Caudill et al., "High Level Waste Packaging and Storage, Waste Management Program Budget Facility Study."
10. ARH-905, W. L. Godfrey and P. W. Smith, "Evaluation and Status of In-Tank Solidification," November 1, 1968.
11. ARH-1009, R. E. Isaacson and R. E. Tomlinson, "Atlantic Richfield Hanford Company — Semiannual Report — Research and Development — May 1, 1968 through October 31, 1968," December 31 1968.

FIGURE III-9 Tank 116-TX wet salt cake.

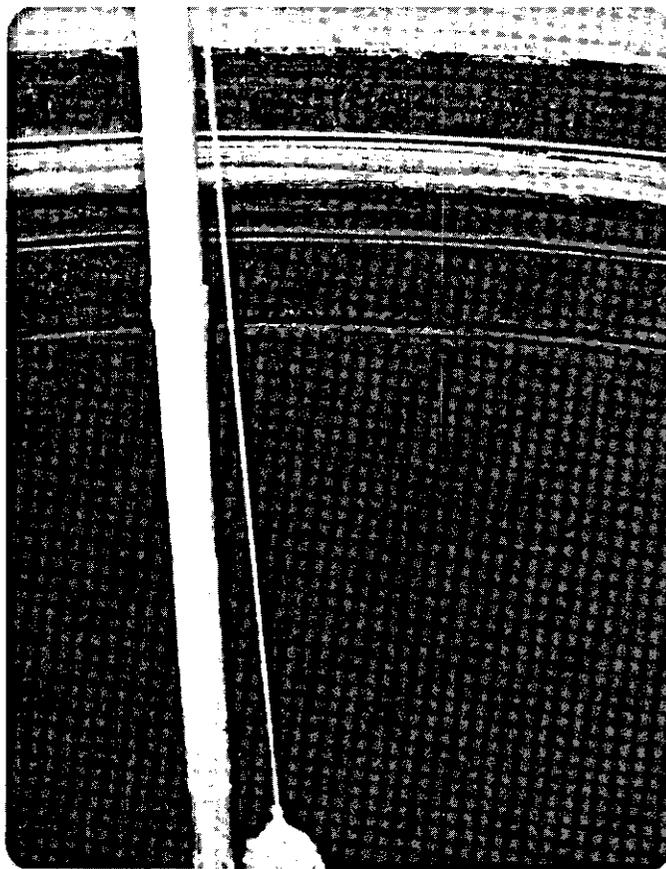
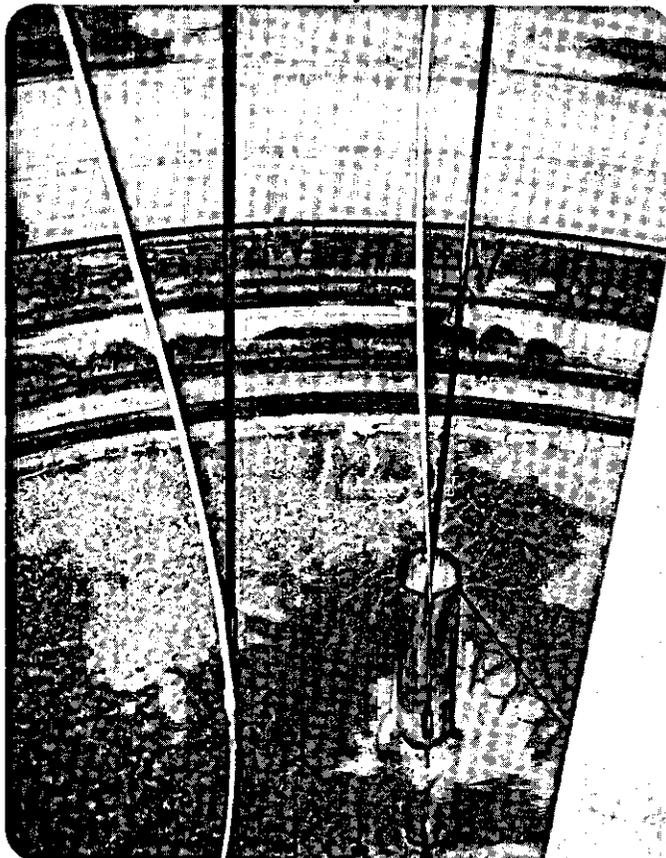
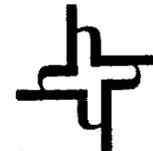


FIGURE III-10 Tank 108-SX dry salt cake.



IV FUTURE OPTIONS in LONG-TERM WASTE STORAGE

R. E. Isaacson — Atlantic Richfield Hanford Company



LONG-TERM STORAGE OBJECTIVE

The objective in long-term storage of Hanford's radioactive wastes is to effectually isolate radionuclides from man's biosphere to the extent that he and his environment will in no way be exposed to deleterious quantities. The wastes must be confined as long as is necessary to ensure that concentrations of radionuclides harmful to man, or to his environment do not migrate into his biosphere.

LONG-TERM RADIOACTIVE WASTE STORAGE CONSIDERATIONS

The most important consideration in evaluating methods for storing radioactive wastes over long time periods (hundreds of centuries) is the relative safety afforded by the various methods. Of secondary importance are the costs of the storage methods. Safety may be achieved by relying on the natural environment in which the waste is placed for confinement and/or upon an engineered (man-made) environment. The latter would probably be used to supplement nature in providing greater assurance for long-term safety.

A true "ultimate" radioactive waste disposal method would not require any surveillance to ensure complete confinement of the wastes. The waste would be irretrievable so that man could not accidentally nor wilfully come into contact with the waste. Two ultimate disposal methods have been suggested to date which would meet these two criteria: physically removing the waste from the earth or transmuting the radionuclides into non-radioactive species. An example of an ultimate waste disposal method would be to shoot the waste into the sun. At the present time, however, this particular method is not technically nor economically feasible so that methods for safely storing the waste on the earth over the long term must be utilized until technology needed to implement an ultimate disposal method is developed. All methods currently under development will require surveillance although in some cases, such as storage in salt mines, it may be minimal. The concept of retrievability, defined to indicate the relative ease by which the waste can be removed from its long-term storage site, becomes an important consideration if agreement is reached that these wastes must be stored until an ultimate waste disposal method is available.

FACTORS FAVORING HANFORD AS A LONG-TERM WASTE STORAGE SITE

General Factors

There are numerous factors which favor Hanford as a long-term radioactive waste storage site. First, the long-term storage would be at the site where the waste is generated. This would avoid the attendant hazards of shipping radioactive wastes over public transportation routes. Second, the site is in a region of low population density (25 miles to the nearest population center). Third, it is removed by several hundred miles from an international boundary. Fourth, it is owned by the U.S. Government.

According to Housner,⁽¹⁾ the site has not been subjected to more than weak ground shaking during historical times, and is in a region of moderate seismicity, verging on minor seismicity. Jones and Deacon⁽²⁾ indicate that tectonic processes resulting in major deformation of the earth's crust follow major fault zones and that persistently active tectonic zones can be identified by recurrent earthquake epicenters closely spaced along lineations which are related to known and hidden faults. Hanford does not lie in a persistently active seismic zone. Jahns⁽³⁾ states that "the possibility of surface ground rupture due to upward propagation of displacement along any fault in the Hanford facility area is so remote that it can be safely disregarded."

Factors Favoring Storage Above the Water Table

In addition to these general factors, there are conditions somewhat unique to Hanford which make long-term storage above the water table attractive. The site enjoys a semiarid climate compared to surrounding areas in the

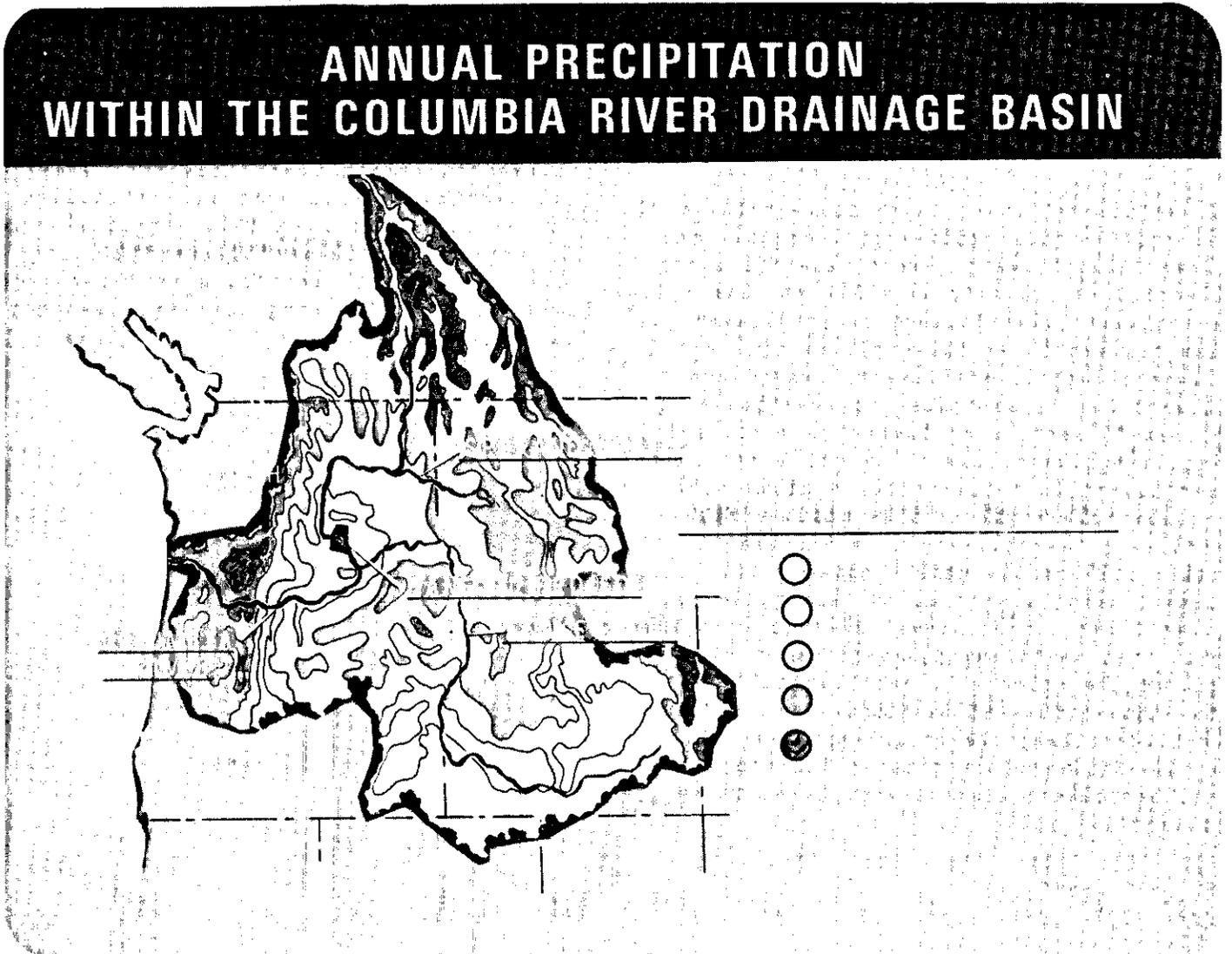
Columbia River Drainage Basin⁽⁴⁾ as shown in Figure IV-1. The height of the Cascade Mountain Range to the west of Hanford, and their continuity from Canada to California, is the major factor which prevents heavy precipitation from occurring on the site. Table IV-1 lists pertinent data on precipitation history at Hanford. Contrary to what some might expect, the annual precipitation at Hanford has not increased in recent years due to increased irrigation in the Columbia Basin. The lowest precipitation on record occurred in 1967 and the fourth lowest occurred in 1965.

TABLE IV-1

HISTORY OF PRECIPITATION AT HANFORD (1913-1968)			
	INCHES	RECENT PRECIPITATION, IN.	
AVERAGE ANNUAL	6.1	1962	6.0
MAXIMUM (1950)	11.5	1963	6.3
MINIMUM (1967)	3.3	1964	5.4
AVERAGE GREATEST SNOW DEPTH	4.3	1965	3.7
MAXIMUM SNOW DEPTH ON GROUND (1969)	12.0	1966	5.9
MAXIMUM CUMULATIVE SNOWFALL (1916)	26.0	1967	3.3
		1968	6.0

Figure IV-2 shows the annual precipitation data for the period 1913 through 1968 plotted on probability paper.⁽⁵⁾ It is interesting to note that the data from 50 years of record would predict the probability of exceeding 18 inches of precipitation to be only 1 in 10,000 years. Climatological and geologic evidence suggests that the area has enjoyed a semiarid climate for the last 10,000 to 20,000 years (since the last ice age). Future precipitation is expected to remain low for thousands of years. The presence of the

FIGURE IV-1



Cascade Mountains, with the attendant meteorological changes in the air masses moving over them, result in atmospheric conditions over the Hanford reservation which virtually eliminate heavy precipitation at Hanford. These mountains should exist with little change in elevation for several thousand years.

Because of the semiarid conditions which have existed at Hanford since the last ice age, the water table ranges from 175 to 335 feet below ground surface at the 200 Area plateau. Studies, based on field data, have shown that the amount of moisture in the soil above the water table is near the residual moisture saturation level, or below that level of moisture content at which water moves through the sediments as a liquid phase. These studies show that the underlying sediments act like a blotter and are capable of retaining additional moisture for long periods of time. The field data were collected by monitoring the subsurface moisture and radionuclide distribution beneath several liquid waste disposal sites that were removed

from service more than 10 years ago. During the disposal operation, water flow in the soil approached saturation immediately beneath the disposal sites (20-30 feet). At one site, depicted in Figure IV-3, the "front" of radionuclides (principally ^{106}Ru , some of which is not readily removed by ion exchange with the soil) was 150 feet below ground surface when waste disposal was stopped. Three years later the front advanced to 225 feet (Δ 75 feet), seven years later the front was at 255 feet (Δ 30 feet), and after eleven years the front was at 260 feet (Δ 5 feet). Groundwater occurs at 335 feet below the site. Even though 10 million gallons of waste were disposed to this site (approximately 3600 ft² surface area), no detectable radiation above background has been observed in the groundwater.

FIGURE IV-2

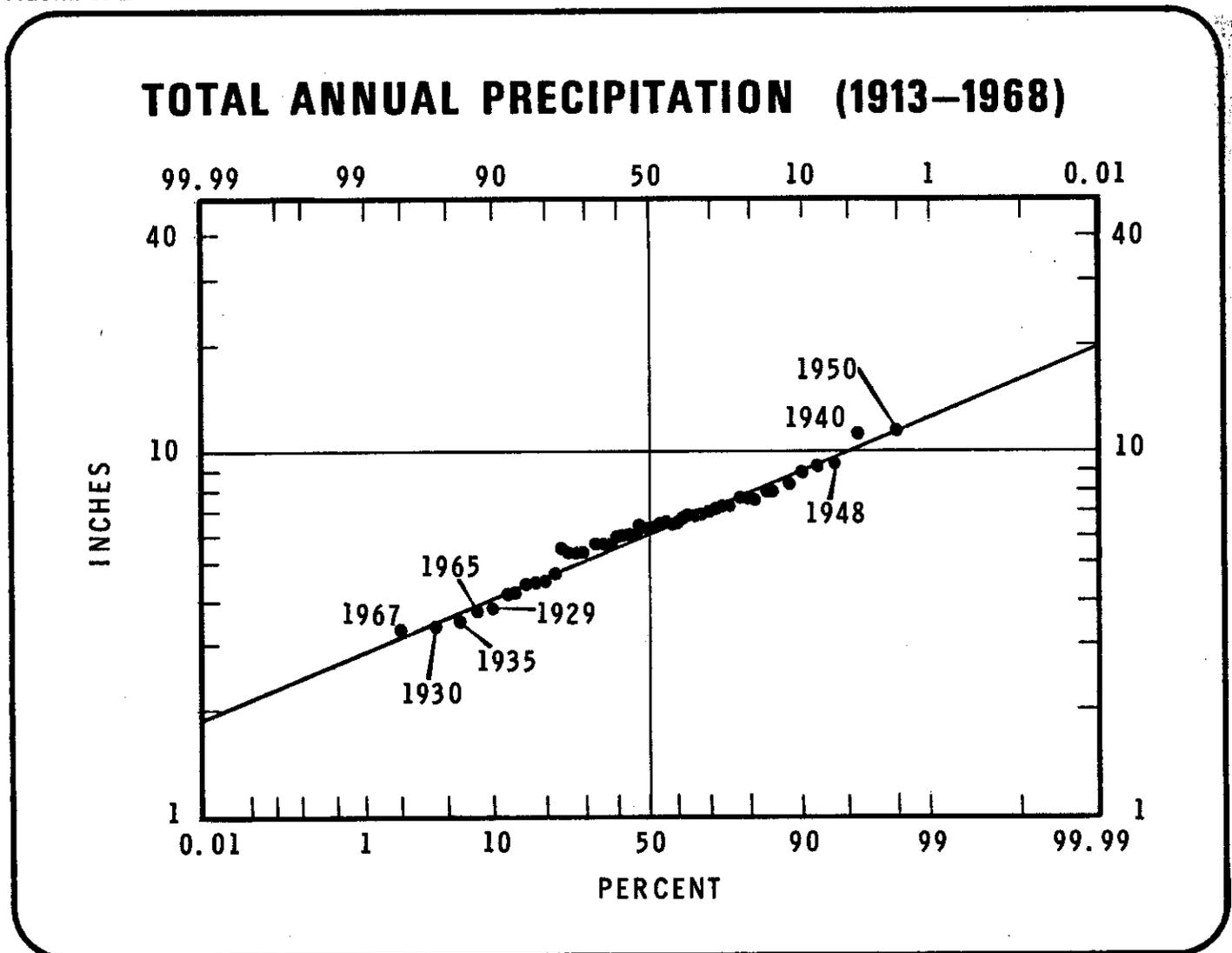
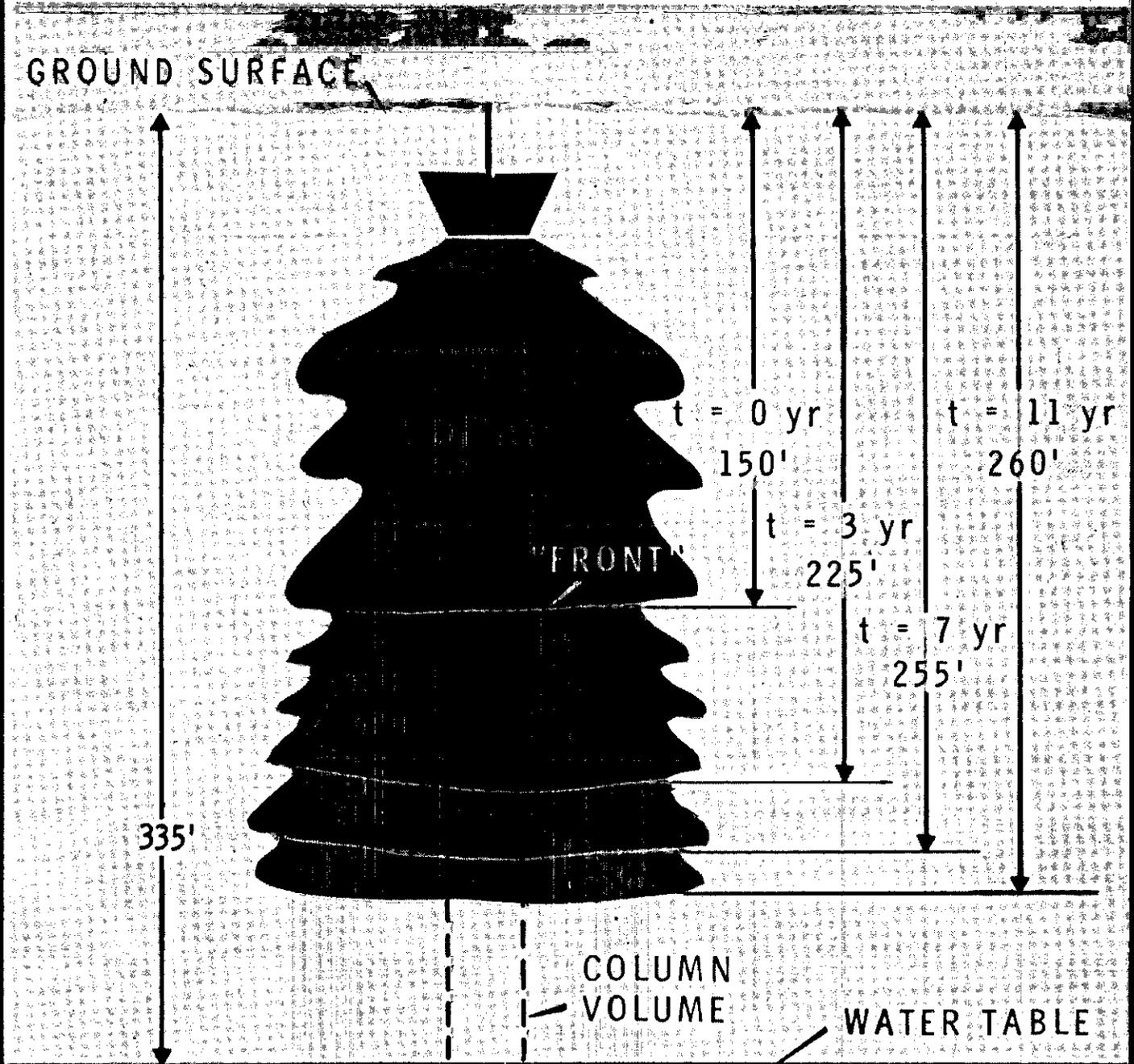


FIGURE IV-3

106 Ru SPECIFIC RETENTION CAPABILITY OF HANFORD SOIL (B C CRIBS)



VOLUME OF WASTE DISCHARGED 10×10^6 GALLONS

Groundwater recharge occurs mainly in the highlands to the west of the Hanford project. The small amount of rain which falls in the area of the disposal sites does not reach the groundwater table in any significant quantity but evaporates before it penetrates more than a few feet below ground surface.

Work by other investigators⁽⁶⁾ in the Spokane Valley, a region having similar soils but nearly three times the annual rainfall (17.5 inches/year), supports this conclusion. An excerpt from their discussion of results is included herein for ease of reference:

"Because the measured soil moistures at depth are approximately 3% weight/weight (roughly 5%, volume/volume) or less, there is an apparent soil moisture deficiency of 3% on a volume/volume basis. This is equivalent to a soil moisture deficiency of about 0.36 inch per foot of depth. The mean annual precipitation in the Spokane Valley is about 17.5 inches. If we arbitrarily consider the entire annual precipitation to occur at a single time, the soil moisture deficiency would be satisfied to a depth of $17.5/0.36 = 48.6$ feet.

"The effective precipitation is estimated by the U.S. Bureau of Reclamation (1966) to be 0.77 foot, or 9.24 inches. This amount of water would satisfy the soil moisture deficiency to a depth of $9.24/0.36 = 25.6$ feet.

"The soil moisture deficiencies found during the test drilling program can be anticipated to recur on a year-to-year basis. The very existence of the deficiencies implies significant moisture movement in response to strongly developed capillary gradients, possibly accompanied by measurable transfer in the vapor phase.

"The fact that there is insufficient annual precipitation to satisfy soil moisture requirements much below 25 feet casts much doubt on possible groundwater recharge by incident precipitation on the outwash plain. It further suggests that, where the water table is 125 feet deep, precipitation could not be expected to influence greatly the movement of pollutants to the water table. Substantial groundwater recharge and the potential for pollutant movement must be localized in areas where precipitation is collected and channelized."

The movement of moisture in the vadose zone was investigated at Hanford using tritium as a tracer. The source of the tritium was believed to be from precipitation which has occurred since bomb testing began about 17 years ago. Wells were drilled to the water table and soil samples were analyzed for water moisture and tritium content as a function of depth below ground surface. Figure IV-4 shows the tritium results for two wells drilled in 1967 and 1968. Note that the tritium concentration

in the soil moisture drops off very sharply within the first 20 feet of soil depth, indicating that precipitation with high tritium content had not penetrated more than about 20 feet. The tritium concentrations below 20 feet are higher than expected and are questionable, however, because contemporary water was added to an adjacent well, located less than 100 feet away. The tritium in this drilling water may have spread laterally, contaminating the natural waters in the vadose zone penetrated by these two wells. Further investigation of the tritium concentrations in the vadose zone is being performed in a third well located more than a quarter mile away. Another theory currently being investigated suggests that if the moisture is moving downward through the lower depths, it may be moving in the vapor phase rather than in the liquid phase. After a heavy rain, the zone of high soil moisture can be traced downward for a few feet below ground surface. The water in this zone gradually decreases with time with no change in moisture content at succeeding depths. The long-lived radionuclides are not likely to be transported downward by water moving in the vapor phase; hence, the radionuclides should remain fixed in position as long as these conditions prevail. Soil samples taken from below dry waste burial sites have shown no movement of radioactive contaminants due to leaching and water migration effects.

FIGURE IV-4

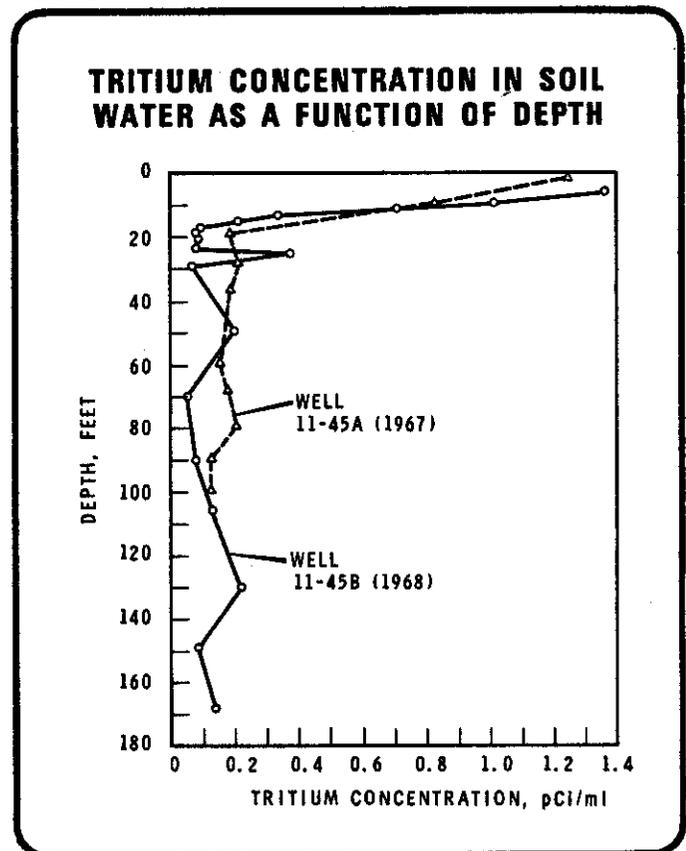
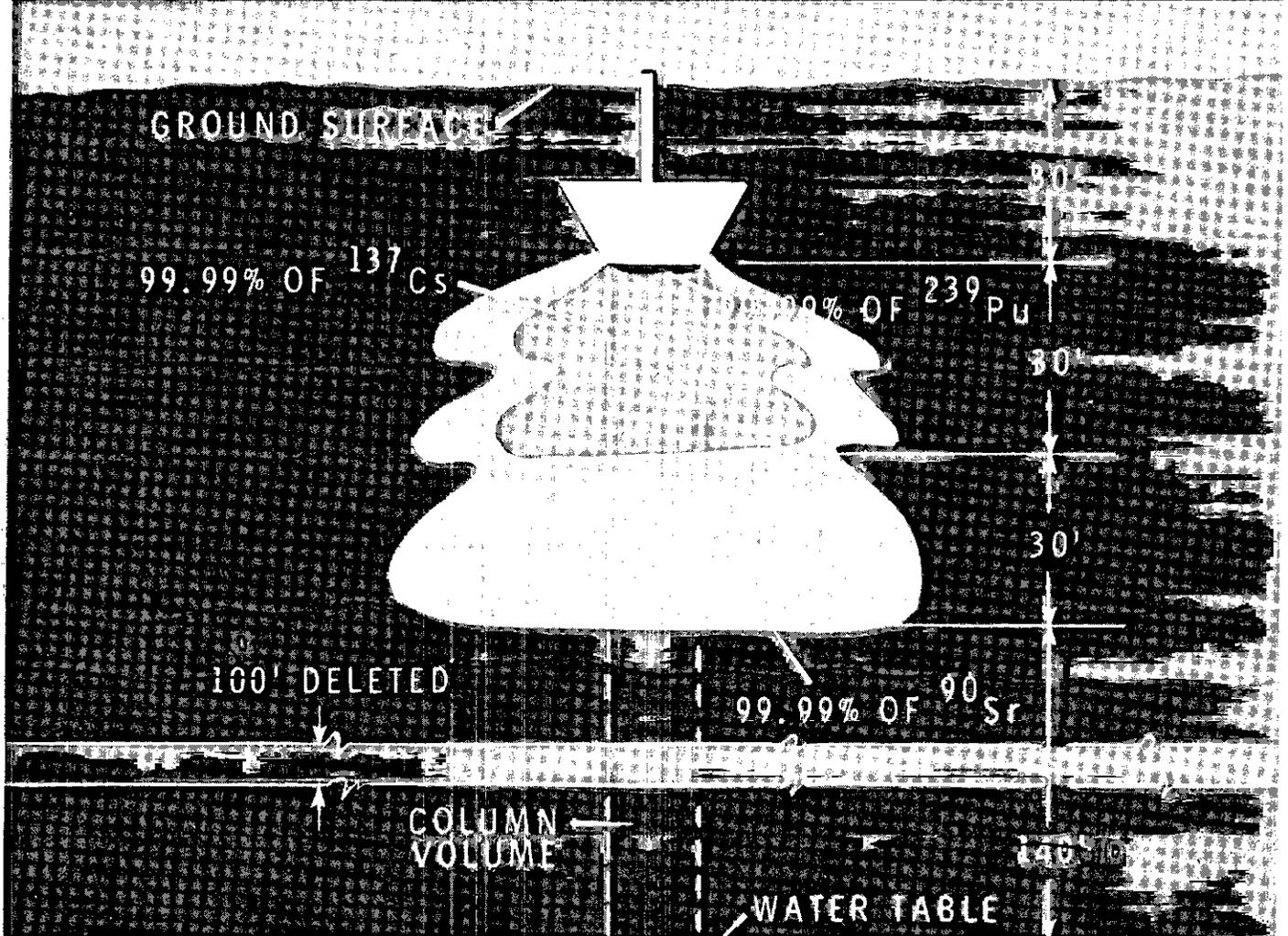


FIGURE IV-5

RETENTION OF LONG-LIVED RADIONUCLIDES ON SOIL AT HANFORD 216-S1 AND 2 CRIBS



TOTAL WASTE VOLUME DISCHARGED: 40×10^6 GALLONS
(90 COLUMN VOLUMES)

TOTAL ACTIVITY DISCHARGED: 750,000 CURIES BETA
2,000 CURIES ^{137}Cs
3,000 CURIES ^{90}Sr

The long-lived radionuclides, ^{90}Sr , ^{137}Cs , and ^{239}Pu tend to be immobilized in the vadose zone on minerals in the soil. These radionuclides are found in the soil immediately beneath the cribs even though many column volumes of liquid waste have flowed through the zone (Figure IV-5). The radionuclide distribution shown in the figure was determined by analysis of soil samples taken from 14 wells in the immediate area. This crib site is not typical of recent storage sites since acidic wastes were allowed to enter the site. Only alkaline wastes are now permitted to be discharged to cribs because of superior radionuclide sorption capability from alkaline wastes. Leaching studies, using soil samples taken from beneath the 216-S1 and 2 sites, show that 500 column volumes of water removed only 15% of the cesium and 30% of the strontium.⁽⁷⁾ The trace amounts of cesium and strontium leached from these sediments were shown to resorb on soil samples taken from the saturated zone. Distribution coefficients in the saturated sediments were 300 for ^{137}Cs and 50 for ^{90}Sr . As determined in the laboratory under simulated natural conditions, the measured migration rates of ^{90}Sr , ^{137}Cs , and ^{239}Pu in the saturated zone were 0.01, 0.001, and 0.00001 the rate of groundwater movement, respectively. These migration rates have also been observed from studies with soil samples from beneath other waste storage sites. Thus, if these isotopes were postulated to enter the groundwater and assuming a groundwater travel time to the Columbia River of three years (the minimum observed from beneath the 200 Areas), the ^{90}Sr , ^{137}Cs , and ^{239}Pu would have decayed 10, 100, and 10 half-lives, respectively, before reaching the river. During this time, the radionuclides would have decayed to innocuous levels.

Water and wind erosion factors were found to be insignificant insofar as long-term storage above the water table is concerned. The topographic features of the 200 Area plateau make it virtually impossible for flash floods to inundate the area. The breaching of all the dams upstream of Hanford on the Columbia River so as to make available the largest possible river flow at Hanford would not inundate the 200 Area plateau. Moderate to high winds are frequent in the area throughout the year. Over long periods of time, wind erosion has and will continue to modify the land surface; however, during the last 10,000-15,000 years it appears that only one to two feet of fine-grained surface material has been winnowed from the glacial outwash sediments which completely blanket the 200 Area plateau.

Thus, an arid climate, long soil columns having high retention capacity for long-lived radionuclides, and the absence of any foreseeable mechanism that is likely to transport radionuclides uncontrollably into man's biosphere make Hanford a unique site for storage of wastes below the ground surface and above the water table.

Factors Favoring Storage Below the Water Table

Geologic structure and stratigraphy of the Columbia Basin provide favorable factors for long-term storage of wastes in deep underground formations.⁽⁸⁾ A generalized cross section of the basalt strata in and surrounding the Pasco Basin is shown in Figure IV-6. More than 100 basalt flows, separated by weathered basalt zones, are present to a depth greater than 10,000 feet in the center of the Basin. The flows are thick and continuous and each covers thousands of square miles. The rocks below about 6,000 feet are not believed to be exposed around the periphery of the downwarped area, nor tapped by wells for water or oil. Some rock strata at depth are relatively impermeable and piezometric gradients appear to be low. The hydraulic pressure below 7,000 feet is thought to be less than the normal hydrostatic gradient. The total dissolved solids content of the water at depth is several thousand parts per million so that the water is very hard. Because of the depth involved, it is unlikely that this water would ever be used for any useful purpose since ample water can be obtained on or near the ground surface at a much lower cost. The chemical content of the water in the several flows indicates relatively little communication between large zones of basalt flows.

LONG-TERM STORAGE ALTERNATIVES FOR HANFORD'S HIGH LEVEL WASTE

The factors that were just discussed indicate that at least two methods for long-term storage of high-level radioactive salt wastes at Hanford warrant consideration. One of these methods, embodied in our current waste management program, is to remove most of the ^{90}Sr and ^{137}Cs and leave

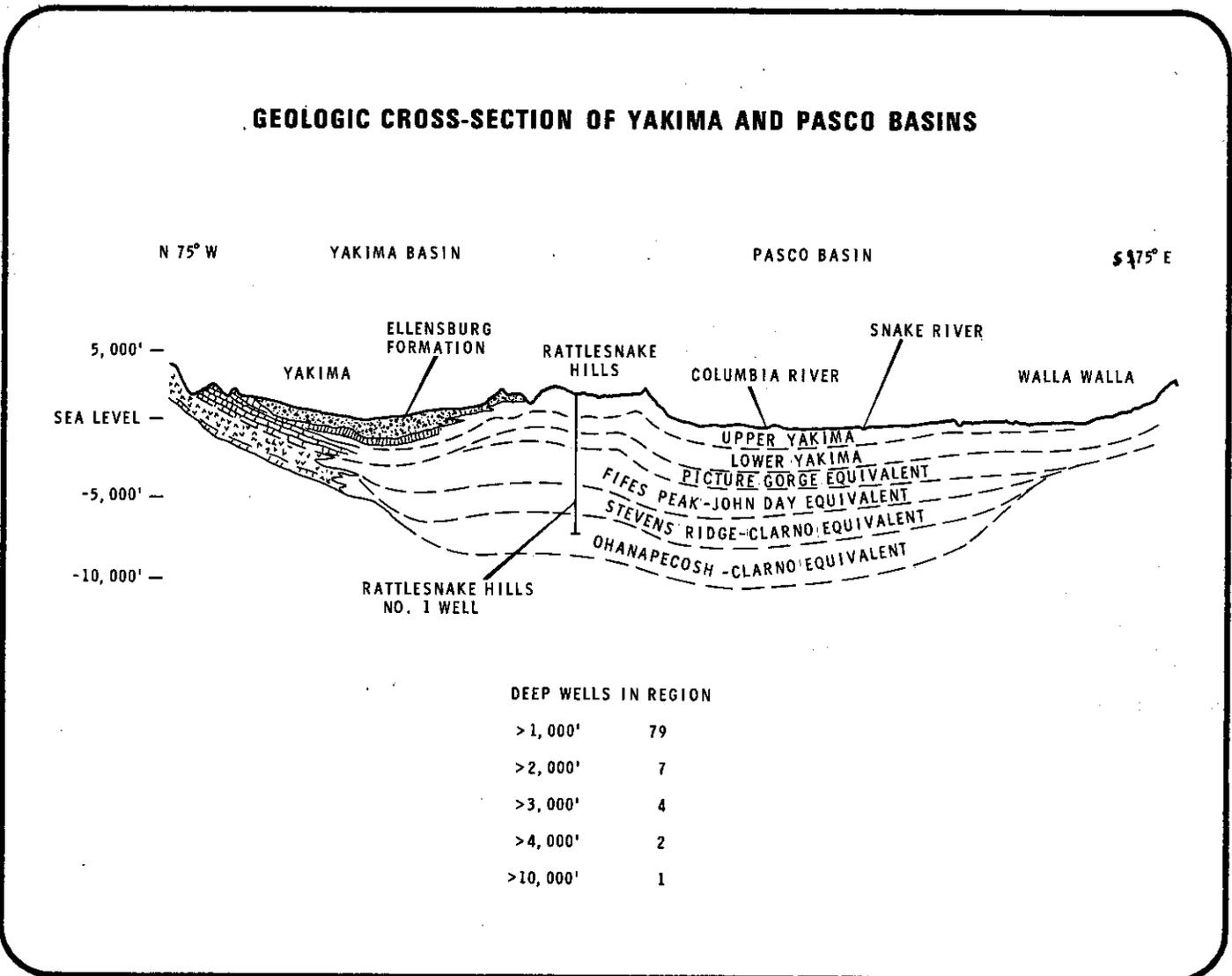
the salt cakes generated by the in-tank solidification process in the existing tanks. The salt cakes might be prepared for long-term storage as shown in Figure IV-7. After it has been determined that the temperature profiles and rates of radiolytic gas formation are sufficiently low, sand or grout could be added to the void space in the tank to prevent total collapse should the tank dome fail. A layer of rock and gravel could then be placed over the tank farm area to give added protection from wind erosion. In this condition, the waste would be stored about 30 feet below ground surface and about 150 feet above the water table.

Characteristics of the salt cake are presented in Table IV-2. Because of the high sodium content of the waste, the salt cakes are relatively soluble in water although the plutonium and strontium are not readily dissolved. Except for the initial few column volumes of leachate, the plutonium concentration in the leachate would be less than the AEC limit⁽⁹⁾ for soluble ²³⁹Pu in water (5×10^{-6} μ Ci/ml).

Preliminary leaching data for salt cakes shown in Table IV-2 indicate that strontium and cesium are less soluble than for the fluidized-bed calcine produced by the Waste Calcining Facility at the National Reactor Testing Station. The salt cake solubility data were obtained by continuously agitating the salt cake sample with water and exchanging the leachate with fresh water every four hours. These solubility tests were much more severe than would be encountered in the field by percolation of water through the salt cake and represent conditions which are not likely to happen under any credible mechanism. By comparison, the calcine leachability data were obtained by recirculating water through a fixed bed of calcine particles.⁽¹⁰⁾

The second possible method for long-term storage of waste at Hanford, currently being investigated, is to remove the salt cakes resulting from ITS operations and slurry it to underground caverns some 3,000-4,000 feet below the water table. Figure IV-8 depicts this alternative. A central or main shaft would be drilled to the zone of the proposed cavern. The caverns (two or more) would then be mined out at a level 30 or more

FIGURE IV-6



feet below the bottom of the main shaft. These caverns would extend radially from this central shaft. Service shafts would also be installed to provide utility services to each of the caverns and to serve as emergency escape shafts during mining operations. For this method, the salt cakes would be removed in the dry state from the tanks, water would then be added in the transfer system in order to slurry the waste to the underground caverns. Because of the poor condition of the tanks, many of which have leaked, the use of water to sluice the salt cakes from the tanks should probably be avoided. Bulkheads would be installed which would be sealed after filling the caverns with waste. The volume of cavern which would be required to contain the salt slurry resulting from removing the salt cake projected to be in inventory through 1980 would be about 25,000,000 cubic feet. Two 30-foot diameter caverns would total about seven miles in length. If sand has been added to the tank (a concept that is being considered to prevent collapse of the tank dome), an additional 15,000,000 cubic feet of underground storage space would be required.

If long-term storage at Hanford is unacceptable, a third possible method would comprise mining the salt cake from the tanks, packaging it in heavily shielded drums and shipping it offsite, presumably to a salt mine. Figure IV-9 graphically illustrates this alternative. Calculations indicate that about 165 trucks per day with a 40,000 pound net pay-

load would be required for a period of five years to ship all the salt cake expected to be inventory by 1980 to a salt mine. Trucks would be leaving Hanford at the rate of one every seven to eight minutes and, assuming they were bound for a salt mine in Kansas over two different routes, the trucks would be spaced on each route at approximately 10 mile intervals. Of course, the trucks must return to the site with the casks for their next load with similar timing and spacing. A fleet of at least 1,500 trucks would be needed

FIGURE IV-7

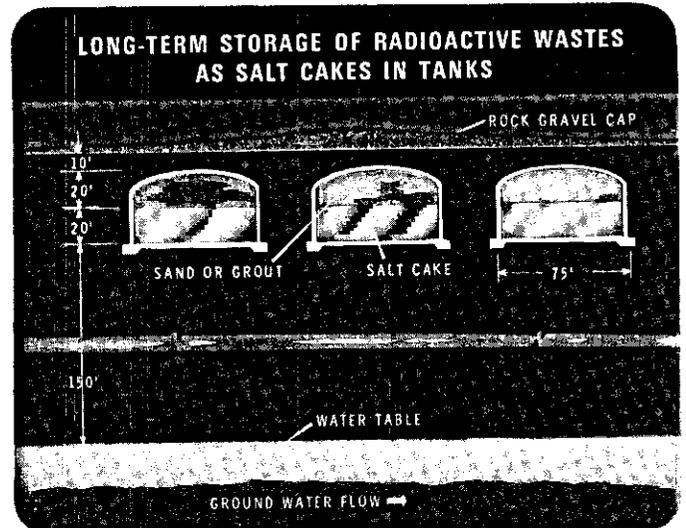


FIGURE IV-8

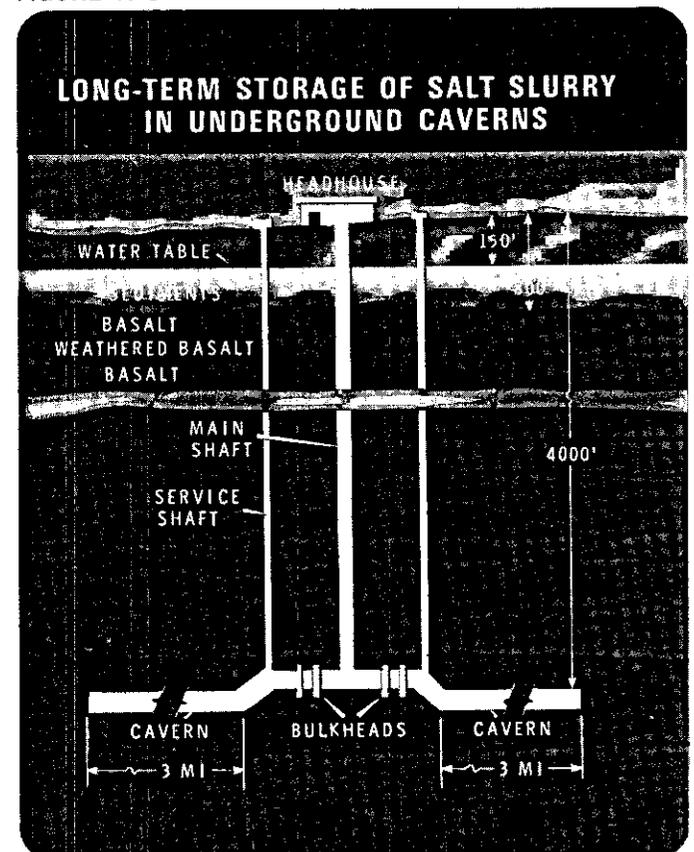


TABLE IV-2

SALT CAKE CHARACTERISTICS			
<u>BULK DENSITY</u> , g/cc	1.6 - 1.8		
<u>TYPICAL COMPOSITION:</u>		<u>WTS</u>	
	NaNO ₃	45	
	Na ₂ CO ₃	30	
	NaOH	10	
	OTHER (Fe, Al, SO ₄ , Ca)	5	
	WATER OF HYDRATION	10	
	<i>Total</i>	100	
	<u>CONCENTRATION, CI/GAL.</u>	<u>DILUTION REQUIRED TO MEET AEC DRINKING WATER LIMIT</u>	
	¹³⁷ Cs	0.5	10 ⁷
	⁹⁰ Sr*	5	10 ⁹
	²³⁹ Pu*	5 x 10 ⁻⁴	10 ⁴
* CONCENTRATION IN BOTTOM 10% OF SALT CAKE ONLY.			
LEACHABILITY BY WATER (% LEACHED IN INITIAL 2 DAYS)			
	<u>SALT CAKE</u>	<u>IDAHO FLUIDIZED-BED CALCLINE</u>	<u>ORNL ASPHALT</u>
	⁹⁰ Sr	1	20
	¹³⁷ Cs	25	70
	²³⁹ Pu	2	--

to complete the transfer in five years. Because of the heavy shielding required to control radiation levels within applicable limits, the shielding weight would comprise nearly 90% of the total truck payload. Since the cask

which is used for shielding must be returned empty to Hanford for reloading, the cost for shipping the casks both ways equals nearly 95% of the total shipping cost.

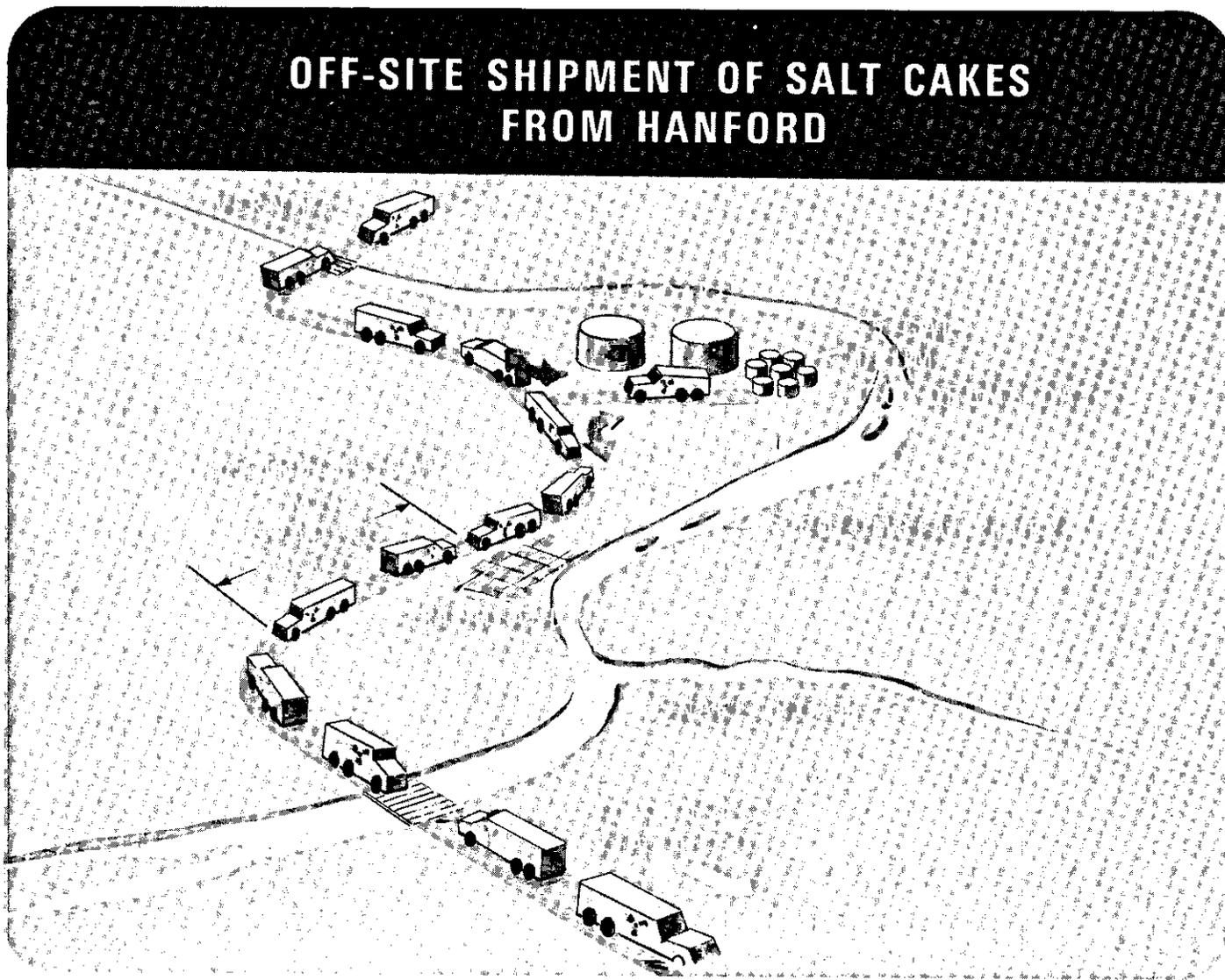
Safety Considerations

Table IV-3 compares operating hazards that would be encountered for each of the three alternatives. Leaving the salt cakes in place is certainly the safest approach from an operating viewpoint and, in particular, avoids the hazards of transporting large quantities of radioactive waste. A qualitative comparison of the long-term storage hazards for the three alternatives is illustrated in Table IV-4. Note that the salt-cake-in-tank alternative is the most vulnerable to the hazards listed, primarily because of the waste's proximity to the ground surface compared to the other alternatives. Because of the unique features at Hanford as described above, the probability of dispersion of radionuclides from any of the hazards is low.⁽¹²⁾

TABLE IV-3

OPERATING HAZARDS-PROCESSING WASTES FOR LONG-TERM STORAGE			
VULNERABILITY TO	SALT CAKE IN TANKS	SALT SLURRY IN CAVERN	SALT CAKE IN SALT MINE
RADIATION EXPOSURE OF WORKERS	LOW	MEDIUM	MEDIUM
ACCIDENTAL SPILLS	LOW	MEDIUM	MEDIUM
TRANSPORTATION ACCIDENT ON PRIVATE PROPERTY	NOT APPL.	NOT APPL.	HIGH
RELEASE OF RADIONUCLIDES TO ATMOSPHERE	LOW	HIGH	HIGH

FIGURE IV-9



One hazard for which the salt-cake-in-tank alternative is particularly vulnerable is an explosion by a nuclear weapon. Although the surface explosion of such weapon on a tank farm is an unlikely event, an enemy force could, nevertheless, aim a rocket at the tank farm. A weapon of about 300 kilotons of TNT yield would be required to completely disperse a tank farm complex of 36 tanks. The ⁹⁰Sr and ¹³⁷Cs produced by the weapon would equal about one percent of the total dispersed ⁹⁰Sr and ¹³⁷Cs. (11)

In order to minimize the probability of dispersion by wind, water movement, and man, administrative control and surveillance would be required to ensure that land use in the immediate vicinity of the tanks is restricted and overburden is not removed. Changes initiated by man which would significantly raise the groundwater table or result in percolation of water through the salt cakes must be avoided and controlled.

Table IV-5 lists the principal barriers against movement of radionuclides into man's biosphere for the three alternatives. The barriers are listed in the order in which they would be called upon to confine the long-lived radionuclides. The results shown in Table IV-6 would be obtained if the alternatives were compared using the long-term waste storage considerations discussed previously. All three alternatives rely heavily upon the natural environment where the waste is located for confinement. The salt-cake-in-tank alternative also includes engineering features to increase the safety of this storage mode, i.e., concrete tank, rock cover, etc.). Routine surveillance must be provided for the salt-cake-in-tank alternative and restrictions placed on land usage. Surveillance would be relatively easy because of the proximity to the ground surface and would result in a high degree of confidence that the waste is safely confined.

The salt-cake-in-tank alternative stores the waste in a location from which the waste is more readily retrievable should it be necessary.

Other Considerations

There is a definite cost advantage favoring the salt-cake-in-tank alternative of some \$110 to \$460 million. The present worth values of the costs are also shown in Table IV-6 assuming a 5% discount rate. Salt cake transfer and shipping costs were assumed to be incurred during the FY-1981 to FY-1985 period. A more detailed breakdown of these costs is presented in Table IV-7. Note that shipping costs alone for transporting the salt cake to a salt mine (Lyons, Kansas) are estimated at \$460 million.

TABLE IV-5

BARRIERS FOR MOVEMENT OF RADIONUCLIDES INTO MAN'S BIOSPHERE	SAFETY CONSIDERATIONS FOR LONG-TERM STORAGE OF HIGH LEVEL WASTE		
	SALT CAKE IN TANKS	SALT SLURRY IN CAVERN	SALT CAKE IN SALT MINE
PRIMARY	LACK OF FLOWING WATER SURFACE STABILIZATION	RELATIVELY IMPERMEABLE BASALT	LACK OF FLOWING WATER
SECONDARY	SPECIFIC RETENTION CAPABILITY OF SOIL	EXTENSIVE OVERLYING LAYERS OF RELATIVELY IMPERMEABLE BASALT	OVERLYING RELATIVELY IMPERMEABLE ROCK
TERTIARY	ION EXCHANGE PROPERTIES OF SOIL	ION EXCHANGE PROPERTIES OF ROCK AND SOIL	

TABLE IV-4

HAZARD	SALT CAKE IN TANKS		SALT SLURRY IN CAVERN		SALT CAKE IN SALT MINE	
	VUL.	PROB.	VUL.	PROB.	VUL.	PROB.
WINDS	○	○	□	□	□	□
EARTHQUAKES	○	○	●	◆	○	○
EXPLOSIVE IMPACT	◆	○	○	○	○	○
FLOODS	◆	○	○	○	○	○
GROUND WATER MOVEMENT	●	○*	◆	○	●	○
MAN	◆	◆*	◆	○	○	○

○ VERY LOW ◆ LOW ● MEDIUM ◆ HIGH □ NOT APPLICABLE

* PROVIDED THAT CONTROL BY MAN IS MAINTAINED.

TABLE IV-6

	SALT CAKE IN TANKS	SALT SLURRY IN CAVERN	SALT CAKE IN SALT MINE
RELATIVE DEGREE OF RELIANCE UPON NATURAL ENVIRONMENT FOR CONFINEMENT	HIGH	HIGH	HIGH
RELATIVE DEGREE OF RELIANCE UPON ENGINEERED ENVIRONMENT FOR CONFINEMENT	MEDIUM	MEDIUM	LOW
SURVEILLANCE REQUIREMENTS	ROUTINE	MINIMAL	MINIMAL
RETRIEVABILITY	GOOD	POOR	POOR
COST, MILLIONS OF 1969 DOLLARS	40 (5)	150 (75)	500 (250)

() = PRESENT WORTH @ 5% DISCOUNT.

TABLE IV-7

COST CONSIDERATIONS FOR LONG-TERM STORAGE OF HIGH LEVEL WASTE (MILLIONS OF 1969 DOLLARS)			
ACTION	SALT CAKE IN TANKS	SALT SLURRY IN CAVERN	SALT CAKE IN SALT MINE
STABILIZE TANKS AND SURVEILLANCE (TO 2600)	40	?	?
REMOVE SALT CAKE FROM TANKS	--	30	30
STORE IN UNDERGROUND CAVERN	--	120	--
SHIP TO SALT MINE	--	--	460
STORE IN SALT MINE	--	--	10
	40	150	500

Considering all factors presently available, the salt-cake-in-tank alternative is preferred. Major advantages include fewer operating risks, surveillance capability, retrievability, and lower cost. Major disadvantages include restrictions on surface land uses, administrative control requirements, and vulnerability to a nuclear weapon. A significant, unexpected change in climatological conditions would be required to necessitate relocation of the salt cakes. Such a change would also require consideration to the relocation of the contaminated soil and buried solids accumulated at Hanford during past waste disposal operations.

Thus far in the presentation, the long-term storage options for the encapsulated cesium and strontium have not been discussed. Because of the relatively small volume of the capsules, their disposition to salt mines or to deep underground formations would not generate large differences in cost. The capsules can be held in water-cooled basins at Hanford until final storage criteria are formulated.

TABLE IV-8

CONTAMINATED SOIL AND SOLIDS LONG-TERM STORAGE HANDLING COSTS (MILLIONS OF 1969 DOLLARS)		
ACTION	LEAVE IN PLACE	SHIP TO SALT MINE
SURVEILLANCE AND WELL REPLACEMENT (THRU 2600)	60	?
SHIP TO SALT MINE (1.5 x 10 ⁹ FT ³)	--	5000
STORE IN SALT MINE	--	> 500
	60 (10)	>5500 (2500)

() - PRESENT WORTH @ 5% DISCOUNT.

LONG-TERM STORAGE ALTERNATIVES FOR HANFORD'S CONTAMINATED SOIL AND BURIED SOLID WASTE

The apparent options for long-term storage of the contaminated soil beneath waste storage sites and buried solid waste include: 1) leaving the soil and solid waste in their present locations above the water table; 2) digging up the soil and solid waste and moving it to concrete vaults in another location at Hanford; and 3) transporting the contaminated soil and solid waste offsite. The operating and long-term storage hazards for these alternatives are similar to those for the high level wastes but lesser in magnitude due to the lower concentration of radionuclides in storage.

The biggest problem is the very large volume of waste to be handled. The volume of soil and solid waste which would require movement has been estimated 1.5 billion ft³. This volume includes all soil contaminated above a "nuisance" level (>0.01 μCi beta+gamma/ft³) to a depth of at least 30 feet beneath the cribs. Deliberate leaching of the radionuclides from the soil with acid or complexing agents as a method for removing the radionuclides is not practical because of the poor yield which would be obtained and the huge volumes of contaminated liquid wastes which would require treatment.

TABLE IV-9

PLUTONIUM CONTAMINATED SOIL AND SOLIDS LONG-TERM STORAGE HANDLING COSTS (MILLIONS OF 1969 DOLLARS)		
ACTION	LEAVE IN PLACE	SHIP TO SALT MINE
SURVEILLANCE AND WELL REPLACEMENT (THRU 2600)	10	?
SHIP TO SALT MINE (1 x 10 ⁸ FT ³)	--	400
STORE IN SALT MINE	--	50
	10 (2)	450 (200)

() - PRESENT WORTH @ 5% DISCOUNT.

Another problem is the high cost for transportation. Estimated long-term storage costs for two of the alternatives are shown in Table IV-8. Note the very large cost for shipping the soil and solid waste offsite. Present worth values of the costs are also shown assuming that the soil is transferred to the salt mine during the period FY-1981 to FY-1985. If it is desired only to remove soil and solid waste contaminated with plutonium at greater than $0.02 \mu\text{Ci } ^{239}\text{Pu}/\text{gram}$ of soil, then about 100 million ft^3 of soil and solid waste would require movement. Costs for moving this soil and solid waste are shown in Table IV-9.

Leaving the contaminated soil and salt waste in place is preferred from both safety and cost viewpoints. Factors which favor storage of salt cakes in tanks are also applicable to storage of contaminated soil and buried solids. Surveillance would be required to ensure continuing confinement of the radionuclides. If in the final analysis, the salt cake in tank storage concept is rejected, then the contaminated soil and buried solid waste should also be considered for relocation.

DEVELOPMENT PROGRAMS FOR LONG-TERM STORAGE ALTERNATIVES

Areas requiring additional development to prove the feasibility of long-term waste storage at Hanford are discussed below.

● **Salt Cake Storage in Tanks** Studies are continuing to define leaching rates of the ^{90}Sr , ^{137}Cs , and ^{239}Pu from salt cakes. The use of additives is being investigated to reduce leaching rates. Thermal conductivity and chemical stability of the salt cakes will be determined. Methods for removing the salt cake from the tanks will be investigated and promising methods will be tested.

● **Soil-Waste Interrelationship Studies** Since the long-term storage alternatives for leaving the salt cakes in tanks and the contaminated soil and buried solids in place are preferred, considerable development work is required to show that the radionuclides will be confined until decay renders them innocuous. A detailed knowledge of waste-soil interactions and movement of wastes and radionuclides in the vadose and saturated zones must be obtained. Sophisticated techniques using analog computers have been developed for calculating changes in water table elevations and flow streamlines throughout the Hanford project for postulated changes in groundwater recharge and elevation of the Columbia River. The program is based on field transmissibility data from pumping tests, on more than 30 wells.

Future work will extend program capability to movement of water through the partially saturated zone and to movement of radionuclides in the saturated and unsaturated zones. To date, waste storage practices have resulted from 20 years of field experience including extensive laboratory work.

● **Seismic Studies** Considerable disagreement has been expressed concerning the seismic stability of the area. Some authorities believe the area to be quite stable while others cite evidence that might indicate the possibility of two fault systems adjacent to the Hanford Reservation. One of these fault systems is located along the north flank of the Saddle Mountains 16 miles north of the waste storage sites and the other is the Rattlesnake Mountain-Wallula-Milton-Freewater system which is 10 to 11 miles south of the waste storage sites. Recent excavation on Gable Mountain, where a smaller fault was also purported to exist, revealed no evidence of significant faulting. Excavation of areas on the north flank of the Saddle Mountains and along the Rattlesnake Mountain-Wallula-Milton-Freewater structure are also planned to better define the potential seismicity of the area.

● **Exploratory Deep Well** A contract has been let with the Calvert Western Exploration Company to drill a well about 7,500 feet deep near the 200 East Area. Its purpose is to investigate the feasibility of underground storage of wastes at Hanford and to corroborate data taken from the Rattlesnake Hills Unit No. 1 well. Extensive coring, sampling, hydrological testing, and well logging are planned. Swabbing and pumping tests using packers will be performed to determine rock permeabilities and formation water pressures. Water samples will be analyzed to determine mineral and gas content. If the data from the first well are promising, at least two additional wells will be drilled to obtain further data pertinent to storage of wastes in basalt flows. Included would be a long-term hydrological test to determine flow characteristics of wastes through the rock.

● **Engineering and Hazards Analyses** Supporting the above development program would be continuing engineering and hazards analyses of the long-term storage methods under consideration. A preliminary hazards analysis for the long-term storage of salt cakes in tanks has recently been completed.⁽²¹⁾ It is planned that technology for two methods for long-term storage would be developed with one being the preferred method and the second a backup method.

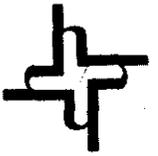
Studies on alternative methods of solidifying the high level wastes will be pursued so that in the event the Purex plant continues to operate for more than 10 years, other technology will be available to solidify these wastes, if desired. Development of technology for solidification of high level liquid radioactive wastes has been underway at the Waste Solidification Engineering Prototype (WSEP) facility for the past few years. There are new problems which must be solved, however, before technology developed to date can be applied to solidification of the Hanford Purex Plant high heating waste. Two of these problem areas are fluoride corrosion due to the presence of fluoride in Purex high heating waste and about a 10-fold scale-up factor of the solidification equipment. The latter is caused by the

high salt content of the waste. A research and development program costing more than \$2 million has been estimated over a three-to-four-year period to solve these problems. Development programs are now underway to reduce the salt content of the Purex waste stream so that it can be concentrated to a smaller volume for treatment prior to long-term storage. Reduction in the salt content should realize large waste management cost savings whether the waste is fractionized as at present or solidified using WSEP technology. Studies are also underway to eliminate the chemical fuel element decladding operation, which generates large volumes of high salt, low-heating waste, by replacement with a mechanical dejacketing system.

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V HANDLING of CONTAMINATED GASEOUS , SOLID, and LIQUID EFFLUENTS in CHEMICAL PROCESSING PLANTS



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INTRODUCTION

The reprocessing of irradiated fuels generates large volumes of waste associated with trace to high concentrations of radioactive materials. Essentially all of the fission products are associated with relatively small volumes of aqueous wastes, which are processed to minimize volume and stored in underground tanks as indicated in Section III. I will discuss the very large volumes of gaseous, solid, and liquid wastes that have associated with them relatively small quantities of radioactive materials.

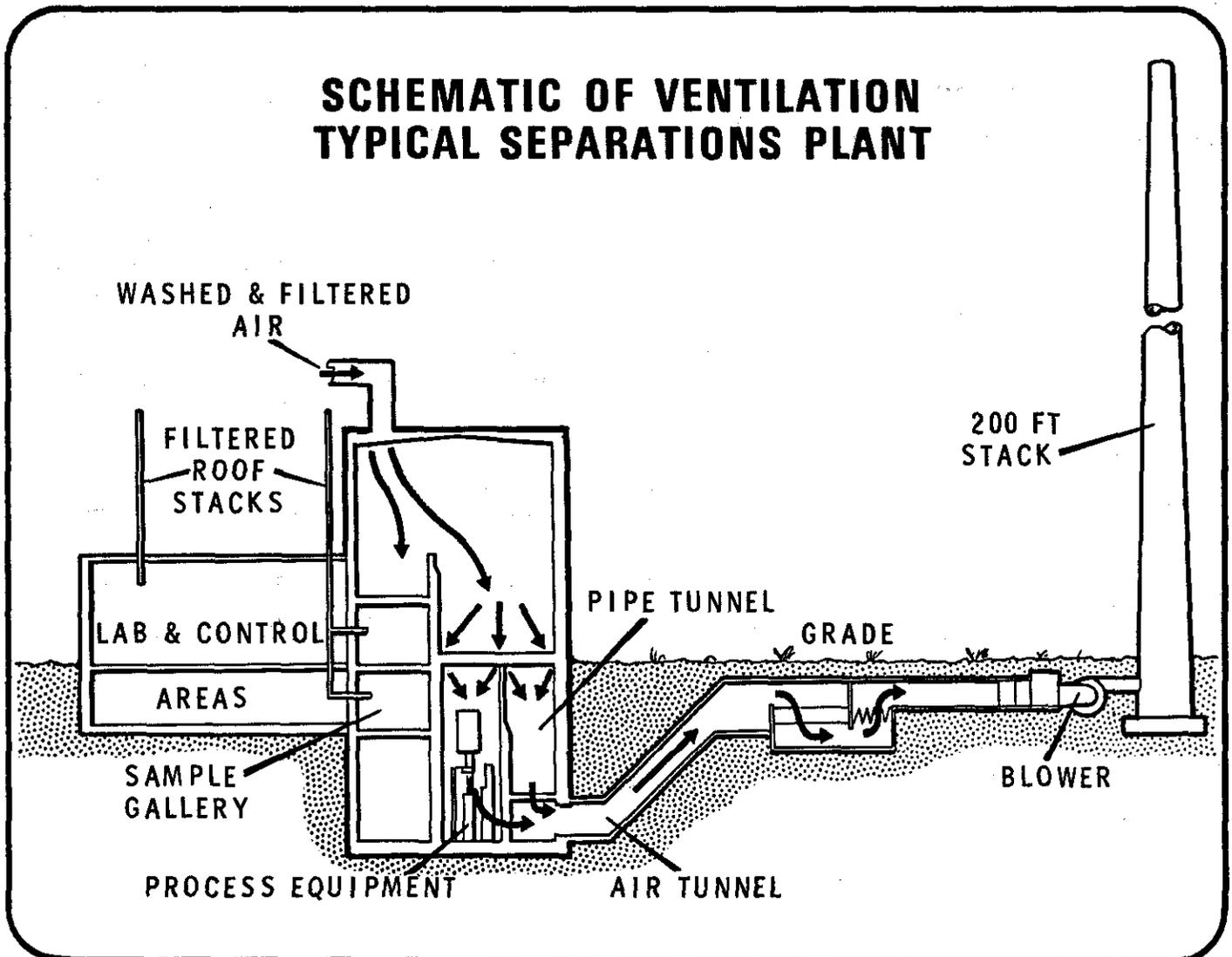
GASEOUS EFFLUENTS

As indicated in Table V-1, rather large quantities of air are drawn through the processing buildings to maintain tolerable

conditions of temperature, humidity and contamination within the processing areas. In each case, the major flow of air is through potentially contaminated areas; this air is filtered and discharged from a single tall stack. Process areas having little likelihood of becoming contaminated to a hazardous degree are vented through filters to the atmosphere through multiple shorter stacks generally just above roof level.

Figure V-1 depicts a typical ventilation flow pattern for a chemical reprocessing plant. Air is drawn through a washer and filter and is blown into a processing area. The air passes sequentially from the less contaminated to the more contaminated zones. After passing through the most

FIGURE V-1



contaminated zone, the air is drawn through an exhaust duct to high efficiency filters and is then blown through a 200-foot stack to the atmosphere. For areas not likely to be contaminated, such as the pipe and operating galleries, sample galleries, etc., ventilation exhaust would normally be through filters and roof vents. In all cases a regular

program of monitoring, sampling and analysis is maintained to assure that radioactivity discharged to the atmosphere is held within appropriate limits.

A wide variety of high efficiency filters is in use as indicated in Table V-2. Each of these systems has advantages and disadvantages. The paper filters are very efficient but lose strength when wet and develop a high pressure drop at relatively low dust loading. The glass fiber filters have the same operating and failure characteristics as the paper filters, but are significantly less failure-prone. The sand filter is the least failure-prone and also the least efficient.

Air that comes in close contact with process materials picks up process chemicals and radioactive contaminants. These gases are segregated into separate vent systems according to pressure requirement and compatibility of the process gases. The gases are processed for removal of noxious materials in a variety of ways as indicated in Table V-3. Once the noxious materials have been scrubbed to acceptable levels, the process vent gases are exhausted to the ventilation system for additional filtration and return to the atmosphere.

The gaseous contaminants of potential concern are listed in Table V-4. As previously indicated, all of the radioactive materials are being released to the atmosphere at concentrations well within the appropriate AEC guides. Similarly, hydrogen fluoride is not detectable in the atmosphere. Nitrogen oxides, however, are currently exhausted to the atmosphere in concentrations above appropriate guides. The values listed here represent the peak concentrations at the point of exhaust at the top of the stack. By contrast, the AEC guide indicates that the maximum concentration that should be permitted in inhabited areas is five parts per million. Using our best estimate of the dilution that would be experienced while

TABLE V-1

PLANT	THOUSANDS OF CFM	
	STACK HEIGHT, <100'	STACK HEIGHT, 200'
PUREX	105	120
B PLANT		65
Z PLANT		295
REDOX	29	36
REDOX - LABORATORY	100	
T PLANT		36
TANK FARMS	60	25*
TOTAL	294	577

* STACK HEIGHT ABOUT 150'

TABLE V-2

VENTILATION FILTERS		
TYPE	PLANT	RATED EFFICIENCY, %*
THREE STAGE PAPER	Z PLANT	99.99 +
TWO STAGE PAPER	B PLANT, AR VAULT	99.99
TWO STAGE GLASS WOOL	PUREX	99.9
SAND	UO ₂ , T PLANT	99.5

* FOR 0.3 MICRON PARTICLES

TABLE V-3

GASEOUS WASTES PROCESS VENT SYSTEMS	
EQUIPMENT GROUPED ACCORDING TO:	
PRESSURE REQUIREMENTS	
COMPATIBILITY OF PROCESS OFF-GASES	
NOXIOUS MATERIALS REMOVED	
IODINE ABSORBER - PUREX	
AMMONIA SCRUBBER - PUREX, B-PLANT	
NO _x ABSORBER - PUREX, U-PLANT	
HF SCRUBBER - Z-PLANT	
EXHAUST FILTERED AND RELEASED TO VENTILATION SYSTEM	

TABLE V-4

CONTAMINANT	AT POINT OF RELEASE		AEC GUIDE	
	PEAK	AVERAGE	AT GRADE	AT 200'
NOBLE GASES	X	X	-	-
TRITIUM	X	X	-	-
I-131, Ci/wk	1.1	0.1	3	30
PARTICLES, Ci/wk				
ALPHA	-	1.8×10^{-4}	1×10^{-3}	1×10^{-2}
BETA	-	3×10^{-2}	2	20
NO _x , ppm				
PUREX	3,400		5	-
UO ₂ PLANT	3,000		5	-
AR VAULT	200,000		5	-
HF - Z PLANT	NOT DETECTABLE		-	-

moving from the top of the Purex stack to the ground level, we estimate that the concentration of nitrogen oxides at the top of the stack should be limited to about 170 parts per million. In other words, we are now emitting nitrogen oxides at concentrations about 20 times the appropriate guide concentration. While the NO_x concentration is greater at the UO₂ and AR Vault stacks, more atmospheric dilution can be expected and the needed improvement factor is less than at Purex.

Our improvement plans center around the reduction of nitrogen oxide concentrations as they are released to the atmosphere. A year ago, we had identified a program that would reduce NO_x concentrations at grade level to the guide concentration of five parts per million. We then proposed to proceed with these programs as funding became available. During the last year, however, we have noticed a trend that appropriate regulatory agencies seem to be moving toward a guide concentration closer to a half part per million. We are therefore re-examining our plans with the intent of identifying an optimum method for reducing NO_x concentrations to a half part per million at grade level. These improvement programs will probably be recommended for FY-1972 funding.

CONTAMINATED SOLID EFFLUENTS

As indicated in Table V-5, more than 4-1/2 million ft³ of contaminated solids have been buried on the 200 Area plateau since the start of the chemical processing operation. About 130 acres have been used for this purpose. Most of these wastes are so-called dry wastes—soiled clothing, laboratory supplies, tools, etc. These dry wastes have been boxed in cardboard, wood or metal and transported to the burial ground in trucks. Larger pieces of failed equipment have been boxed in wood or concrete and transported to the burial ground on railroad cars. We have also received some scrap from offsite for burial, but this constitutes a relatively small percentage of our efforts. The packaging of these materials is designed to maintain safety only until the material is safely buried. Once buried, we place no reliance on the container for confinement of these materials.

The burial garden takes the form of a series of parallel trenches up to several hundred yards long as indicated in Figure V-2. The smaller dimensions apply to the dry wastes, while the larger dimensions apply to the burial of failed equipment in larger boxes. Small boxes are dumped into the open trench. Large boxes containing highly radioactive equipment are dragged into place with long tow lines. After the wastes are placed in the trench they are covered with dirt with a bulldozer.

Our principal concern during the burial operations (Table V-6) centers around 1) the assured confinement of contaminated materials during transport and 2) minimizing the exposure of operating personnel. After burial our concern centers around 1) the pickup of radioactive materials by plants or animals and 2) the migration of radioactive materials through the ground. We maintain a continuing close surveillance of the burial site to assure that no migration takes place. The

TABLE V-5A

SOLID WASTES TYPES AND QUANTITIES 1968		
SOURCE AND TYPE	VOLUME FT ³	CONTAINER
DRY WASTES*		
ARHCO	78,000	CARDBOARD & WOOD BOXES METAL DRUMS
OTHER RI CONTRACTORS	63,850	CARDBOARD & WOOD BOXES METAL DRUMS
FAILED EQUIPMENT		
ARHCO	29,300	WOOD OR CONCRETE BOXES
OFF SITE SCRAP	4,800	METAL DRUMS
TOTALS	176,200	
<hr/>		
CUMULATIVE THROUGH 1968		
4,700,000		
* CLOTHING, SWABS, PAPER, TOOLS, LABORATORY HARDWARE, ETC.		

TABLE V-5B

SOLID WASTES TYPES AND QUANTITIES 1968 (cont.)				
SOURCE AND TYPE	URANIUM (LBS)	PLUTONIUM (GRAMS)	FISSION PRODUCT (CURIES)	LAND AREA USED (ACRES)
DRY WASTES*				
ARHCO	5	550	3,400	2.1
OTHER RI CONTRACTORS	33	1,025	1,600	1.6
FAILED EQUIPMENT				
ARHCO	NEGLECTIBLE	4,600	71,200	0.7
OFF SITE SCRAP	1,329			0.2
TOTALS	1,367	6,175	76,200	4.6
<hr/>				
CUMULATIVE THROUGH 1968				
	580,000	351,000	445,000	131
* CLOTHING, SWABS, PAPER, TOOLS, LABORATORY HARDWARE, ETC.				

only evidence of migration observed at this time involved some "hot" tumbleweeds. Sterilization of the soil over the burial site eliminated that migration mechanism.

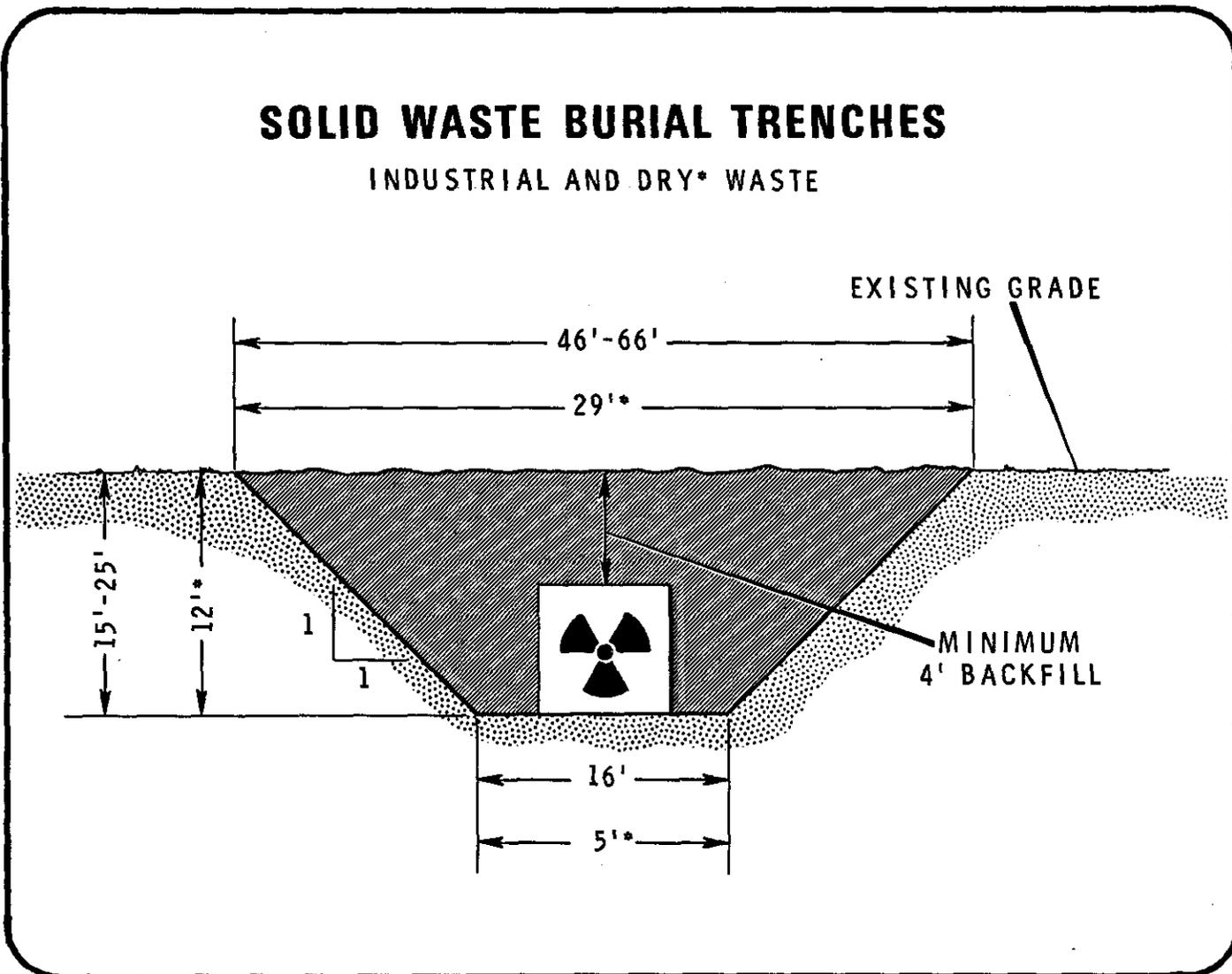
Some of the Purex processing equipment is so large and becomes so contaminated in service that its transport to the burial ground would require the exposure of operating personnel to more radiation than we are willing to accept. We have therefore constructed a railroad tunnel (Figure V-3) adjacent to the Purex Plant for the burial of this material. The equipment is placed in a wooden box on a flatcar and the car is pushed into the tunnel for storage. We now have 10 cars in two tunnels having capacity for 48 cars. While no decision has been made on the future of these tunnels, it is likely that they will be filled later with sand.

At the present time we have no plans to change our solids burial practices. We know of no significant hazards associated with this operation and believe that we can continue with current practices indefinitely, as long as surveillance is provided

TABLE V-6

SOLID WASTES SAFETY CONSIDERATIONS	
CONCERN	CONTROL
DURING BURIAL OPERATION	
LIQUID MOBILITY	SORPTION BEFORE BURIAL
RELEASE OF CONTAMINATED PARTICLES	CONFINEMENT IN PLASTIC SHEET, APPLIED FILM OR FOAM, WITHIN BURIAL BOX
PERSONNEL IRRADIATION	DISTANCE
AFTER PLACEMENT	
PICK-UP BY PLANTS, ANIMALS	BURIAL DEPTH >4'
MIGRATION OF RADIOACTIVE MATERIAL	ABSENCE OF DRIVING FORCE SORPTIVE CAPACITY OF SOIL AREA SURVEILLANCE

FIGURE V-2



CONTAMINATED LIQUID EFFLUENTS

Low Level Aqueous Wastes

The chemical reprocessing operation uses very large quantities of water most of which never comes in contact with radioactive materials. These low-level aqueous wastes (Table V-7), which are primarily cooling water and steam condensates, are discharged to ponds for percolation through the ground to the groundwater. The upper limit of acceptable contamination has been rather arbitrarily picked at $5 \times 10^{-5} \mu\text{Ci/ml}$. This limit is based on an empirical observation that these levels do not contaminate the environment to such an extent that pickup by wild animals, birds, and plants becomes a significant problem.

The quantity of radioactive materials indicated to be present in these low-level wastes is suspect. These numbers were obtained by multiplying very large volumes by very low concentrations and the concentrations were measured

TABLE V-7

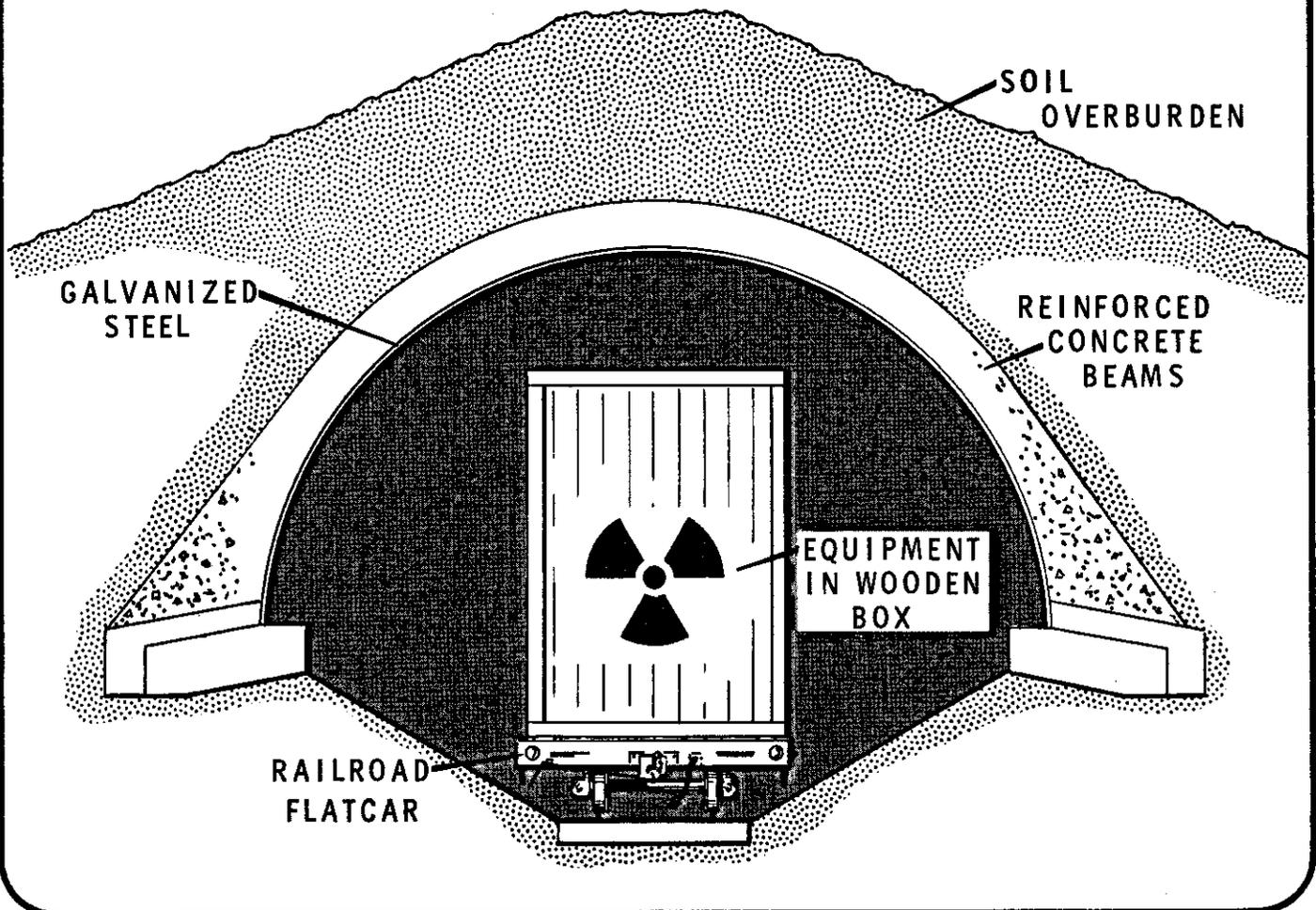
LOW-LEVEL AQUEOUS WASTES TYPES AND QUANTITIES

PLANT	VOLUME MM GALLONS	FISSION PRODUCT, CURIES
PUREX	3,047	816.6
U(UO ₂)	318	3.4
Z (234-S & 231-Z)	164	- - -
B	760	12.8
T (INCL. PNL)	125	5.1
REDOX	187	40.6
TANK FARMS	414	12.7
POWER HOUSES	845	- - -
LAUNDRY	15	0.2
TOTAL (1968)	5,875	892
APPROXIMATE CUMULATIVE TOTAL THROUGH 1968	108,500	114,000

NORMALLY CONTAMINATION-FREE COOLING WATER AND STEAM CONDENSATES DISCHARGED TO PONDS.
LOW PROBABILITY OF CONTAMINATION ABOVE $5 \times 10^{-5} \mu\text{Ci/ml}$.

FIGURE V-3

TUNNEL FOR STORAGE OF RADIOACTIVE EQUIPMENT



in a laboratory handling highly contaminated samples. Other data indicate that the Purex number is high by a factor of 10 or more, and that more than half the smaller quantity was present in the water as it was received from the Columbia River. We are taking steps to improve our measurement capability in this area.

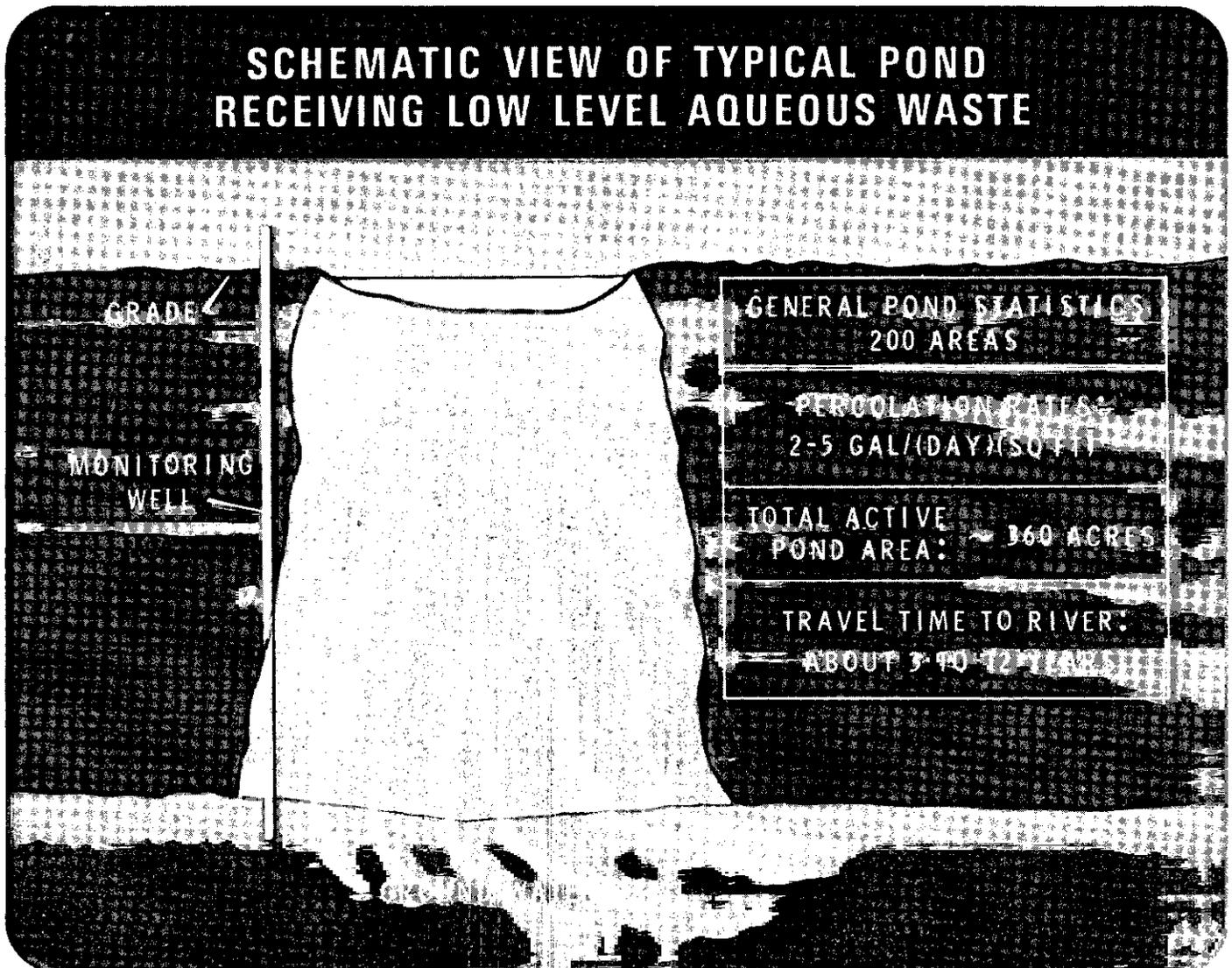
A large fraction of any contained radioactivity is sorbed or filtered and held in the soil beneath the pond area (Figure V-4). While the continued flushing action of flowing water does cause the sorbed ions to move, their rate of movement is significantly less than that of the water. Laboratory studies^(1,2) indicate, for example, that strontium will move at a rate about 100 times slower than the water itself, cesium about 1000 times slower, and plutonium about 100,000 times slower. While the small amounts of radioactivity that enter the ponds cannot be said to

be confined, we can assure that large decay factors will be realized before these materials reach the groundwater or the Columbia River.

Our concern (Table V-8) during the operation of the pond centers around the possibility of contaminating the shoreline and the vegetation and wild fowl in the area. Our principal controls are at the source of the waste. Instruments monitor the activity of the water as it leaves the plants. In some cases, diversion systems can be automatically activated so that contaminated water can be treated as an intermediate level waste as discussed later. When a pond area is deactivated we expect to cover the contaminated area with sufficient soil to avoid contamination pickup by plants and wild life.

Our plans to improve our water disposal practices (Table V-9) center around the development of better instruments for on-line detection of very low levels of radioactivity and improved reliability of diversion and

FIGURE V-4



confinement systems. While this program sounds simple, its success depends on producing reliable detection devices beyond the limits of current technical capability. In the future, we hope to catch diverted streams in tanks for distillation or purification by ion exchange.

Intermediate Level Liquid Wastes

Much smaller volumes of liquids become contaminated by direct contact with radioactive materials. While the quantities of radioactive materials contained in these "intermediate level" wastes represent a minute fraction of the quantities of radionuclides processed, these wastes do constitute a significant quantity in terms of contamination control.

Intermediate level liquid wastes include two types—organic and aqueous solutions. The organic wastes (Table V-10) are primarily solvents that have become degraded and are no longer useful in the solvent extraction processes. Most of these wastes are stored in tanks pending acquisition of an incinerator capable of burning these materials safely. We do not now have the capability to store the wastes from the Z Plant plutonium reclamation facilities, however, and these wastes are now being routed to the ground on a "specific retention basis". In other words, the liquid is being held in the soil by capillarity above the water table as indicated in Section IV.

Intermediate level aqueous wastes (Table V-11) are process condensates and salt solutions containing relatively small quantities of radionuclides. Most of these wastes are very dilute solutions of nitric acid and the radioactive cations can be readily sorbed on ion exchange media such as the clay fractions of the Hanford soils. Some of the wastes, such as salt wastes from the plutonium reclamation

processes, contain complexing agents that would hinder the sorption process. These wastes are stored in tanks when possible and released to the ground on a specific retention basis when storage is not yet feasible.

Intermediate level wastes are released to the ground by use of subterranean structures called cribs (Figure V-5). A crib is constructed by digging a ditch about 15 feet deep and up to 1400 feet long, backfilling with rock and covering with an impermeable membrane and soil. A distributor running the length of the crib is designed to

TABLE V-9

LOW-LEVEL LIQUID WASTES IMPROVEMENT PLANS

- DECREASE FREQUENCY OF WATER CONTAMINATION
- DEVELOP IMPROVED DETECTION INSTRUMENTS
- IMPROVE RELIABILITY OF DIVERSION SYSTEMS
- DEVELOP IMPROVED ANALYTICAL CAPABILITY

TABLE V-10

ORGANIC WASTES TYPES AND QUANTITIES-1968

TYPE	SOURCE	QUANTITY, GALLONS	DISPOSITION
CCl ₄ - DBBP	Z PLANT	4,300	SPECIFIC RETENTION CRIB
CCl ₄ - TBP	Z PLANT	10,000	SPECIFIC RETENTION CRIB
CCl ₄ - LARD OIL	Z PLANT*	875	SPECIFIC RETENTION CRIB
NPH-TBP-HDEHP	B PLANT	18,000	HIGH-LEVEL WASTE TANKS
NPH-TBP	PUREX	44,000	HIGH-LEVEL WASTE TANKS
HEXONE-TBP-NPH	REDOX	31,000	STORED PENDING INCINERATION

TABLE V-11

INTERMEDIATE LEVEL WASTES TYPES AND QUANTITIES 1968

PLANT	VOLUME MM GAL	FISSION PRODUCTS CURIES	U Kg	Pu GRAMS	⁹⁰ Sr CURIES	¹³⁷ Cs CURIES
PUREX	150	1,484	50	<50	27.8	22.9
U (UO ₂)	2.3	.03	8	-	-	-
Z	1.6	-	-	680	-	-
Z*	0.27	-	80	8,406	-	-
B	11.4	6,929	-	2	<33.4	917
REDOX	11.9	291	9	11.5	<13.2	16.8
TANK FARMS	29.4	3,479	1	<1	<25	667
TOTAL	207	10,183	148	<9,230	<99.4	1,624

PROCESS CONDENSATES, SCRUBBER AND UTILITY EFFLUENTS, AND SALT WASTES HAVING SIGNIFICANT PROBABILITY OF BEING CONTAMINATED.

* PLUTONIUM HELD BY SPECIFIC RETENTION

TABLE V-8

LOW-LEVEL AQUEOUS WASTES SAFETY CONSIDERATIONS

CONCERN	CONTROL
DURING OPERATION	
CONTAMINATION OF SHORELINE, VEGETATION AND WILD FOWL	DIVERSION SYSTEMS SURVEILLANCE COVERING CONTAMINATION
MIGRATION OF CONTAMINANT TO RIVER	ION EXCHANGE CAPACITY OF SOIL
AFTER DEACTIVATION	
SURFACE CONTAMINATION	COVERING, STABILIZATION
MIGRATION	ABSENCE OF DRIVING FORCE ION EXCHANGE CAPACITY OF SOIL

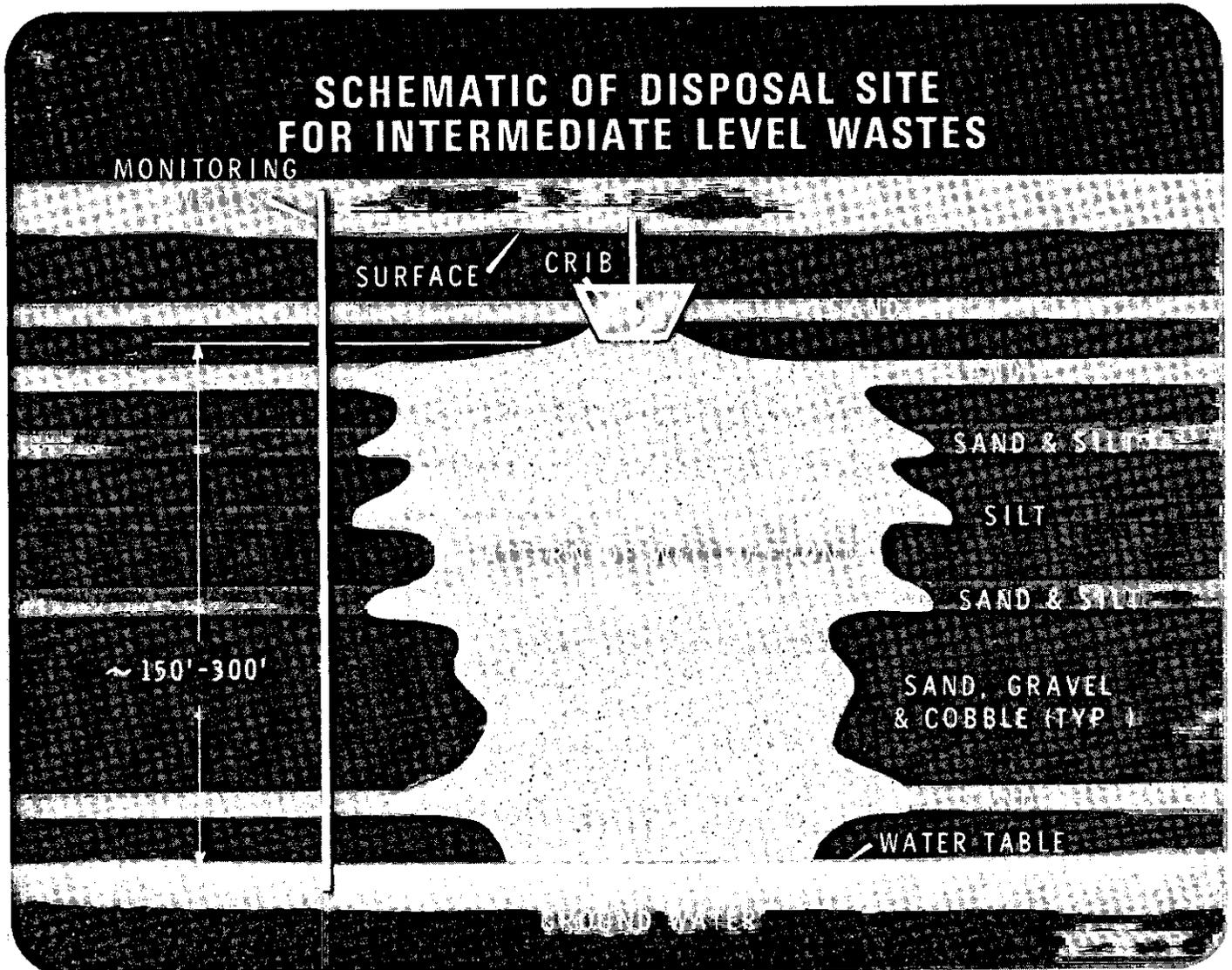
distribute the liquid uniformly along the crib length. The released liquid percolates through the soil both vertically and horizontally depending on the character of the soil through which it is moving. In coarse gravel the liquid moves downward with little or no spreading and sometimes contraction. About half of the soil between the crib and the groundwater are silts and sands having a high clay content. Percolation rates through this material are slow causing the liquid to spread laterally and involve much more soil than that directly beneath the crib.

When it is necessary to discharge organic or complexing materials to the ground as a liquid, the volume is limited such that the soil can retain the material above the groundwater by capillarity. Field data indicate that up to 10% of the soil volume can be held by capillarity with

little or no downward motion. This capability is a direct result of the arid conditions that have existed in this area for the past 10,000 years.

While the coarse gravels have little capacity to sorb or filter radioactive materials, the clays make good filter beds and have good ion exchange properties with capacities up to one milliequivalent per gram. The ion exchange capacity of the clays varies widely with the type of ion being sorbed (Figure V-6).⁽¹⁻²⁾ Tritium and nitrate ions, for example, are sorbed little if at all. Ruthenium is held relatively well, but a small fraction of the ruthenium is of such ionic form that little sorption takes place. The tritium, nitrate, and the small fraction of ruthenium then flow to and with the groundwater at essentially the same rate as the water. These materials enter the groundwater at concentrations slightly above the appropriate limits for drinking water, but are rapidly diluted below such limits as they flow toward the Columbia River. This is discussed in more detail in Section VII. Cesium and

FIGURE V-5



strontium are more tightly held by the soil, most of these radionuclides being held within the first thirty feet below the crib. When these ions are detected in the groundwater at concentrations approaching one-tenth of the maximum permissible concentration for drinking water, the crib site is deactivated, and the process effluents are routed to a new crib. Plutonium is held very tightly by the soils with essentially all of the plutonium being held within 10 feet of the point of release. This ion exchange mechanism is reversible, of course, and the sorbed ions would migrate if subjected to continued flow of water. We therefore isolate a deactivated crib site from any source of water other than natural rainfall.

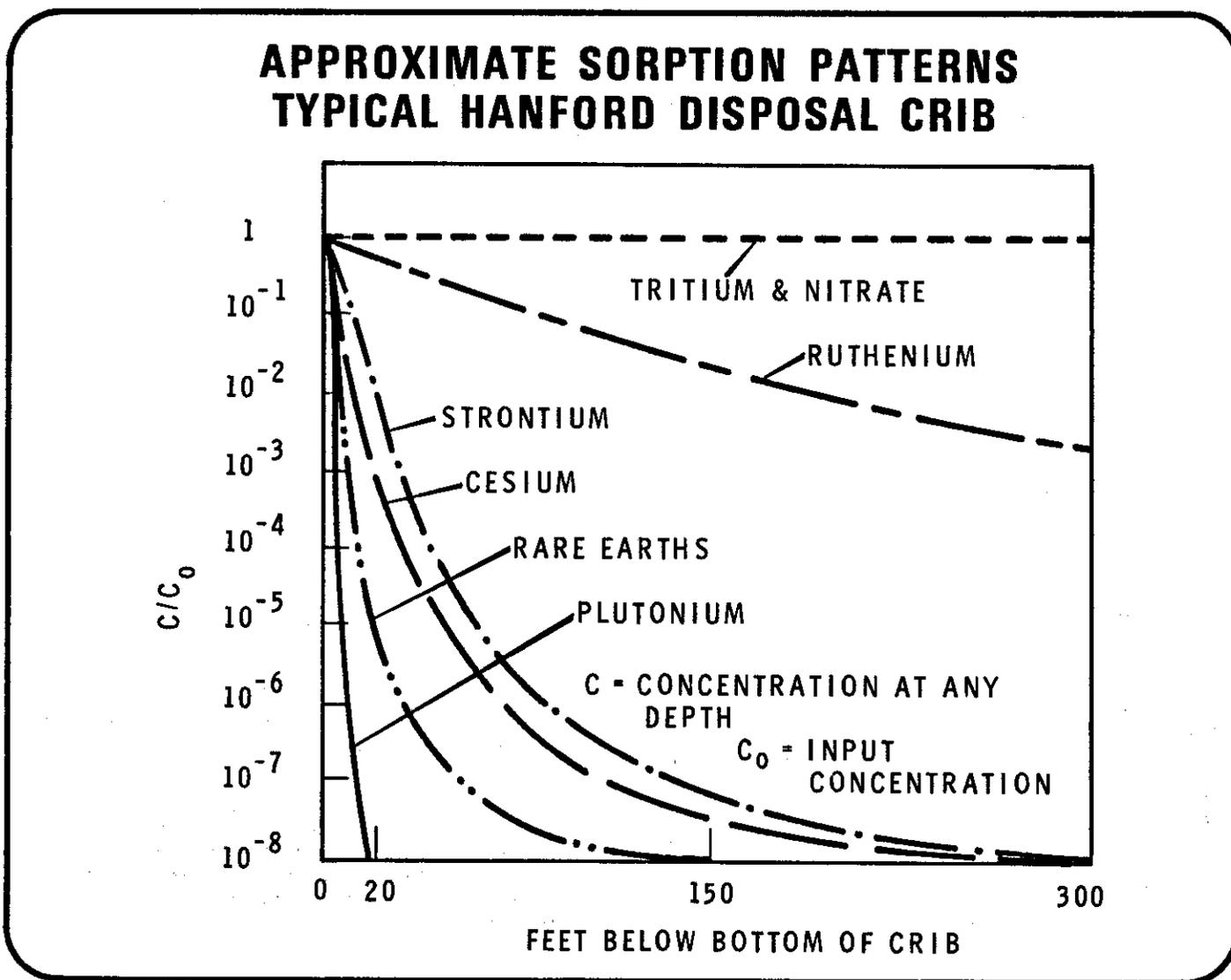
As indicated in Table V-12, significant quantities of radionuclides have been stored in the soil during the operation of this project. Essentially all of the isotopes of concern are caught and held by the soil by filtration, ion

exchange, or by specific retention (capillarity). Most of the fission products decay very rapidly with the current inventory amounting to less than one-tenth the quantities measured at time of discharge. Cesium and strontium will, of course, be present at significant

TABLE V-12

INTERMEDIATE LEVEL LIQUID WASTES IN THE SOIL CUMULATIVE THROUGH 1968					
ITEM	UNIT	SORPTION	RETENTION	TOTAL	DECAYED INVENTORY
VOLUME	MM GALLONS	6,722	36.6	6,759	
LAND AREA	ACRES	50	75	125	
URANIUM	KILOGRAMS	59,000	51,000	110,000	110,000
PLUTONIUM	KILOGRAMS	200	59	259	259
FISSION PRODUCTS	BETA KILOCURIES	2,153	922	3,075	210
STRONTIUM-90	KILOCURIES	31	11.8	42.8	31.8
CESIUM-137	KILOCURIES	16.5	32.2	48.7	35.6

FIGURE V-6



concentration for hundreds of years. Most of this inventory was deliberately routed to the ground in the 1950's to make tank storage space available at a time when plutonium was urgently needed. Uranium and plutonium will be present for hundreds of thousands of years.

Our principal concern during the release of intermediate level wastes centers around the potential contamination of the groundwater (Table V-13). Controls are placed on the character and volume of the wastes released to the crib sites, and the groundwater beneath the sites is monitored periodically to detect any potential breakthrough. After a crib site has received the maximum quantity of wastes judged to be safe, the crib site is physically isolated from all other process systems. After such deactivation, we rely on the absence of driving force to

keep the radioisotopes in the soil above the groundwater. We continue to monitor the groundwater beneath the site and to observe the migration of isotopes through the soil above the groundwater. We have observed that the most mobile readily measurable isotope, ruthenium, migrates downward a few feet in the first year after crib deactivation, and that the rate declines to a few inches per year within a few years.

Our improvement plans center around the reduction in the quantity of radioactive materials routed to the ground for retention (Table V-14). Our first priority is the elimination of the organic and high salt aqueous wastes being routed to the soil from the Plutonium Reclamation Facility for storage on a specific retention basis. We intend to modify the Z Plant facilities in FY-1971 to retain the organic wastes for incineration; and to route the salt wastes to underground tanks for storage.

TABLE V-13

INTERMEDIATE LEVEL WASTES SAFETY CONSIDERATIONS	
CONCERN	CONTROL
DURING OPERATION-CRIBS	
CONTAMINATION OF GROUNDWATER	PRETESTING OF PROCESS EFFLUENT FOR COMPATIBILITY WITH SOIL COLUMN SAMPLES
	EXCLUSION OF COMPLEXING AGENTS
	PERIODIC MONITORING OF GROUNDWATER BENEATH SITE
DURING OPERATION-SPECIFIC RETENTION	
CONTAMINATION OF GROUNDWATER	LIMITING VOLUME PER UNIT AREA
	PERIODIC MONITORING OF GROUNDWATER BENEATH SITE
AFTER DEACTIVATION	
CONTAMINATION OF GROUNDWATER	PHYSICAL ISOLATION FROM PROCESS SYSTEMS
	ABSENCE OF DRIVING FORCE
	PERIODIC MONITORING OF GROUNDWATER BENEATH SITE

Second priority goes to the elimination of a Purex scrubber waste which contains relatively large quantities of ammonia and fission products. We intend to reroute this material to an evaporator; the condensate would be cribbed as an intermediate level waste and the concentrate routed to storage in underground tanks. Elsewhere our process development centers around the reuse of process effluents to reduce the release of nitrate ion and the use of ion exchange to remove low-level contaminants from the effluents.

In summary, we have deliberately designed our waste disposal practices to take advantage of the favorable conditions of soil and climate inherent in this region. We are, however, greatly reducing the amount of nitrate ion and radionuclides being discharged to the soil to be consistent with national trends. We are convinced that the radioactive materials being stored in the Hanford soils are safe. Continued isolation of these materials can be assured as long as man maintains administrative control over this area. While different methods of waste disposal will undoubtedly evolve in the future, we believe the current practices can be continued for decades without significant hazards.

TABLE V-14

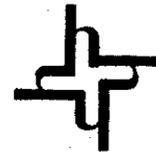
INTERMEDIATE LEVEL WASTES IMPROVEMENT PLANS
REDUCE VOLUME AND PLUTONIUM CONTENT OF Z PLANT WASTES AND ROUTE TO UNDERGROUND TANKS
ROUTE PUREX AMMONIA SCRUBBER WASTE TO CONCENTRATOR FOR TANK STORAGE
RECYCLE PUREX CONDENSATES TO REDUCE VOLUME OF EFFLUENT
INSTALL ION EXCHANGE UNITS TO REDUCE CESIUM AND STRONTIUM CONTENT OF CONDENSATES FROM WASTE CONCENTRATION UNITS
MONITOR HIGH RISK STREAMS, RECYCLE OR DIVERT AS REQUIRED
OBTAIN AND DEMONSTRATE INCINERATOR FOR ORGANIC MATERIALS

References:

1. Brown, D. J., "Migration Characteristics of Radionuclides Through Sediments Underlying the Hanford Reservation," ISO-32, May 29, 1967.
2. Raymond, J. R. and V. L. McGhan, "The Effects of Ben Franklin Dam on Hanford Waste Disposal Facilities Investigation," BNWL-412 PT1, R. W. Nelson, D. B. Cearlock, A. E. Reisenhauer, and B. R. Freidricks, "The Effects of Ben Franklin Dam on Hanford Ground Water Flow System Analysis," BNWL-412PT2, May, 1967.

VI FUELS and REACTOR WASTE DISPOSAL PRACTICES

C. D. Corbit — Douglas United Nuclear, Inc.



FUELS

The fuel preparation facilities, located in the 300 Area (Figure VI-1), are operated by Douglas United Nuclear, Inc., for the Atomic Energy Commission. Two types of fuel elements are fabricated: one for the single-pass reactors and the other for N Reactor.

The single-pass reactor fuel elements are produced from machined uranium cores which are received from offsite. The cores are dipped into a molten aluminum-silicon alloy bath and inserted into aluminum cans. The aluminum silicon alloy forms a bond between the surface of the uranium cores and the inner surface of the aluminum can walls, providing high heat transfer rates between the coolant water and the fuel elements.

Fuel elements for N Reactor are produced by a coextrusion process. Bare, machined uranium billet cores, received

from offsite, are placed in Zircaloy tubes and then canned in a copper jacket. The billets are heated and extruded through a hydraulic press. The extrusions are cut into fuel element lengths, the copper jacket is dissolved, and end caps are put on to form a finished Zircaloy clad fuel element. The coextrusion of the uranium and the Zircaloy jacket bonds the two materials.

In either fuel jacketing process the uranium bearing waste originates:

1. As residue in chemical and rinse tanks,
2. In the matrix of bonding materials that are associated with the systems components, and
3. As contamination on scrap, fines, and turnings.

FIGURE VI-1 Aerial view of 300 Area.



Liquid Effluents

Recovery waste materials are an inherent part of the processes used. Inventory control also greatly assists the management of radioactive wastes in fuel fabrications as all streams are processed for maximum practical material recovery before release to the environs. Tanks having potential to contain uranium are routed to a uranium recovery facility (Figure VI-2) prior to release into the process sewer. In the coextrusion process a lime pit is used to neutralize acids.

FIGURE VI-2 Uranium recovery facility.

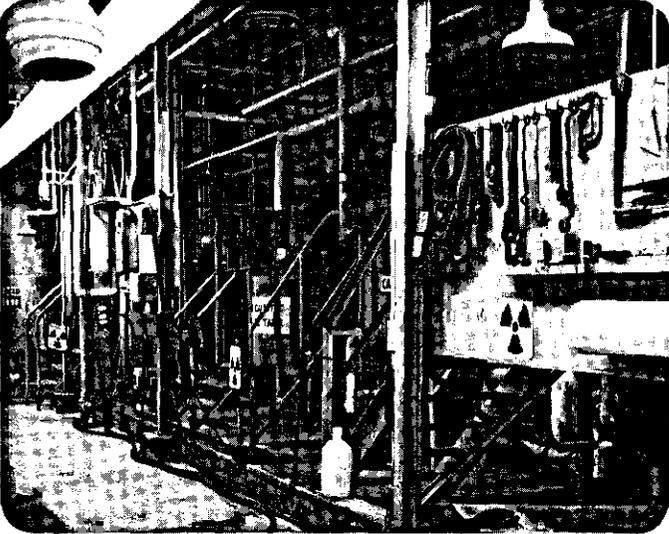


FIGURE VI-3 Active seepage pond.



Fabrication of special fuel and target elements, such as plutonium or neptunium, is performed inside of hoods having absolute filters. All contaminated waste material originating in this system is taken to the 200 Area plateau for disposal.

Perforated spacers, used in the K Reactors, are decontaminated in the 100 Areas and are anodized in the 300 Area fuels facilities. Trace amounts of activation products that remain on the spacers after they were decontaminated in 100 K Area are released with the processing solution to the seepage pond.

The liquid wastes in the 300 Area are discharged into one of two seepage ponds (Figure VI-3) that provide at a minimum particulate removal as the liquids percolate through the ground and enter the Columbia River.

Approximately 4,000,000 gallons of water flow through the process sewer each day and are discharged into a three-acre pond. Less than 1,000 pounds of uranium are discharged to the ponds annually and about 900 tons of chemical were discharged in 1968. The use of the two ponds is rotated and the pond that is dry is scarified to enhance the percolation rate of the liquid through the soil and to the Columbia River.

A proportional sequential effluent sampler operates continuously at the entrance to the pond. A composite weekly sample is submitted for chemical analysis. The average results for 1968 (in ppm) are:

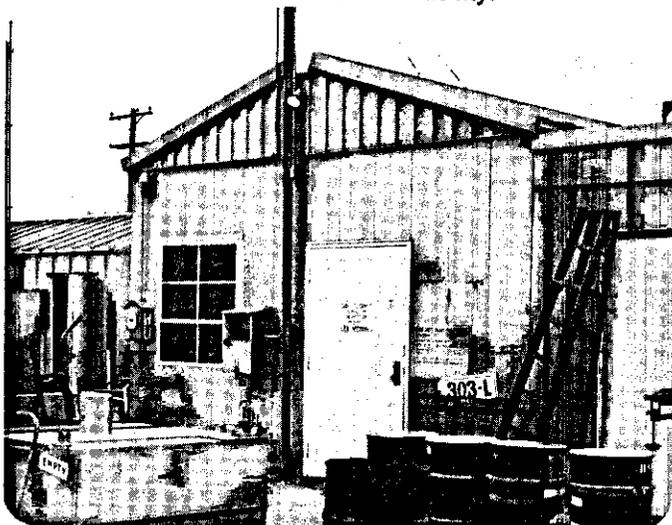
Elements	Pond Samples	Riverbank Seepage Samples	USPHS Drinking Water Limits
Cl	2.04	2.6	250
Cu	0.024	0.01	1.0
Fe	0.025	0.10	0.30
F	2.98	3.1	0.9-1.7
No ₃	136	128	45
SO ₄	30	39	250
Cr	0.047	0.024	0.05
U	0.16	0.28	—
pH	8.5	7.6	6.5-8.5

The radiological analysis of the process pond water shows a weekly average of 0.144-2.6 $\mu\text{Ci/ml}$ beta and 0.046-0.620 alpha emitters which is considerably less than the .5 $\mu\text{Ci/ml}$ release concentration allowed by AEC-RL Appendix 0510. These releases include chemical and radionuclide releases from the Pacific Northwest Laboratory.

Gaseous Effluents

The nature of the fuel preparation processes is such that radioactivity does not enter the air that is discharged to the environment. The Transuranium Pilot Plant, Analytical Laboratory, Thoria Process Plant, and the Oxide Burner Facility (Figure VI-4) are examples of plants that have potential for environmental releases of radioactive

FIGURE VI-4 303-L Oxide burner facility.



materials. These facilities are equipped with absolute filter systems to prevent such releases.

One gaseous waste management problem exists in the 300 Area; under extreme atmospheric inversion conditions, concentrations of oxide of nitrogen occasionally become unacceptably high. This problem is currently under engineering analysis and a solution is expected in the near future.

Solid Wastes

A fenced burial ground is maintained across the highway from the 300 Area exclusion area (Figure VI-5). There are two trenches in this burial ground; one is used for thoria wastes and the other for uranium wastes. Approximately 50,000 cubic feet of compacted contaminated material is buried each year. The amount of radioactivity buried to date is an insignificant fraction of a curie.

FIGURE VI-5 300 Area Uranium-Thoria burial ground.

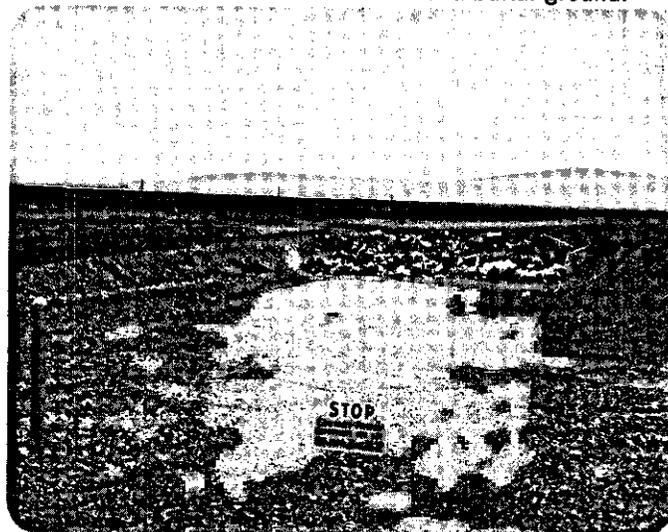


FIGURE VI-6 Uranium contaminated scrap.



When a burial site is abandoned, concrete posts are erected to designate the boundary. A building and a parking lot have been constructed in and on abandoned burial grounds.

Selected aluminum scrap that is slightly contaminated with up to 0.01% of fixed uranium (Figure VI-6) is sold to offsite customers. The weight of the contaminated material accumulated in 1968 was 435,000 pounds.

REACTORS

The three reactors operated by Douglas United Nuclear, Inc., for the Atomic Energy Commission are graphite-moderated, thermal spectrum reactors, containing horizontal fuel columns cooled by light water.

Two of the reactors, KE and KW (Figure VI-7), are single-pass water cooled reactors. The single-pass reactors use treated Columbia River water passed at a high rate through the reactor process tubes over the fuel element surfaces, where it absorbs fission-liberated heat, and after a brief retention in basins is returned to the river.

The third reactor, N, is a recirculating light water cooled reactor. High purity deionized water is also circulated at a high rate through the reactor process tubes and over

the fuel element surfaces. It then passes to heat exchangers where the heat is removed by a secondary recirculation water loop and then back to the reactor to complete the loop. Heat energy in the secondary loop is removed by flashing a portion of the flow into steam. The steam is either delivered to Washington Public Power Supply System for electric power generation or condensed by river water.

A cross-section diagram of a Hanford Reactor is presented in Figure VI-8 and shows how elements are charged into a process tube by a process operator standing on the front work platform. Thus, irradiated elements are forced out of the rear face and into a water-filled basin.

Liquid Effluents

The radionuclides in the reactor effluent are formed by neutron activation of Columbia River water salts and other elements not removed in the water treatment process, water treatment additives, corrosion products from the water system and fuel surfaces and impurities left on/or embedded in fuel element jacket surfaces. The parent materials are absorbed in the film which forms on the fuel element and reactor tube surfaces and adheres for extended periods of time to further increase radionuclide production. Extensive studies have been made to reduce the radionuclide generation rate by increasing the

FIGURE VI-7 Aerial view of 100-K Plants.



efficiency of parent isotope removal during the coolant treatment process and to reduce or eliminate the in-reactor residence time of the parent isotopes. Water treatment process innovations are already in place which have reduced the radionuclide generation rate by a factor of up to 10 depending on the radionuclide in question. Such studies are expected to continue.

The effluent flows from the reactor to a retention basin where it is held up on the order of one-half hour prior to release into the river. This permits decay of the very short half-lived radionuclides. Studies are also underway to investigate methods of removing the radionuclides from the effluent. One promising method appears to be ground disposal; percolation into the soil and radionuclide retention by ion exchange with the soil would provide long-time periods for decay before the water reached the river. Another method might be flocculation of the effluent. Either method will involve capital expenditures of millions of dollars.

The primary N Reactor coolant is deionized water. This limits radionuclide generation to corrosion products. The formation, transport, and deposition characteristics of the corrosion produced radionuclides are under investigation with the expectation of reducing the quantities currently in existence. A feed and bleed system is employed to

aid in maintaining modest radioactive levels in the system. The bleed water which contains corrosion product radionuclides is directed to a crib for disposal (Figure VI-9). The water percolates through the ground and is essentially freed of most radionuclides by the soil before entry into the Columbia River.

In N Reactor, decontamination wastes are pumped to a 900,000-gallon tank (Figure VI-10) for temporary storage. Stored liquid wastes are pumped to a loadout facility

FIGURE VI-9 N Reactor crib inlet.

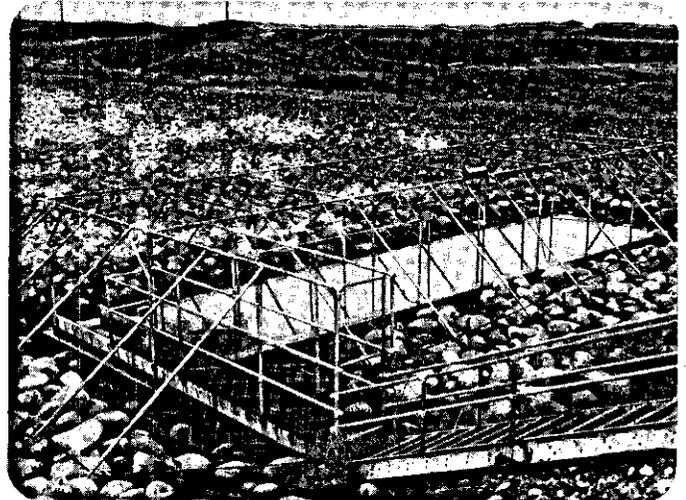
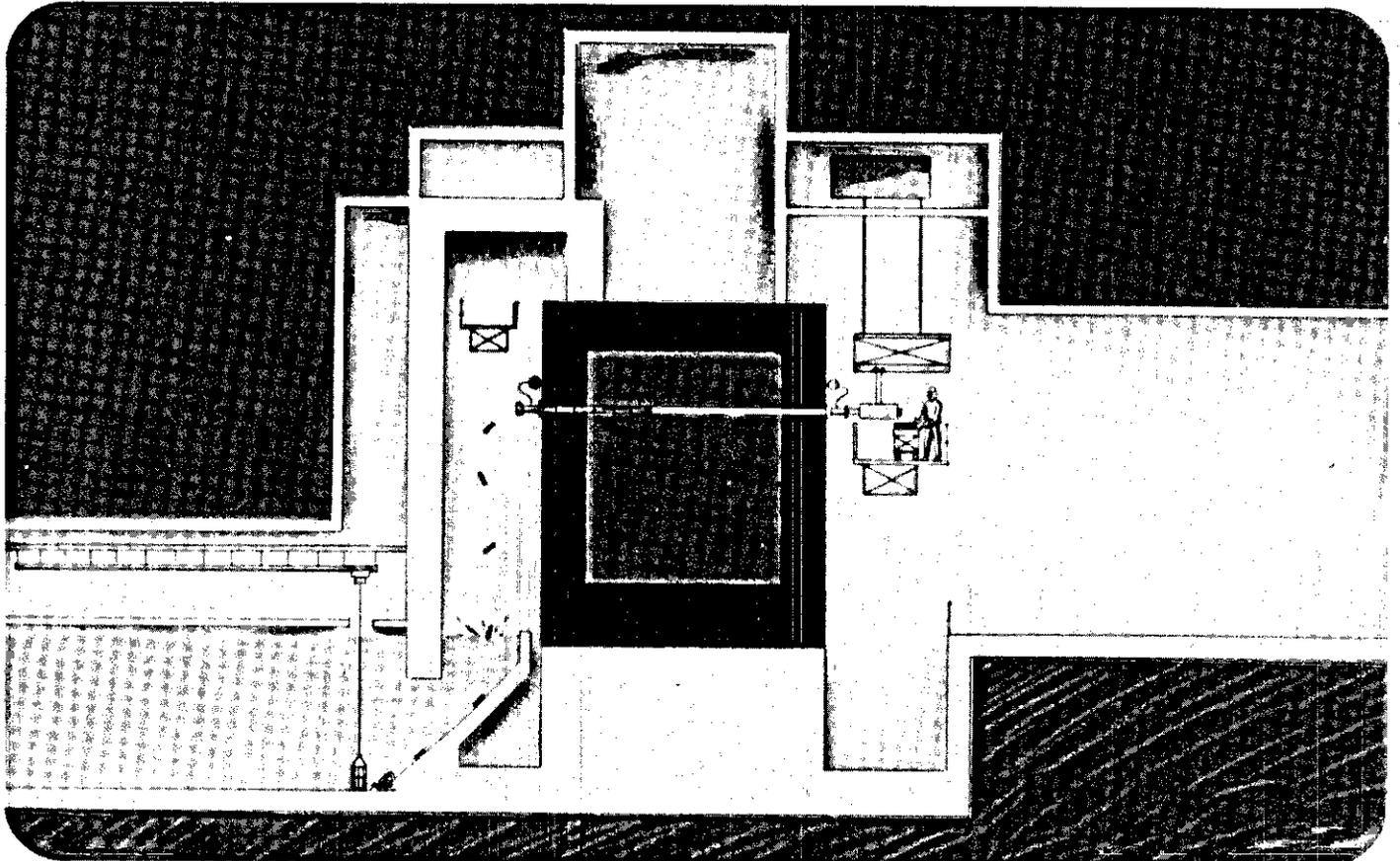


FIGURE VI-8 Reactor cross section.



(Figure VI-11) and into tanks fitted to railroad cars. The decontamination wastes are then transported to the 200 Area for processing.

In general the flow rate of the streams is essentially constant during reactor operation. During shutdowns the

FIGURE VI-10 Decontamination waste tank.

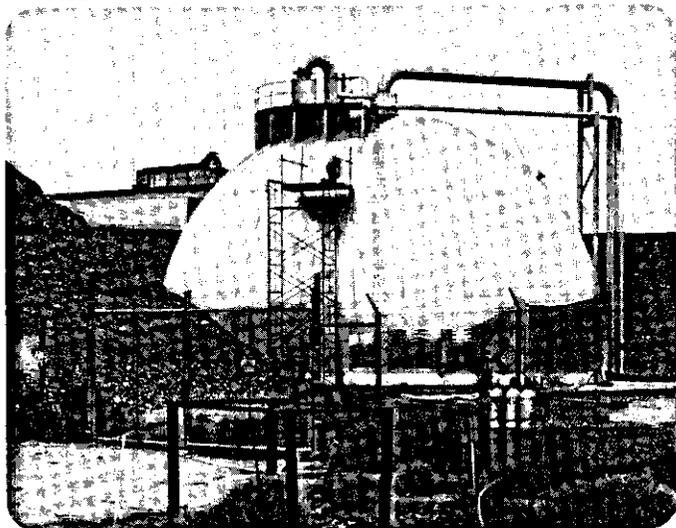
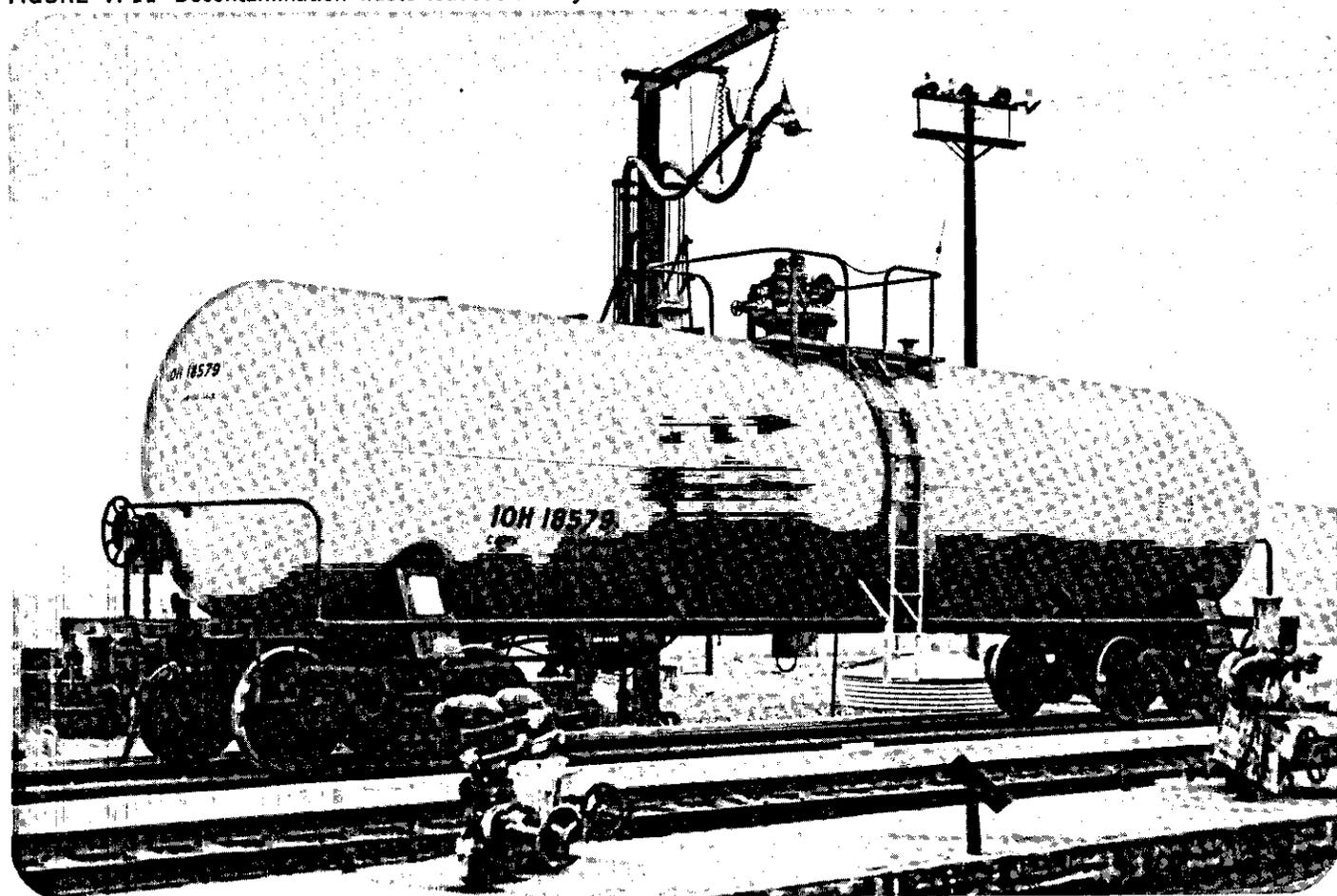


FIGURE VI-11 Decontamination waste loadout facility.



coolant flow for the K Reactor coolant stream is reduced to about 10 percent or less of the operating flow. N Reactor condenser coolant flow is reduced to about one-fourth of the operating level flow. Thus, depending upon operating modes, the radionuclide release rates fluctuate widely. Even during sustained operation a substantial variation in radionuclide generation rate (depending on the season of the year) can occur. Some of the radionuclide concentrations in the K Reactor effluent are influenced by the composition of the river water. Those such as ^{76}As , ^{239}Np , ^{32}P , and ^{65}Zn have maximum transport rates in the Columbia River that can vary by a factor of three. Chromium-51, whose source is the sodium dichromate added at a constant rate for corrosion inhibition, is generated at an essentially constant rate. However, the reactor shutdowns and reduced use of dichromate have lowered release concentrations by a factor of four. It is possible for the transport rate of ^{137}I to increase a factor of 10 above the normal rate when a fuel element jacket fails.

The radionuclides in reactor effluents are largely soluble with only a small fraction being colloidal, particulate or

particulate-associated. Analytical measurements made on the residue and filtrate from samples of K Reactor effluent water showed the following:

Radionuclide	Colloidal, Particulate, and Particulate Association Percent
²⁴ Na	0.7
³² P	4
⁵¹ Cr	3
⁴⁶ Sc	73
⁶⁴ Cu	26
⁶⁵ Zn	28
⁷⁶ As	3
²³⁹ Np	1

The colloids and particulates are very small; the diameter being on the order of 0.1 micron or less. Electrophoretic migration experiments have demonstrated that ⁷⁶As exists both as arsenious acid and an equilibrium mixture of monohydrogen arsenate and dihydrogen arsenate. Phosphorus-32 exists during reactor operation as an equilibrium mixture of monohydrogen phosphate and dihydrogen phosphate. During shutdowns the concentration of a polymer more condensed than the tetrameta-phosphate builds up. Chromate ion is the chemical form of ⁵¹Cr. Manganese-56 exists as either Mn(III) or Mn(II); however, it is apparently not a simple ion of either one but possibly a complex. Sodium-24 exists as the sodium ion.

Although the liquid waste streams carrying radioactivity contain a large number of curies, the radionuclides having relatively long half lives comprise only a minuscule fraction of the total. The long-lived radionuclide content of all the liquid streams is shown on the following table:

Radionuclide	Half-Life Years	Curies Per Year
⁹⁰ Sr	28	15
¹³⁷ Cs	30	5
¹⁵² Eu	13	150
⁶⁰ Co	5	400
³ H	12	10,000

The bulk of the single-pass reactor cooling water effluent is discharged into the main channel of the Columbia River. A small percentage of this effluent is discharged into an elongated open trench in 100 K Area. The water thus discharged percolates through the soil to reach the river, and much of the radioactivity is retained in the soil. Additionally, leaks from the effluent system result in small depositions of radionuclides in the soil column. Thus, while 99% of the activity is discharged into the Columbia River, the portion remaining in the soil is considered solid waste.

Gaseous Effluents

Air leaving the reactor facilities passes through absolute filters for particulate removal and then through one-inch

charcoal beds for halogen removal. The efficiencies of the filters and charcoal beds are considered to be more than 99% and 95% respectively.

The released gaseous wastes do not measurably contribute to non-occupational dose. To date, gases released to the environs are considered non-radioactive, except the ⁴¹Ar released from the retention basins. Argon-41 contributes to worker exposure (1 to 500 mrem whole body dose/year) and is considered to be low level activity (dose at or below 1/10 of the occupational standard AEC Manual Chapter 0524). Filters containing radioactive particulates are buried as solid radioactive waste.

Solid Wastes

The carriers for buried solid wastes range over a broad span. Included are paper, rags, structural concrete and steel, wood and a variety of metals, such as aluminum, steel, and Zircaloy. The metallic solids have diverse configurations ranging from small tools and eight-inch long fuel element spacers to large equipment pieces typified by 40 foot control rods and portions of test facilities. More than 99% of solid radioactivity is contained in the matrix of solids having diverse configurations. Less than 1% of the activity includes a minute percentage of the dried salts of the activation and fission products associated with the coolant stream. In the case of the cationic radionuclides, these would be expected to be sulfates, and in the case of anionic nuclides, calcium salts would be anticipated. The solids removed from the reactor contain activation products within the metallic matrix that is formed in situ. For example, ⁹⁰ZrNb is formed in Zircaloy process tubes; ⁶⁵Zn and ⁶⁰Co are formed in aluminum process tubes, and ⁵⁹Fe and ⁶⁰Co are formed in steel. Less than 1% of the solid waste radioactivity consists of fission products, the long-lived portion of which is not considered to be of future concern. Therefore, the waste of concern is ⁶⁰Co in a homogeneous matrix of metal alloys and as such is insoluble and cannot percolate through the soil into potable water supplies even if inundation of burial sites occurs.

Radiocontaminated and irradiated wastes are transported to a centralized burial ground in 100 K Area (Figure VI-12). This burial ground has a locked gate to control access.

When perforated spacers are being removed, they are placed in a cask and the cask full of spacers is placed in the back of a shielded truck (Figure VI-13) and transported to the burial ground. Once inside of the burial ground, the truck hauls the spacers to large iron-lined pits. The cask is removed from the truck by a hydrocrane and the contents

FIGURE VI-12 Access gate to 100-K burial ground.



FIGURE VI-13 Shielded truck for cask transport.

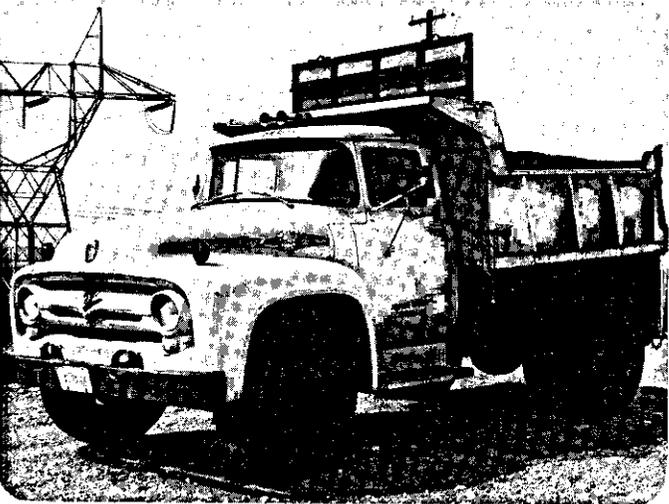


FIGURE VI-14 Hardware trench.



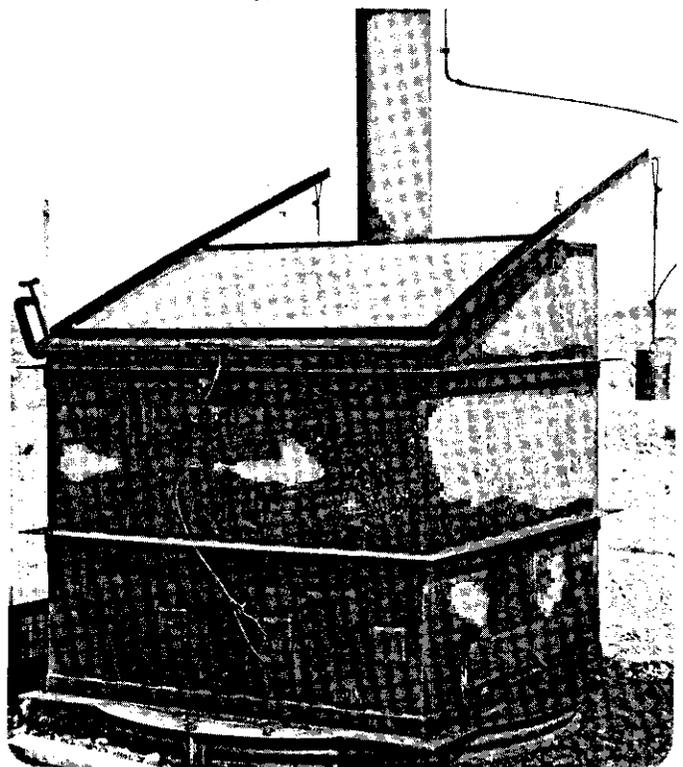
dumped into the pit. After most of the activity has decayed (3-5 years) a pit is clammed out and the spacers are buried close to the pits. Other lower activity metallic wastes are disposed of in a trench (Figure VI-14).

Most of the combustible waste is currently being burned in a crude prototype incinerator (Figure VI-15). This burning is part of an overall study on methods to reduce the volume of waste buried and thereby minimize the acres of ground requiring long-term surveillance. Results to date show that radioactivity releases are negligible, and carbon releases are large. Based on these studies, either an advanced type of incinerator will be designed for use in the reactor areas or compaction methods improved.

N Reactor spacers are made of carbon steel. The iron is activated and produces most of the dose rate measured during the first two years. These spacers are flushed hydraulically from the 105 storage basin to three underground spacer pits that are vented. As soon as the last pit is filled, the lid from the first pit will be lifted and the spacers removed with an electromagnet, placed into a container and hauled for disposal in the 100 K Area burial site.

The basis for the DUN solid radioactive waste classification includes identification, dose rate, physical half life and toxicity of the radionuclides, allowable population (non-occupational) exposure (AEC Manual Chapter 0524) and allowable periods of decay time. In addition an infinite source has been used in dose calculations for the limiting radionuclide (^{60}Co).

FIGURE VI-15 Prototype incinerator.



Classification	Conc. ⁶⁰ Co /g Matrix	Components & Average Conc. Ci ⁶⁰ Co /g Matrix
Nonradioactive	0 - 2 nanocuries (2 x 10 ⁻⁹)	
Low Level*	>2 nanocuries - 1 microcurie (2 x 10 ⁻⁹ - 1 x 10 ⁻⁶)	Combustible contaminated items (5 x 10 ⁻⁸)
Intermediate Level	>1 microcurie - 1 millicurie (1 x 10 ⁻⁶ - 1 x 10 ⁻³)	Al Spacers 5 x 10 ⁻⁶ N Steel Spacers 5 x 10 ⁻⁶ Zr Tubes 1 x 10 ⁻⁴ Al Tubes 2 x 10 ⁻⁴ Horizontal Rods 2 x 10 ⁻⁴ Al Thimbles 2 x 10 ⁻⁴ Vert Rod Tips 2 x 10 ⁻⁴
High Level	>1 millicurie (1 x 10 ⁻³)	Stainless Steel 2 x 10 ⁻² Nickel Alloys 2 x 10 ⁻² Constantine Stringers 9 x 10 ⁻² Germinal Stringers 2 x 10 ⁻¹

* These wastes are not sampled; measurements are made by hand monitoring devices.

Wastes with very low activity levels (<2 μCi/g matrix) are considered non-radioactive in the 100 Areas and are "releasable." Radioactive wastes require radiological control; low level for up to 25 years, intermediate level up to 100 years and high level for more than 100 years (in practice ~145 years — see Figure VI-16).

Evaluation of total curies disposed of to the burial sites has proven to be a meaningless number. After the radionuclides had been identified and the relative abundance of each established, it was determined that ⁶⁰Co was the only truly significant radionuclide (in solid activated metal components) from a safety standpoint.

Comparison of these same data in bar chart form show that the decay of ⁶⁰Co is extremely slow when compared to the total activity buried (Figures VI-17 and 18).

On the other hand, most of the ⁶⁰Co inventory in the reactor area facilities is not in the burial grounds, but rather remains in the reactor building (105 building) in the thermo-shield and other irradiated in-pile hardware. The in-reactor inventory is a factor of six (at a minimum) greater than the out-of-reactor inventory (Figure VI-19). However, the factor of six differential may be a factor of 10 low. Current calculations were based on low ⁶⁰Co impurity levels in the thermo-shield as would be found if eastern iron were used. The thermo-shield may be made of western iron which is notorious for high ⁶⁰Co impurity levels. Because of these facts, samples will be taken in the future to more precisely define levels of radioactivity.

FIGURE VI-16

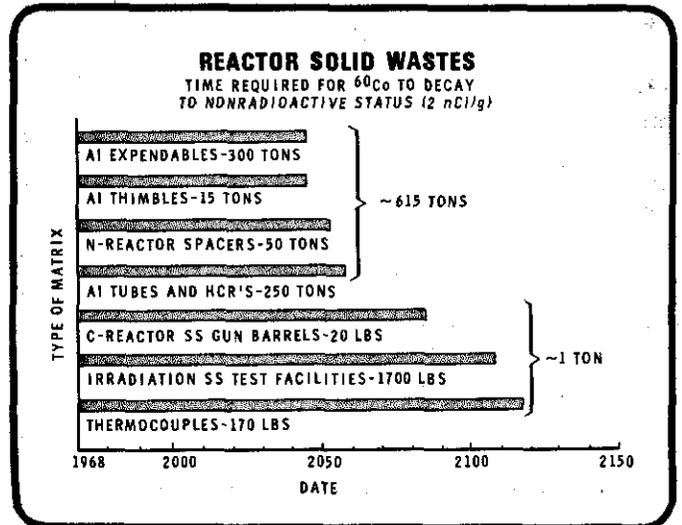


FIGURE VI-17

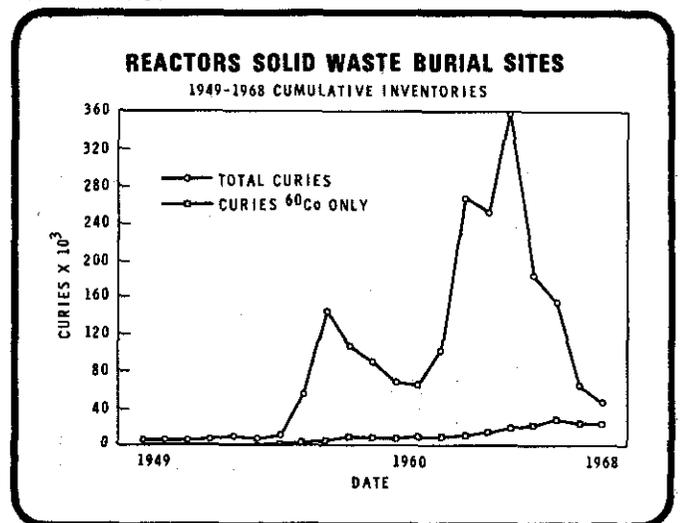
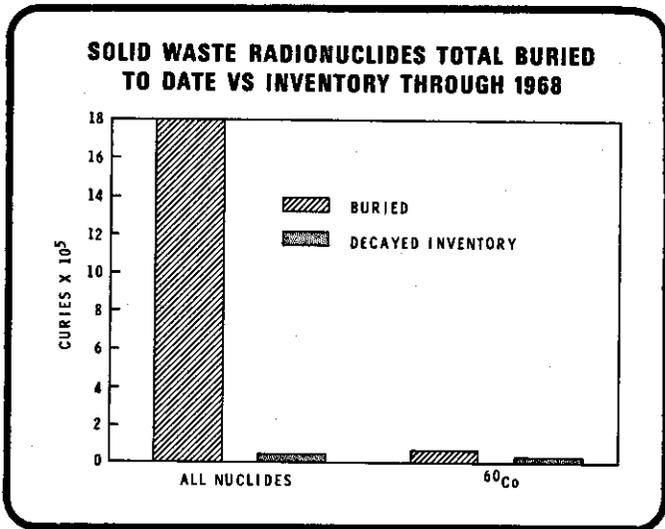


FIGURE VI-18



Effluent water entering the N Reactor crib contains a small amount of radioactive material. This activity is slightly different in nature than that found in the single-pass machines; there is little material with half lives of a few days or week. This is because the water is deionized (Figure VI-20).

The radionuclides found in the single-pass reactor retention basins and trenches are believed to be of low activity level and an extensive sampling program has been initiated to thoroughly define this condition. All of this activity should be decayed away to less than two nanocuries per gram of matrix before the year 2100 (Figure VI-21).

FIGURE VI-19

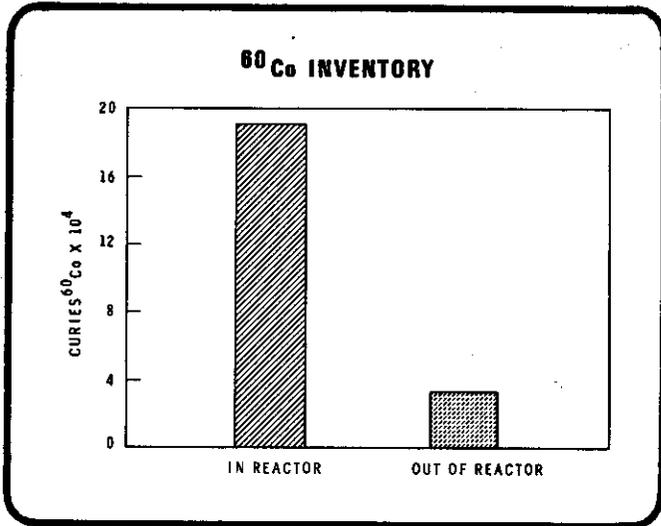


FIGURE VI-20

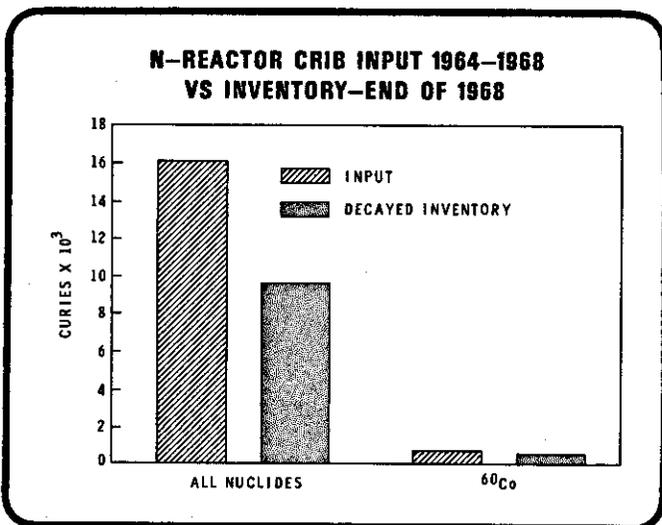
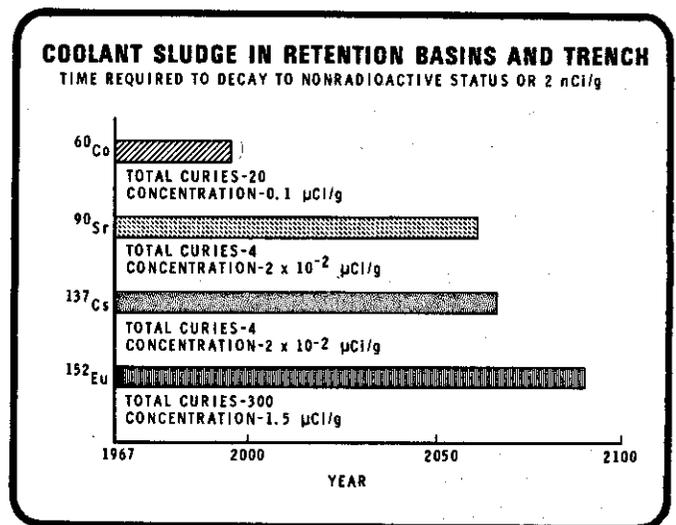
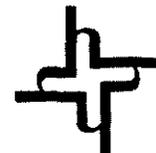


FIGURE VI-21



VII MOVEMENT of HANFORD RADIONUCLIDES THROUGH the ENVIRONMENT

R. F. Foster — Battelle Memorial Institute Pacific Northwest Laboratory



INTRODUCTION

The objective of radioactive waste management programs is to minimize the release of radionuclides to the environment and thus to minimize the radiation exposure to people and other life forms to the extent that this is practical. The ultimate measure of the success of the program is, then, the magnitude of the radiation dose that is actually received by people who live in the vicinity of nuclear installations and whose habits tend to make them especially vulnerable to exposure from the waste. This discussion is concerned with:

- The identification of the people who are most apt to receive radiation exposure from the Hanford plants
- The program that is in place to determine how and where these people may be exposed
- The exposure pathways that are of greatest significance
- The magnitude of the exposure that has been received
- Extrapolation of the current knowledge and practices to provide some estimates of the magnitude of the dose that might be received in future years.

Most of the exposure that now occurs is the result of chronic releases of low-level wastes. Occasionally there have been unplanned releases that have temporarily added to the exposure of some people in specific localities. The probability that unplanned releases of a similar or quite different nature will occur in the future is recognized.

THE EXPOSED POPULATIONS

About 90,000 people live near the Hanford project — either in the Tri-Cities or in the agricultural area nearby. Because of the variety of foods and beverages available to these people, the different amounts of radionuclides they contain, and because of different home sites and recreational preferences, no two individuals have precisely the same intake of radionuclides or encounter quite the same radiation exposure.^(1, 2) Figure VII-1 shows the urban and agricultural communities that are close to the Hanford Reservation.

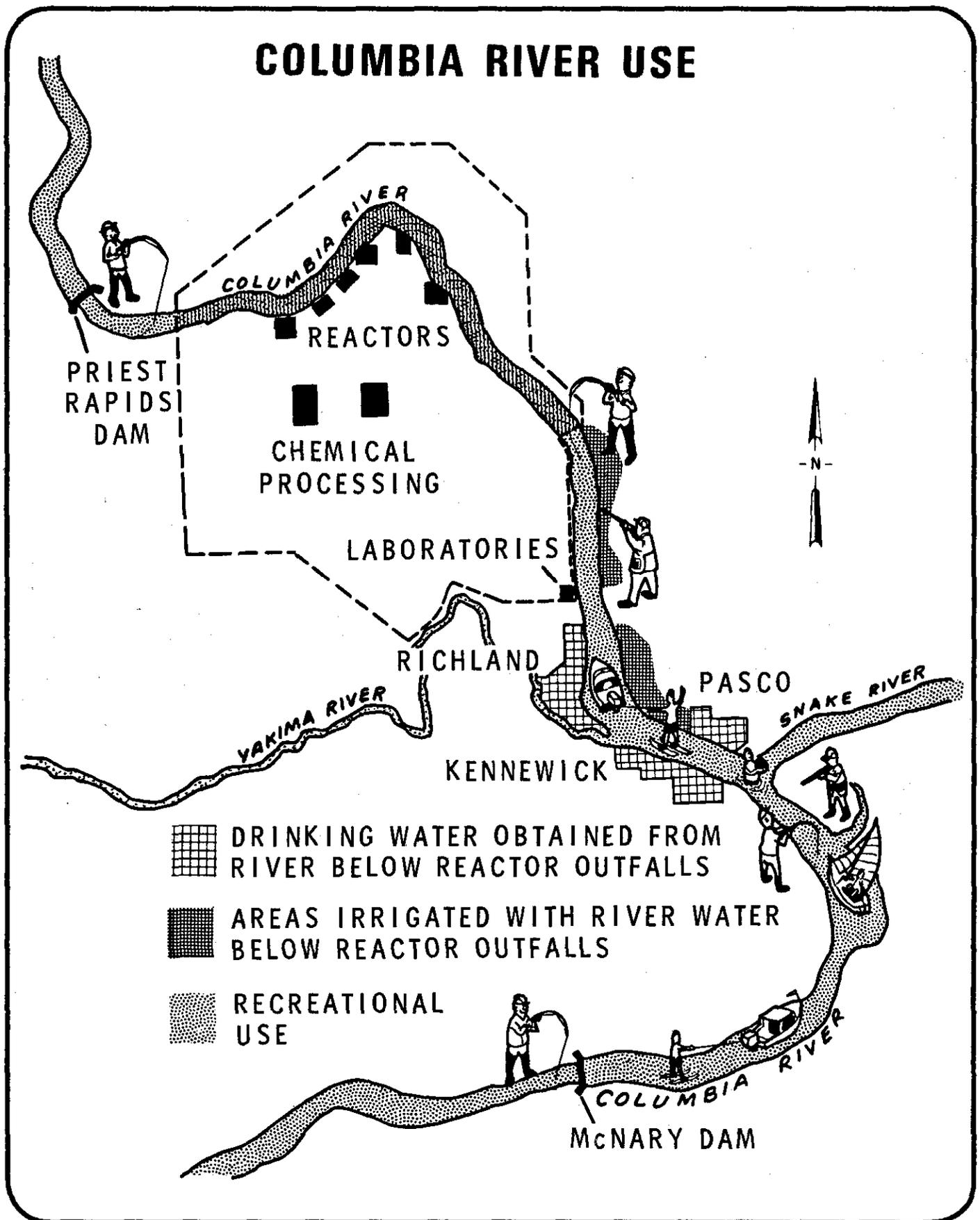
The cities of Richland, Kennewick and Pasco all derive their water from the Columbia River, which is a source of radionuclides principally because of the effluent from the reactors. The residents of Richland take in more radionuclides with their drinking water than do the residents of Pasco or Kennewick. The people that live on farms and obtain their water from wells receive virtually no exposure from their drinking water.

The amount of land that is irrigated with water pumped from the Columbia River downstream from the Hanford reactors is quite small. At Ringold there are a few small farms that are irrigated with water pumped from the river. Fruit is the principal product of these farms, but the farmers do have a few cows and chickens to supply their personal needs. Between Richland and Pasco is the Riverview farm area (about 5000 acres) that is also irrigated with Columbia River water. Much of this area is actually a suburban-type development with some family gardens. The larger farms are devoted principally to hay, fruit and beef, but a few dairy farms are also present.

The Ringold, Riverview and Benton City farming areas are "downwind" from the chemical separations plants, and are more likely to receive airborne contaminants than are the farms to the northwest of the Hanford Reservation.

Fishing on the Columbia River is permitted throughout the year, both above and below the region of the reactors. But this is sport fishing only. Commercial fishing (for salmon) does not occur within 150 miles. Since local fish accumulate some radionuclides from the river water, they constitute a major source of nuclide intake for the individuals who eat them in large quantities. The fishermen and also the swimmers and water skiers receive some radiation exposure directly from the water and shoreline.

FIGURE VII-1



SOURCES AND ROUTES OF EXPOSURE

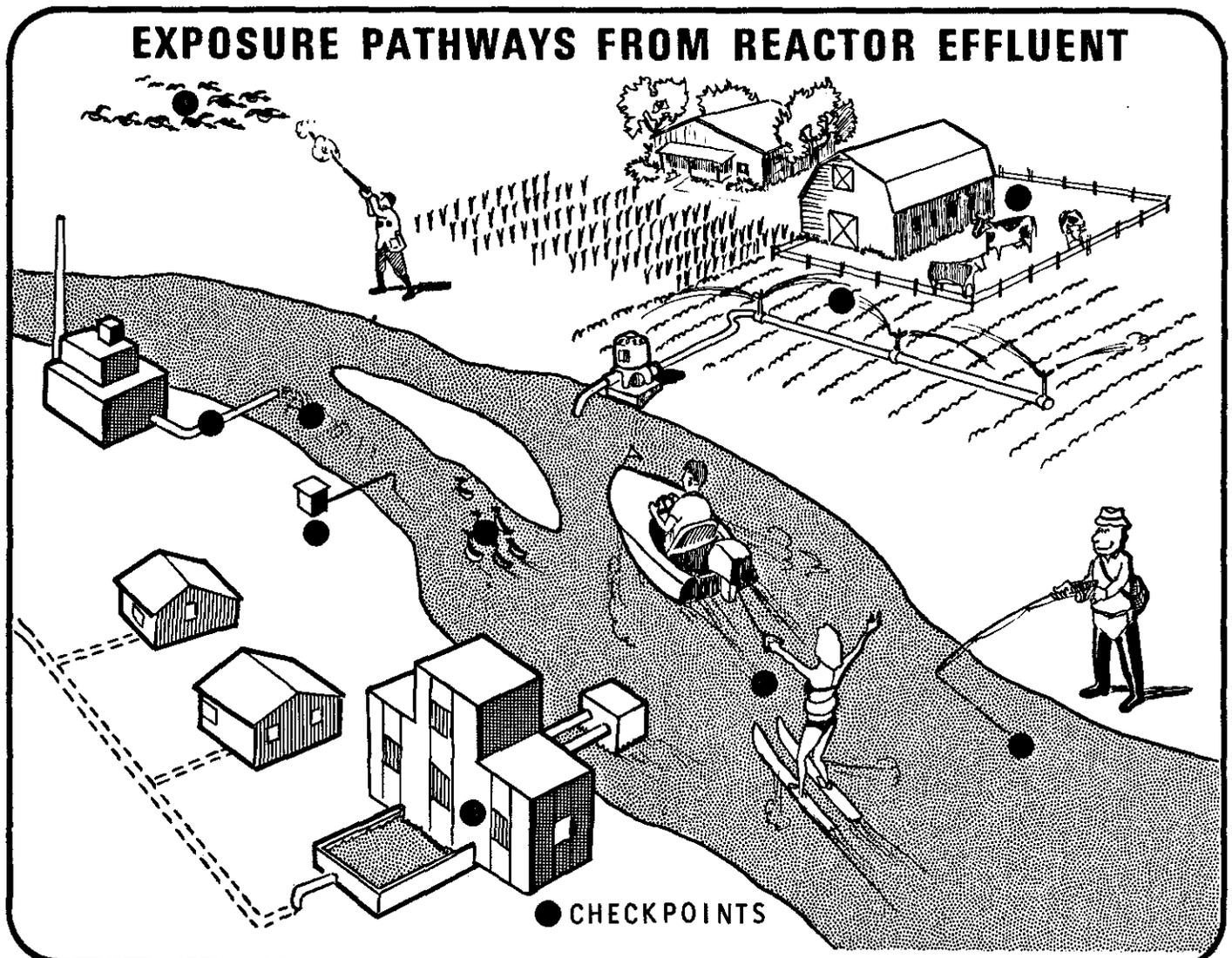
Reactor Effluent and the Columbia River

Although the greatest quantities of radioactive waste are generated and retained at the 200 Area chemical separations plants, the reactors, with single-pass cooling, discharge the greatest amounts of radioactive contaminants to the environment.⁽²⁾ For the most part, the radionuclides released to the Columbia River with the reactor effluent are short-lived neutron activation products. Some fission products are also present, however, and these come both from "tramp" uranium present in the cooling water and from occasional ruptures of the fuel elements. During an "average" day in 1968 the quantities of nuclides moving downriver past Richland amounted to about: 400 Ci ⁵¹Cr; 700 Ci ²⁴Na; 30 Ci ³²P; 300 Ci ²³⁹Np; 30 Ci ⁴⁶Sc; 100 Ci ⁷⁶As; 50 Ci ¹²²Sb; 30 Ci ⁶⁵Zn; and 2 Ci ¹³¹I. Smaller quantities of a number of other nuclides are also present, but their contribution to human exposure is insignificant. The

contribution of the dual-purpose N-Reactor to the quantities of nuclides in the river is also relatively insignificant.

Figure VII-2 illustrates the important ways in which members of the general public may receive radiation exposure from the presence of radionuclides in the river water. For persons who do not eat substantial quantities of fish or game birds, or use the river extensively for recreation, the drinking of water available in the municipal supplies of Richland and Pasco constitutes the dominant pathway. People who consistently eat vegetables, milk, meat, and eggs from farms irrigated with water pumped from the river downstream from the reactors receive a greater dose than the residents of Richland. The individuals that receive the greatest dose are people who consume large amounts of locally-harvested fish, and game birds taken near the river. Persons who spend a

FIGURE VII-2



great amount of time swimming or boating on the river, or fishing on the river bank, receive some external exposure from the radionuclides present in the river water or deposited at the shoreline.

Stack Gases and the Atmosphere

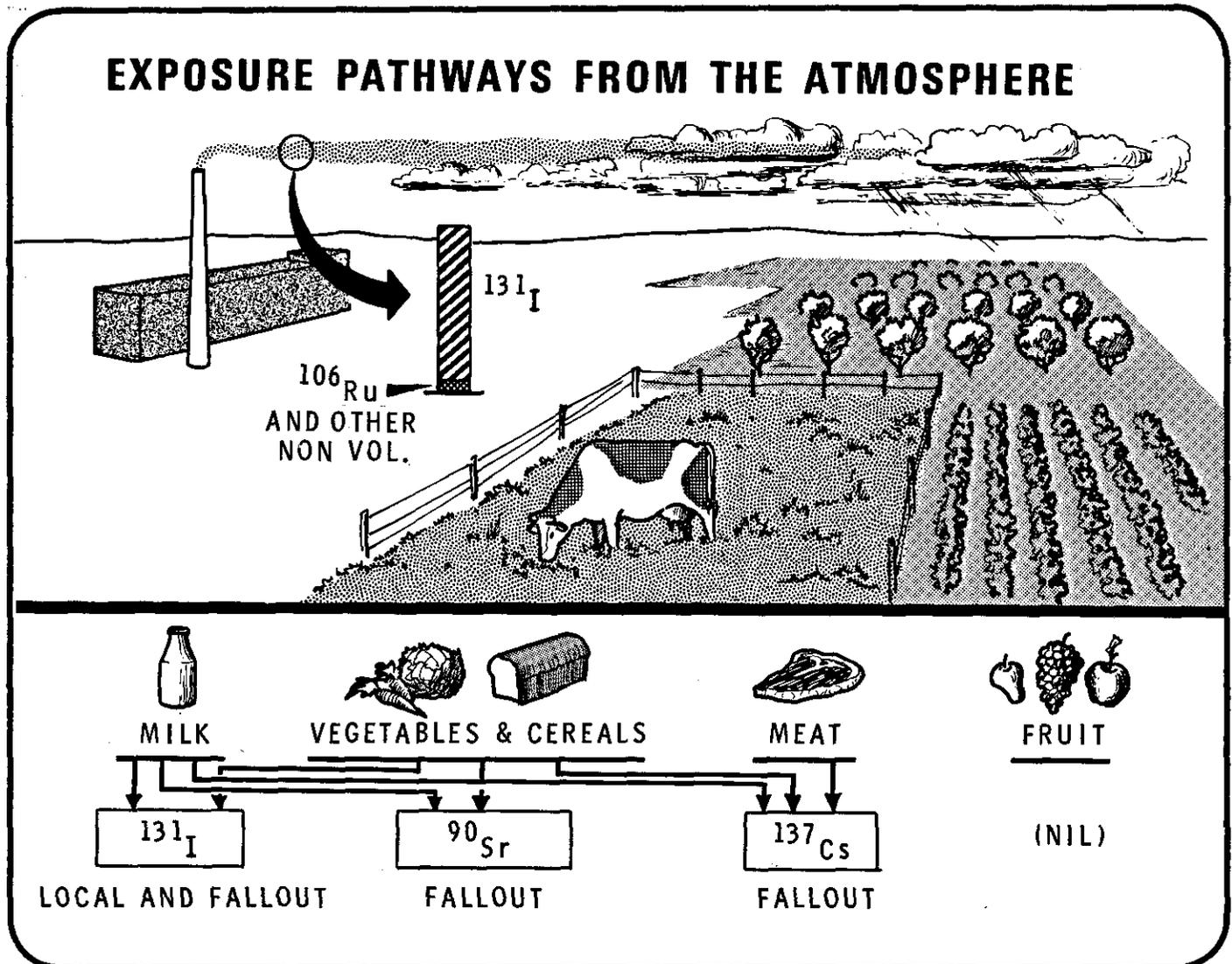
The principal release of radioactive materials to the atmosphere is associated with the processing of the irradiated fuel in the chemical separations plant (now only Purex).⁽⁴⁾ As indicated in Figure VII-3, the nuclide of greatest interest is ¹³¹I, because of the pasture grass-cow-milk pathway that leads to its deposition in the thyroid. Since there is no farming on the Hanford Reservation, the nearest places where this exposure route now operates are the farms on the east side of the Columbia River and to the south near Benton City and West Richland. The prevailing winds carry most of the airborne contaminants

toward the Ringold and Riverview farms, east of the 300 Area. During 1968 the average rate of release of ¹³¹I from the Purex stack was only about 0.1 Ci per week. At this low level, ¹³¹I is not usually detected in samples of milk from the most vulnerable farms, and any fresh fallout from foreign weapons testing in the atmosphere easily obscures the Hanford ¹³¹I.

Of secondary importance to ¹³¹I in the stack gases are the longer-lived fission products ¹⁴¹Ce, ¹⁴⁴Ce, ¹⁰³Ru, ¹⁰⁶Ru, ⁹⁵Zr-Nb. Dilution in the atmosphere is sufficient to reduce their concentration beyond the project boundaries to levels that are very difficult to detect and their contribution to human exposure is virtually nil. The same is true for the portion of tritium released as a gas.

Ruthenium-106 can leave the chemical process as a true gaseous species, but by the time it is discharged from the stacks it is usually associated with particulate matter. Because of good process control and filtration of the stack

FIGURE VII-3



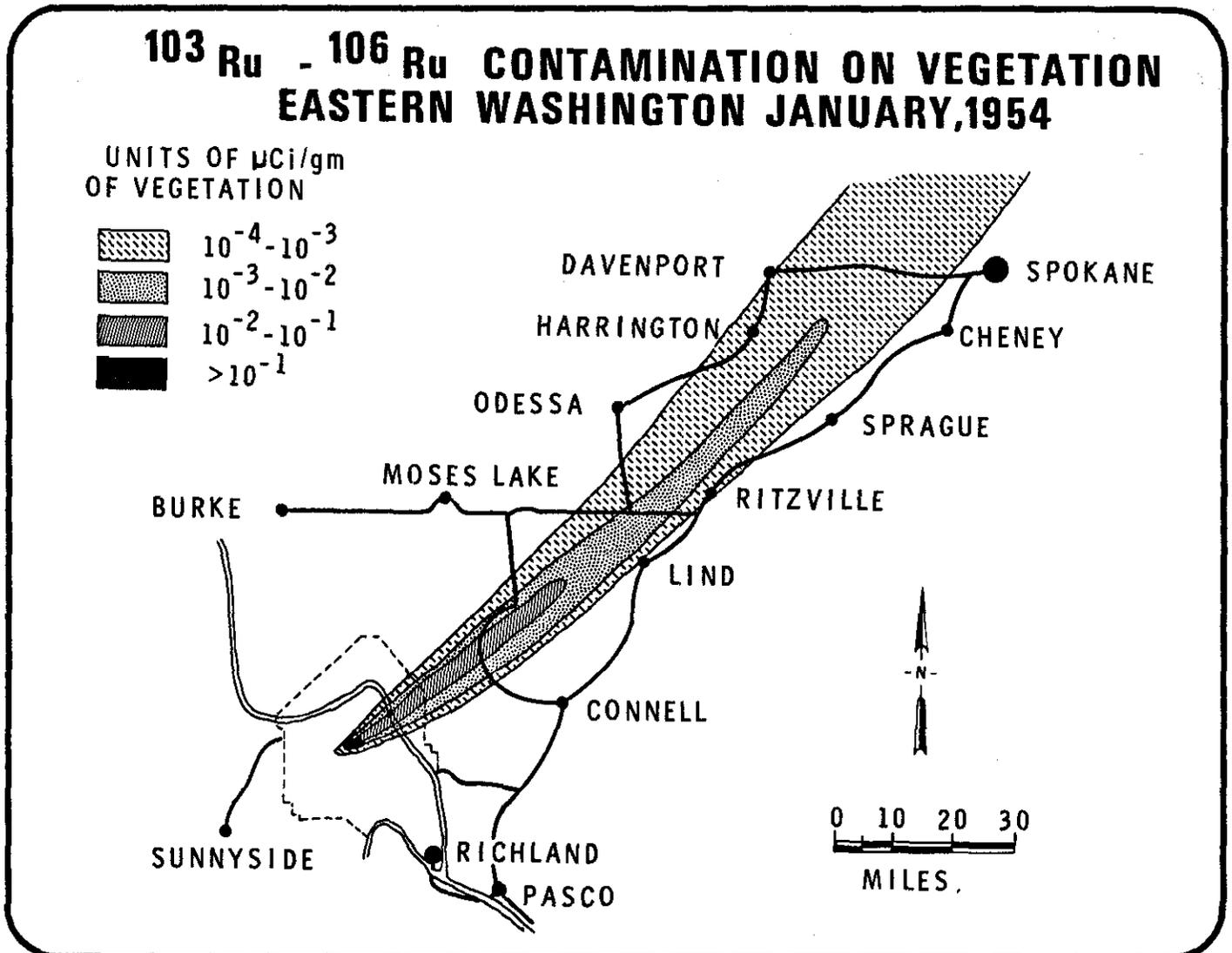
gases, ^{106}Ru particulates have not been a significant problem for more than a decade. Some problems were encountered during the early years of operation of the Redox plant, however. During the years 1952 through 1954 several releases of ^{106}Ru particulates occurred that prompted temporary control of access to some segments of the reservation. An unusually large release in January 1954, at a time when a high velocity, steady wind was blowing, resulted in ^{106}Ru deposition that was detected as far away as Spokane. (5) Figure VII-4 shows the relatively narrow deposition pattern from this "worst case."

If ^{106}Ru particulates are abundant in the environment, one can postulate their ingestion with the consumption of vegetables that have not been thoroughly washed or peeled. Except for this route, radiation exposure is most apt to be directly from the particulates as a source external to the body. At this time, ^{106}Ru from the separations plant stacks is not detectable offsite, and thus the dose to the general public from this source is nil.

Cribbed Waste and the Groundwater

The low and intermediate level wastes that are discharged to ground in the vicinity of the separations plants are not expected to reach the environment in significant amounts and their contribution to the radiation dose received by members of the general public is nil. Nevertheless, we must take cognizance of the pathway which is most likely to lead to human exposure. As illustrated in Figure VII-5, this is percolation of the nuclides through the vadose zone (200 to 300 feet thick) to the water table; transport by the groundwater some 6 to 15 miles to the Columbia River; dilution and transport by the river water to the municipal water supply intakes of the cities of Richland, Kennewick and Pasco; and, finally consumption of the nuclides by the residents of these cities. One can also postulate that the nuclides would be taken up by Columbia River fish.

FIGURE VII-4



However, for the fission products involved, this route of exposure does not appear to be as important as the drinking water route.

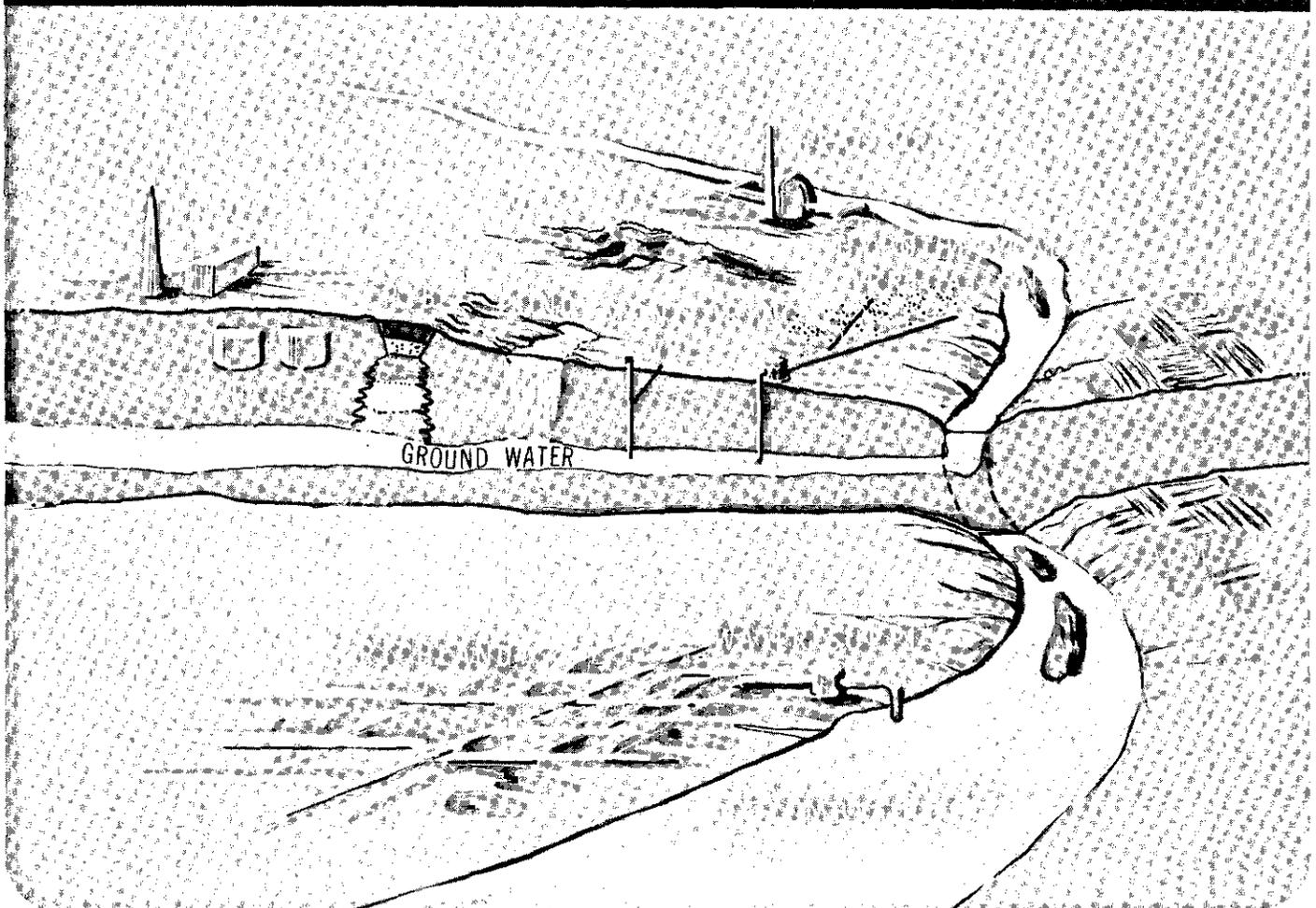
The very long-lived nuclides ^{239}Pu , ^{90}Sr , and ^{137}Cs are effectively fixed in the soil. (6, 7) On the other hand some of the ^{106}Ru , which usually occurs in the waste as a neutral molecule or an anion, is not well fixed on the soil and travels through the ground nearly as fast as the groundwater. The principal radionuclides which actually migrate in or with the groundwater are tritium and ^{106}Ru - ^{106}Rh . (8) Cobalt-60 and ^{99}Tc are also detected in the groundwater, but at much lower concentrations. The presence of nitrate ion in the groundwater also warrants attention, although this contaminant is not radioactive. Nitrate ion has its origin as nitric acid used to dissolve the fuel elements,

and relatively high concentrations of the ion are carried by the aqueous waste streams. Some of this nitrate is discharged to the "cribs" with the intermediate-level radioactive waste and, once in the ground, it moves quite freely with the groundwater.

Conceptually, it would be possible for the radionuclides in the groundwater to reach people without first entering the Columbia River. This would be via pumped irrigation and wells used for a drinking water supply. As long as the land is under the control of the AEC, use of groundwater for agricultural or domestic purposes in areas where the concentrations of ^3H , ^{106}Ru , and nitrate are relatively high is not likely. Consideration has, however, been given to the release of some project lands that are several miles distant from the ground disposal sites. (6, 9) The potential exposure that could result on such parcels of land should they eventually be irrigated with well water is an important factor in evaluating whether or not they should be released without restriction.

FIGURE VII-5

EXPOSURE PATHWAYS FROM GROUND WATER



ENVIRONMENTAL SURVEILLANCE

In order to keep track of the kinds and quantities of radioactive materials moving through the several environmental pathways, and to make meaningful estimates of the dose that Hanford wastes contribute to people who live in the region, an extensive surveillance program is required.⁽¹⁰⁾ The basic elements of this program include:

- Radiochemical analyses to determine the kinds and concentrations of radionuclides being transported by the atmosphere, the river, and the groundwater.
- Radiochemical analyses of water and foods consumed by people.
- Dose rate measurements of the external radiation that people may receive from the river and from natural background and fallout.
- Continuous monitoring of the radiation level from river water as a safeguard against unexpected acute exposure.
- Repetitive searching (with portable survey meters) for abnormal radiation levels on the ground that may result from unusual releases of contaminants to the atmosphere.
- Similar searching for abnormal radiation levels along The Columbia River.

All of this surveillance is for radioactive contaminants subsequent to their release to the environment. Each operating facility monitors or samples its radioactive waste before it is released, and maintains records of the kinds and quantities that are discharged. Figure VII-6 shows the locations of the routine monitoring and sampling sites on and near the Hanford Reservation. A few additional air monitoring sites are located beyond the region shown in this figure.

Surveillance of the groundwater beneath the Hanford Project is maintained with data from more than 500 wells.⁽¹¹⁾ The locations of these wells are shown in Figure VII-7. About half of the wells are located close to the 200 Area disposal sites and can be considered as a part of the waste management and control system because data obtained from them are used to determine when discharge to specific disposal sites should be discontinued. Data from well water samples are used to develop iso-concentration maps illustrating the extent of migration of contaminants in the groundwater, and these same wells, some of which are equipped with piezometer tubes, are used to generate a composite picture of the direction and velocity of flow of the groundwater.

The level of effort during 1968 on environmental surveillance was approximately as follows:

Samples for Radiochemical Analyses

Columbia River water	600
Drinking water	750
Groundwater	2000
Air (atmosphere)	3000
Fish	900
Other Foods	850
Miscellaneous	500

Direct Radiation Measurements

Ground Surface	800
Roads	3000 miles
Aerial	1600 miles
Columbia River	1200
Field (general gamma)	1500

In addition to these measurements, over 300 water samples were analyzed for nonradioactive pollutants. Also, groundwater elevations and temperatures are measured in many of the wells.

RADIATION DOSE FROM HANFORD OPERATIONS

It was pointed out in an earlier section that the doses received by persons who live near the project will be quite different, dependent upon where the individual lives, what kinds of foods he eats, and how much time he spends on the river. Hypothetically, the individuals that receive the greatest dose are ones that drink water pumped from the river, eat fish which they catch from the river several times each week, eat produce from farms irrigated with Columbia River water, and drink milk from farms downwind from the 200 Area and 300 Area stacks.⁽¹²⁾

FIGURE VII-6

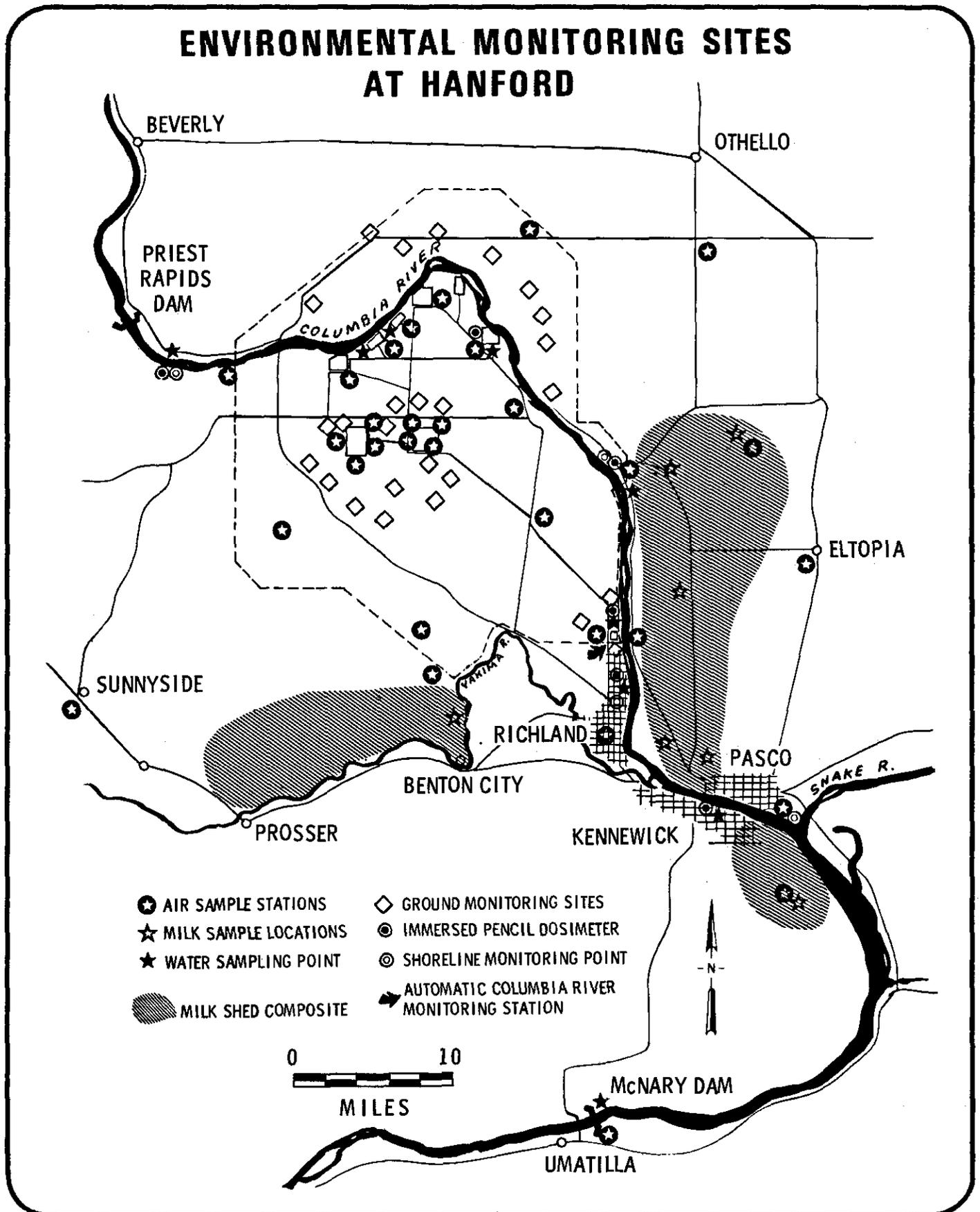


FIGURE VII-7

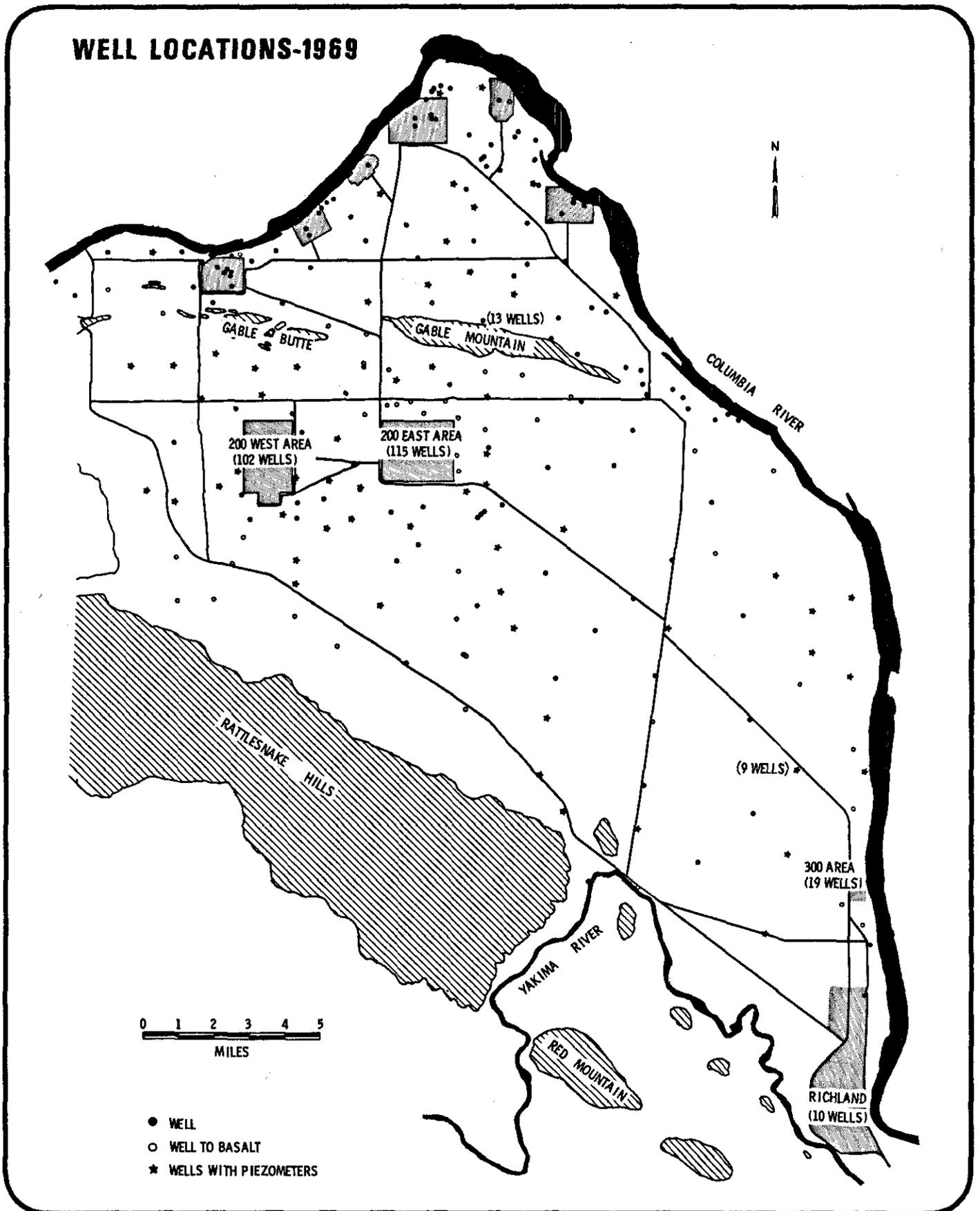


Figure VII-8 shows a preliminary estimate of the dose that such a hypothetical individual could have received in 1968. Several organs (bone, whole body, GI tract, and thyroid) are considered separately because they are exposed quite differently by different nuclides. The dose to the bone is substantially greater than that received by other organs, and amounted to about 15% of the limit. Virtually all of this dose is from ^{32}P discharged to the river with reactor effluent. Strontium-90 from worldwide fallout also makes a contribution, however. There is essentially no contribution from the chemical separations plants.

dose to members of the general public. This is because of the ^{131}I releases to the atmosphere that eventually reach small children via milk. In 1968 this route contributed a dose of no more than 10 mrem, or about one percent of the limit. Another five percent was contributed by the ^{131}I and ^{137}Cs released to the river by the reactors. Had there been any significant ^{131}I in the atmosphere from worldwide fallout, the dose to the thyroids of local residents from the fallout would have substantially exceeded that from the Hanford facilities.

Figure VII-9 shows the preliminary dose estimates for the average Richland resident. The limits are lower than for the "maximum individual," because a large number of people are involved. The largest dose is estimated for the infant thyroid and this amounts to about 10% of the limit. Drinking water is the dominant pathway for all "critical organs," although swimming and boating on the river may be of greater significance to the whole body dose received by many individuals. Only in the case of the thyroid do the separations plants have an impact on the

RADIATION EXPOSURE SOURCES IN THE FUTURE

Of the several potential sources of radioactive materials to the environment, the one of greatest concern into the future is the waste stored or retained in the ground. This is the waste released at the ground disposal sites, or which has leaked from the waste tanks. The discharge of low level wastes to the river by the reactors or to the atmosphere will essentially stop when the processes are stopped, but the longer-lived nuclides held in the ground will pose an administrative problem for many years into the future.

In this section our intention is to 1) describe the state of knowledge concerning the movement of radioactive wastes in the ground, 2) describe changes in the environs

FIGURE VII-8

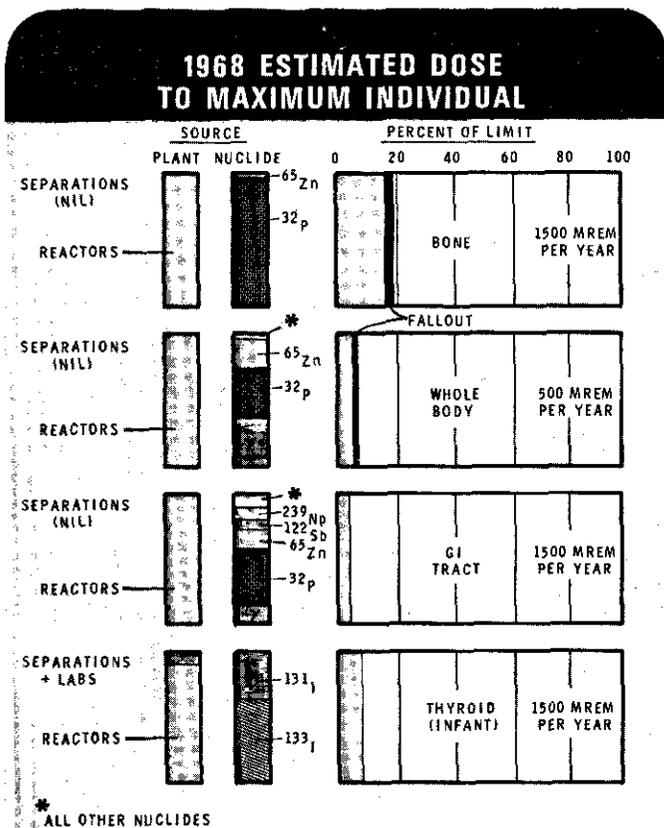
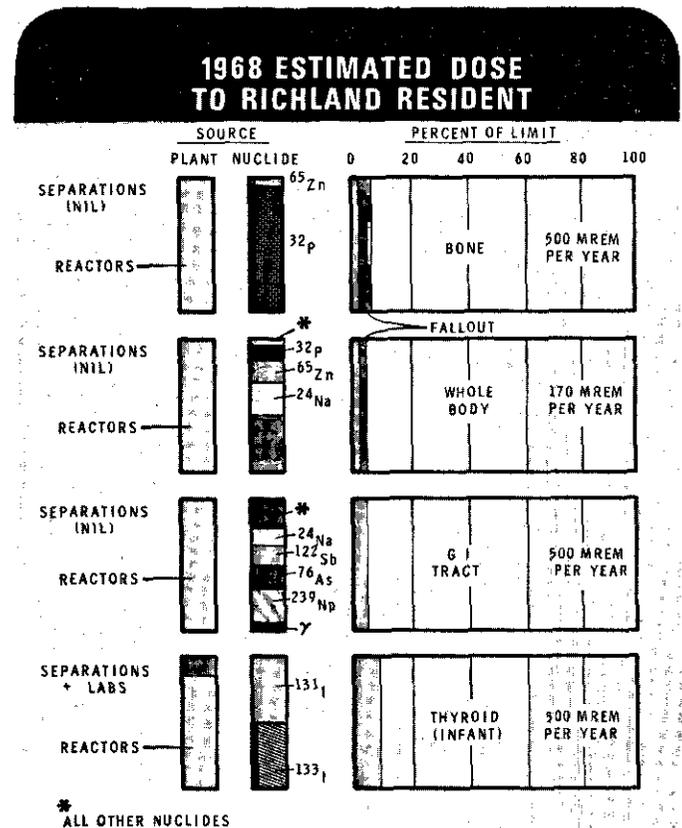


FIGURE VII-9



which might affect the movement of "ground-stored" radionuclides, 3) estimate the hazard associated with such changes, and 4) examine the effect that possible future movement of the "ground-stored" wastes may have on the long-term control of uses of the Hanford reservation.

Present Status

Over the past quarter century, appreciable quantities of radioactive wastes have been placed in the ground through the cribs and by the leaks in storage tanks. Estimates of the quantities now present in the ground, allowing for radioactive decay, are shown in Figure VII-10. To date, this "ground-stored" radioactivity has made no significant contribution to radiation exposure of the public. We must, however, consider the potential for exposure at some future time.

As part of the policy of disposal of waste to ground, Hanford has maintained a continuing R&D program to gain a better understanding of transport phenomena in the subterranean and a continuing monitoring program to actually determine the movement of radionuclides. As a result of these highly complementary programs, a great deal of knowledge has been developed concerning the behavior of various radionuclides in the soil-water system, and the movement of groundwaters in which radionuclide transport takes place.

Information from laboratory investigation and field tests, which is described in more detail in Section IV and V, can be summarized as follows:⁽⁹⁾

- Long-lived fission product nuclides discharged to ground — rare earths, and strontium, for example — and plutonium are almost completely held by reactions with the soil within a few tens of feet of the point of discharge.
- Relatively small quantities of the long-lived emitters "bleed" from the concentrated band and permeate the wet soil column, extending downward and outward in inverse relationship to the degree of retention of the particular elements by the soil.
- Long-lived radionuclides in the wetted column or in groundwater move very slowly — from 1/100 to 1/100,000 as fast as the groundwater itself.
- Tritium and some of the ruthenium move at about the same rate as the moisture in the wetted column or the groundwater.

From our knowledge of groundwater flow we recognize that some of the tritium and ruthenium that reached the groundwater during the first decade of operation must now be entering the Columbia River.⁽⁸⁾ We have not been able to actually measure this, however. While the presence of these nuclides in the groundwater can be measured quite easily at distances of several miles away from the disposal sites, the concentrations become too small to detect by ordinary laboratory methods long before the contaminants reach the river. In and near the river this detection is further masked by the burden of nuclides in the river water.

The distribution pattern for ¹⁰⁶Ru in the groundwater during the last half of 1968⁽¹¹⁾ is shown in Figure VII-11. To provide a convenient point of reference, the zones of concentration used on the figure are expressed in fractions of the concentration guide applicable for drinking water used by members of the public. It should be remembered, however, that no one now uses this water. The few places where the concentrations of ¹⁰⁶Ru reach or exceed the guide (10 pCi per ml) are all within either the 200 E or 200 W Areas. The concentration contour representing 10% of the guide is of somewhat greater interest since, from the 200 E Area, it spreads toward the Columbia River some seven or eight miles from the source. Over the past decade the progression of this "front" towards the river has been very slow, as indicated by Figure VII-12. Because of the stabilized pattern in recent years, we do not expect a significant change from the present concentrations of 200 E Area ¹⁰⁶Ru in the groundwater over the next several years unless a major change occurs at the source.

The 10% contour associated with the 200 W Area is now essentially contained within the area itself. As indicated in Figure VII-12, this level of concentration spread to a somewhat larger zone a few years ago. With the shutdown

FIGURE VII-10

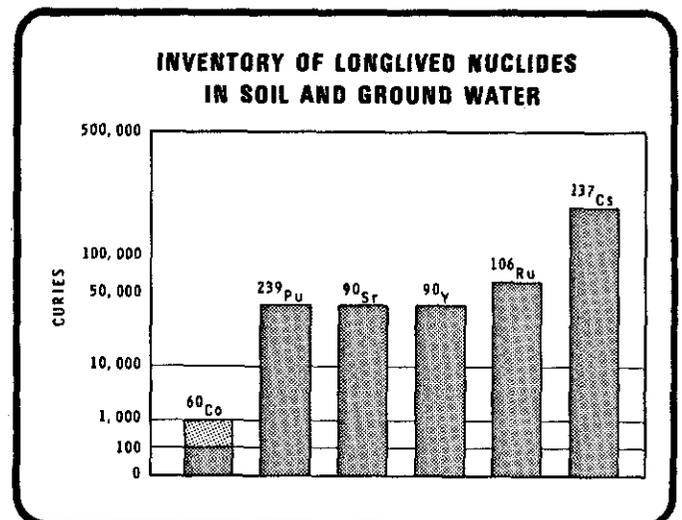
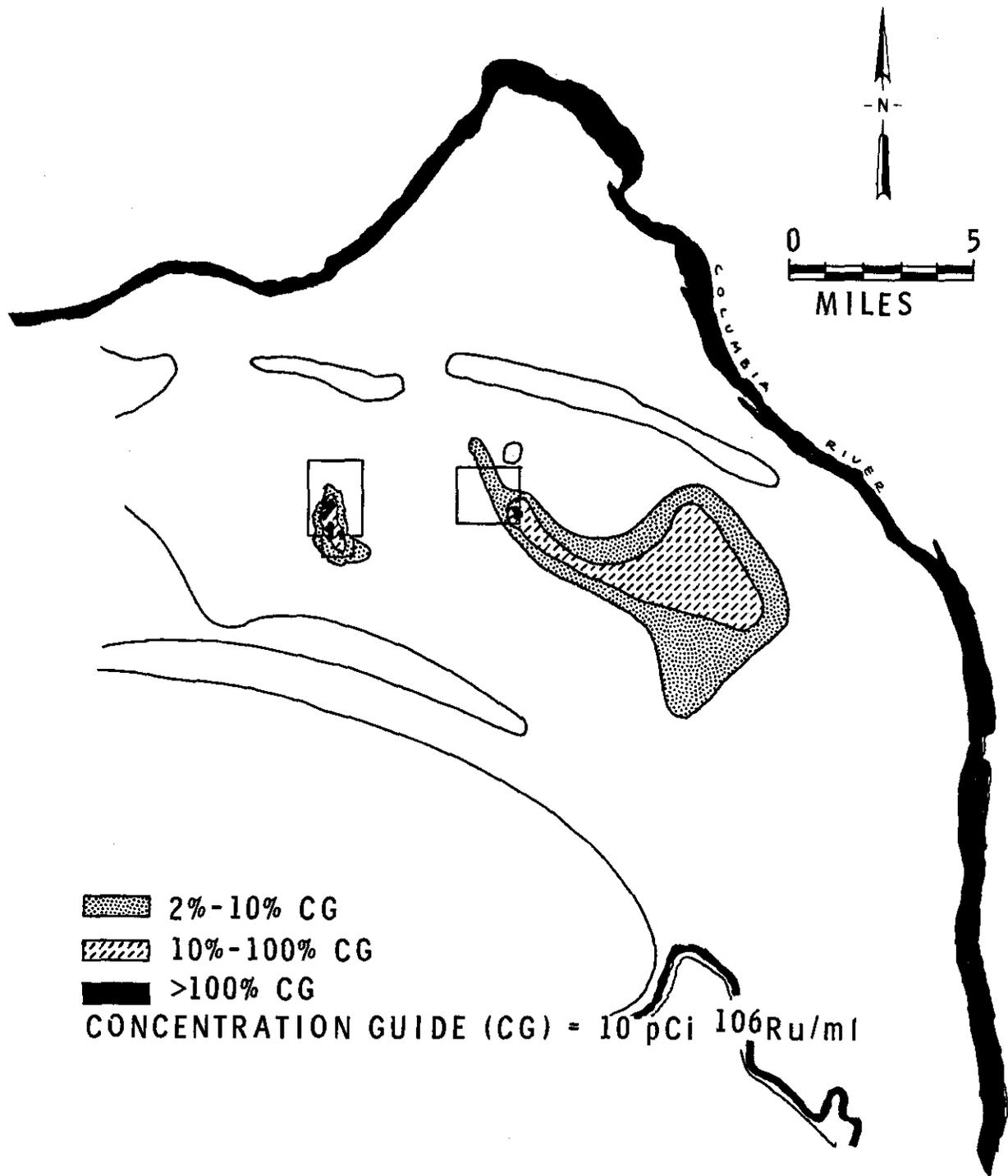


FIGURE VII-11

^{106}Ru CONCENTRATIONS IN GROUND WATER—1968



of the Redox plant in 1966 and discontinuation of the discharges to ground, the concentrations of ^{106}Ru in the groundwater have diminished.

The distribution pattern for tritium in the groundwater (Figure VII-13) is quite similar to that of the ^{106}Ru — as would be expected since both nuclides can be viewed as tracers of the groundwater movement. Somewhat by coincidence, the 10% of concentration guide contour occurs at about the same distance from the 200 E Area as the 10% contour for ^{106}Ru . The tritium "front" is also essentially stabilized at this time.

Future Status

The nature of the distribution of radioactivity in groundwater and the rate of transport to public waters is dependent upon 1) the rate of injection of radioactivity into the groundwater, and 2) the rate of movement of the groundwater itself.

The rate of injection of the radioactivity into the groundwater is dependent, in turn, upon the quantity of radionuclides discharged into the ground, the chemical nature of the waste that may affect the distribution between soil and water, the exposure of contaminated soil to groundwater (groundwater level), and the flow of groundwater through the contaminated soil.

The rate of movement of the groundwater to public waters is primarily a function of the head of groundwater above the river, which is dependent upon the amounts and places of injection of the water (by either natural or artificial means), the permeability of the soil, and the length of the flow path to the river. Of all these factors, the groundwater level has the most important influence on the future movement of "ground-stored" radioactivity. If the contaminated soil is not leached by the groundwater, essentially no transport of the radioactive wastes toward the river occurs.

FIGURE VII-12

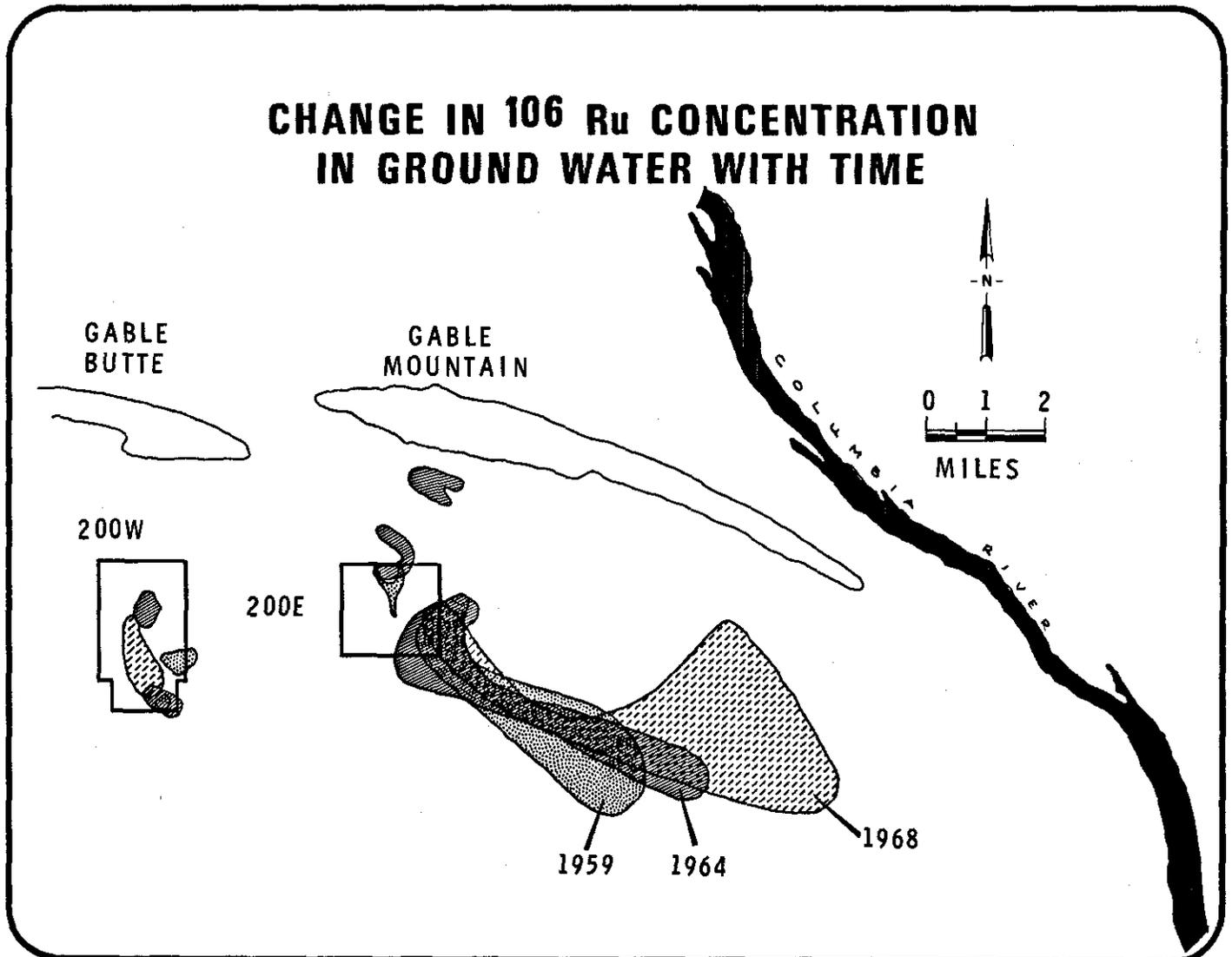


FIGURE VII-13

³H CONCENTRATIONS IN GROUND WATER—1968

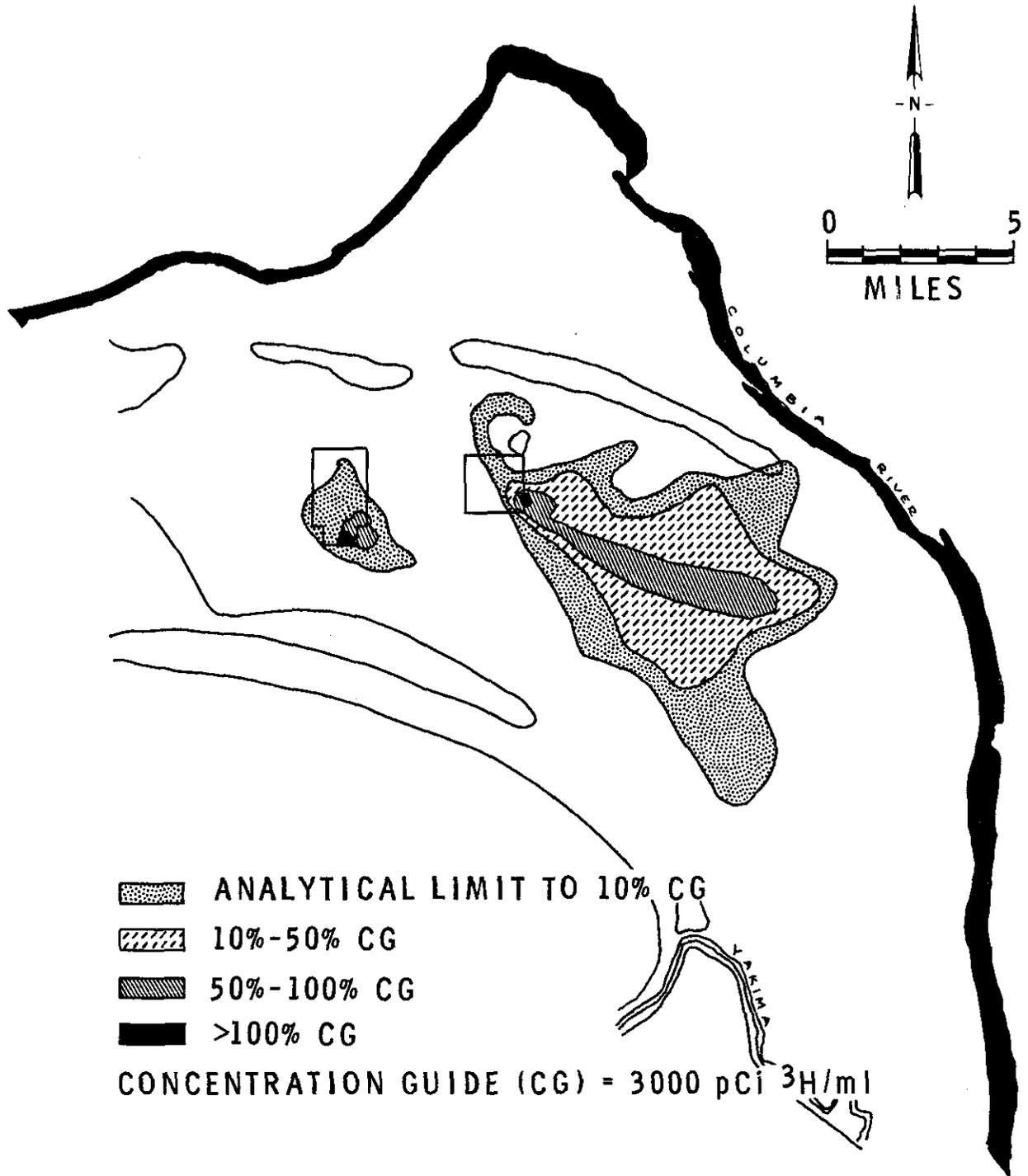
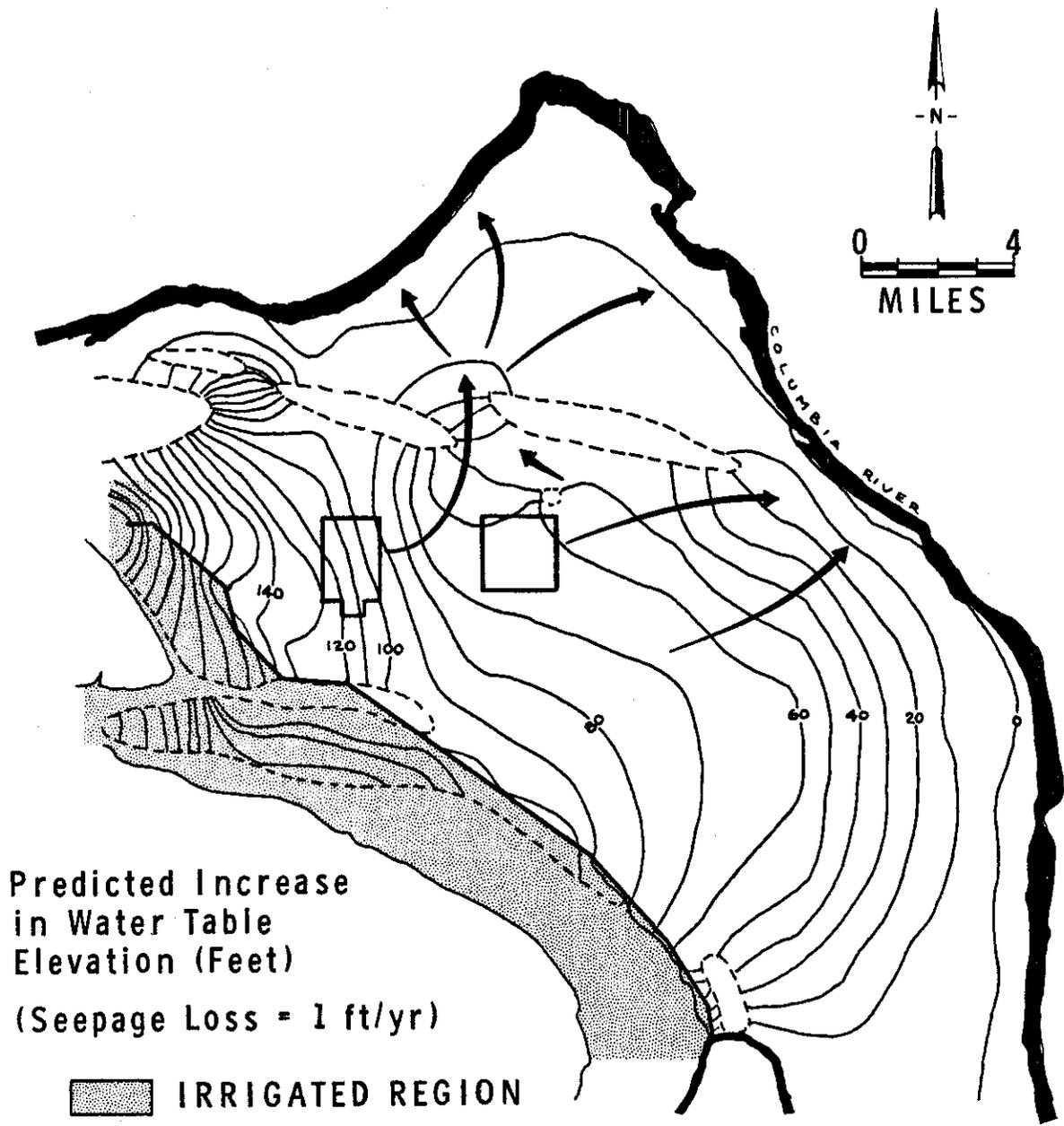


FIGURE VII-14

EFFECT ON GROUND WATER OF IRRIGATING RATTLESNAKE SLOPE

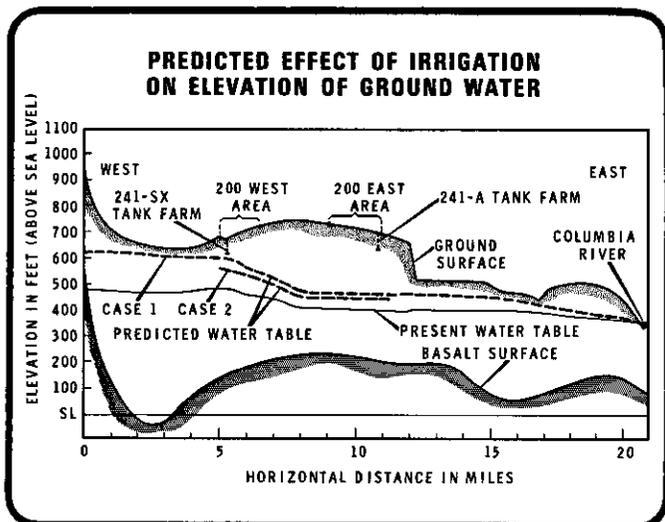


The existing pattern of groundwater flow and contamination could be substantially changed by agricultural developments on the project that either pump water from the ground or add water brought overland from the river. Some studies that have been made of the probable effects of irrigation are described below. While one cannot state a priori that any agricultural venture on the reservation would be incompatible with the present mode of plant operation, each proposal for such use of reservation land needs to be studied carefully before it can be approved. The use of project lands for new industry, particularly in the near vicinity of the Columbia River, would appear to have a lower risk of changing the groundwater regimen. Should the rate of injection of water and contaminants into the ground at the 200 E Area be reduced, as has happened at the 200 W Area, then the zones of nuclide concentrations in the groundwater would be expected to shrink back toward their sources in the 200 E Area.

If, at some time in the distant future, all discharges of waste and cooling water to the ground should stop, it is quite probable that most of the land between the 200 Areas and the river could be irrigated without restrictions imposed by groundwater problems. Another future event that would affect the levels of the groundwater in this region is the construction of Ben Franklin Dam on the Columbia just upriver from the 300 Area.⁽¹²⁾

Although a number of studies have been made over the years to predict the impacts of various occurrences on groundwater levels and flows, we have chosen two cases to illustrate the effect of water amendment on these important hydrological features. The first of these hypothetical studies involves irrigation of 35,000 acres on the eastern slope of Rattlesnake Mountain,⁽⁹⁾ the second, irrigation of four areas (totaling 25,000 acres), and existence of Ben Franklin reservoir at the 400 foot level.⁽¹³⁾

FIGURE VII-15



● **Case 1 — Irrigation of the Slope of Rattlesnake Mountain** The postulated area under irrigation and the predicted effect on the groundwater are shown in Figure VII-14. The contours represent increases in the groundwater table. The most noteworthy features are the large rise in the water table under the 200 W Area and the new flow paths to the river west of Gable Butte and west of Gable Mountain. Figure VII-15 is a cross section through the 200 E and 200 W Areas that shows the predicted water table in relation to the tank farm. The ground disposal sites in 200 West Area would be encroached by groundwater to a much greater extent than those in the 200 East Area. In either case the water level would extend into or quite near to the zones where most of the radionuclides are now retained beneath the waste discharge points. Also, the projected rise in the water table would approach within 50 feet of the bottoms of the high-level waste storage tanks in the 200 West Area. This would reduce the depth of dry soil beneath the tanks that is available for retention of any leakage. Consequently, uncontrolled irrigation in this region is viewed as undesirable.

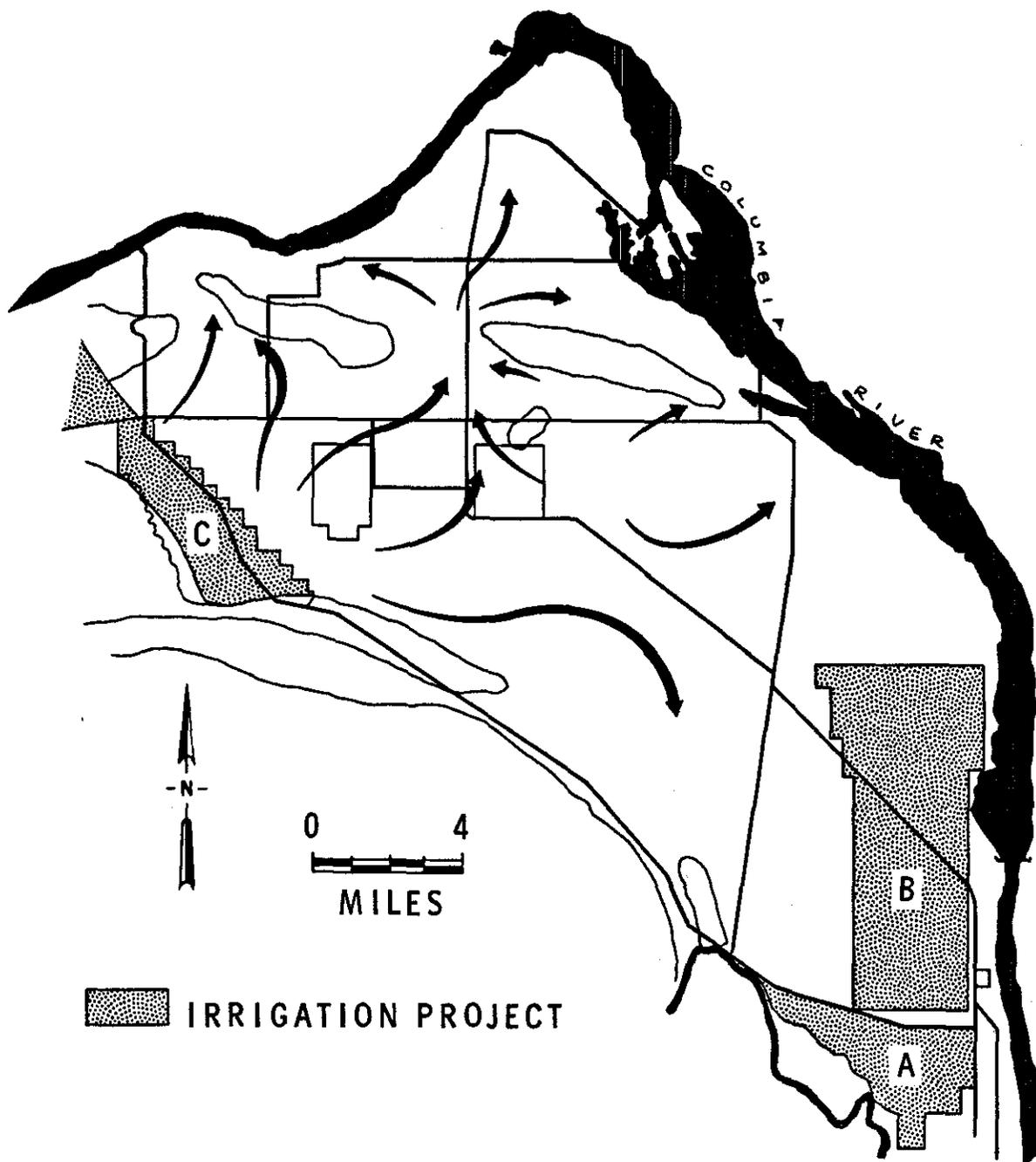
● **Case 2 — Ben Franklin Dam and Irrigation** The areas considered under irrigation in Case 2 are shown in Figure VII-16. Predictions of the effects of these amendments to the groundwater indicate a rise of the water table in the 200 Areas similar to, but not as great as, those of Case 1. Figure VII-16 also depicts the flow patterns for groundwater expected in Case 2. Irrigation of plots A and B results in a barrier to the eastward flow of waste water from the west and deflects these groundwater streams north into the Columbia River and south into the Yakima River. The raised water table east of Yakima Ridge and in the general vicinity of the 200 Areas, coupled with the restriction to eastern flow, enhances movement through the Gable Mountain and Gable Butte "passes." The shortest flow path is now via the route west of Gable Mountain, thence southeast to the river. The travel time is not significantly different than the current major flow route to the east, however.

Ultimate Exposure from Nuclides Now in the Ground
A great deal of attention has been given to the existence of the radionuclides in the soil beneath the cribs and tanks and to the behavior of the groundwater. The potential hazard to people of suddenly releasing these nuclides to the environment is not as great as one might suspect, however.

In order to place the potential hazard in perspective, an unbelievable event that would tend to maximize human exposure has been postulated. Should the nuclides now held in the ground be released, it seems reasonable to expect that they would be moved by the groundwater to the Columbia River where, after mixing with the river water, they could be drunk by people. An absurdly extreme

FIGURE VII-16

PREDICTED GROUND WATER FLOW PATHS FROM CASE 2-IRRIGATION



case would be the flushing of the entire inventory now in the ground into the Columbia River in a single day, and the use of the river by people as their sole source of drinking water.

The inventory of nuclides used in this calculation includes not only the tritium and ruthenium now present in the groundwater, but also the longer-lived ^{90}Sr , ^{137}Cs , and ^{239}Pu now fixed on the soil beneath the cribs and the ^{137}Cs which has entered the ground when high-level waste storage tanks have leaked. The estimated inventories were shown in Figure VII-10. Yttrium-90 has been added as the daughter of ^{90}Sr that has decayed.

By diluting the total inventory shown in Figure VII-10 with one day's flow of the Columbia River, and using 2.2 liters per day as the water intake of a "standard man," the quantities of the nuclide ingested can be calculated. With the use of metabolic parameters recommended by the ICRP, the dose to various organs that would result from the ingested nuclides can be calculated.

During the first year after this "acute" exposure to the separations plant nuclides, the dose to the bone (skeleton) would amount to about 200 mrem; to the GI tract about 130 mrem; and to the whole body about 80 mrem. These doses are illustrated in Figure VII-17 in relation to limits specified by the AEC for annual exposure to members of the public from routine operations. (If the FRC Protective Action Guides derived for accidents were applied, the limits would be about an order of magnitude higher.) The "percents of limit" as shown in Figure VII-17 amount to about 15% for the skeleton, 15% for the whole body, and 9% for the GI tract. The exposure contributed by the ^{90}Sr would continue beyond the first year, but at a slightly reduced rate. In the case of the skeleton, the total dose over a period of 50 years would amount to not quite 3 rem. It should be noted that exposure from the tritium is

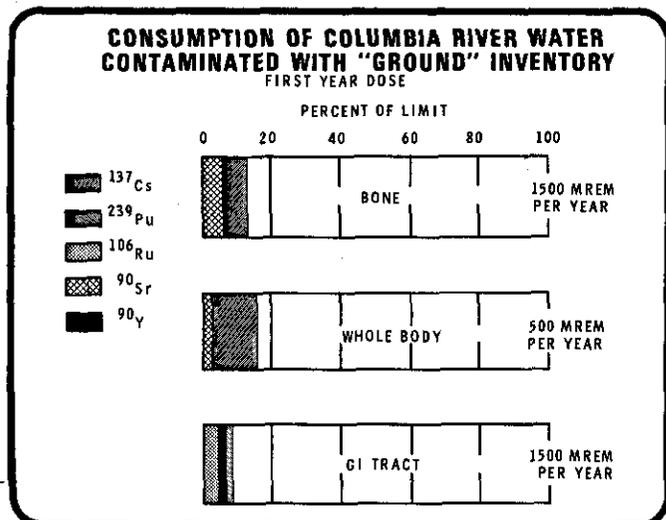
too small to plot. The calculation indicates that it would be less than 1 mrem to the whole body.

In summary, should the entire inventory of radionuclides now held by Hanford soils and groundwater be added suddenly to the Columbia River, the effect during the first year following the release would be to approximately double the small annual dose now received by local residents from all Hanford operations. A dose of even this small magnitude is not plausible, however, because the bulk of this inventory should remain fixed in the soil above the water table.

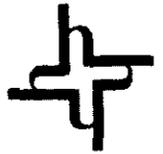
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FIGURE VII-17



APPENDIX



SUMMARY OF EMERGENCY PLANNING

Emergency preparedness under the responsibility of the Richland Operations Office is represented by three manual chapters:

1. RL Chapter 0601,

Emergency, Disaster and Mobilization (EDM) Planning Program

This chapter and its Appendix Handbook assign responsibilities and prescribe procedures to be followed during periods of natural disaster or national emergency, including attack upon the United States, to assure continuity of essential functions and executive direction of the Richland Operations Office.

2. RL Chapter 0526,

Radiological Assistance Plan

This Chapter including its Appendix, and the Interagency Radiological Assistance Plan for Region 8, provide for response to requests from offsite for assistance to recover from accidents involving radioactive material.

3. RL Chapter 06R1,

Procedures for Plant Engendered Emergencies

This Chapter is applicable to control of and recovery from site emergencies. It assigns responsibilities and outlines plans and procedures for providing health and safety assistance to protect plant personnel and the general public from radioactive and other toxic materials accidentally released from the government-owned Hanford facilities and related operations.

Detailed emergency plans for each facility are the responsibility of the operating contractor and must be supplemental to the above RL plans. The three plans above and contractor plans are all closely coordinated so that they are compatible. Wherever possible, they use the same equipment, communications, and personnel, to eliminate confusion. Specialists are on call as required.

DESCRIPTION OF RL EMERGENCY PLANS

RL Chapter 0601,

Emergency, Disaster and Mobilization Planning

At the Richland Operations Office, responsibility has been assigned to the Director, Security Division, for emergency planning to comply with Presidential Executive Order 11089 which assigns preparedness functions to the Atomic Energy Commission. Key elements in our disaster planning program include the Emergency Relocation Center, RL, and contractor (emergency) plans including designated individuals on the Succession of Command and Emergency Cadre, the Damage Assessment Program administered by RL Engineering and Construction Division, vital records protection, and the radiological plotting capability furnished by Battelle-Northwest. Contractor emergency plans are considered an integral part of the Richland Operations Office emergency plan.

On March 1, 1960, the Atomic Energy Commission notified the Washington State Department of Civil Defense that the responsibility for civil defense in the City of Richland had been turned over to the city government and the AEC would be responsible for civil defense activities only within the "controlled area" of the Hanford Project. Prior to March 1, 1960, the Atomic Energy Commission had been responsible for civil defense in the city of Richland as well as the "controlled area." The change was brought about by the desire for self-government by the people of Richland. This included the responsibilities for civil defense. The AEC furnished Richland an up-to-date civil defense capability including thousands of dollars worth of communications equipment and a complete outside warning system. Effective January 1, 1967, the City Council voted to dismantle the sirens due to economic reasons. Consequently, there is no outside audible warning system in Richland.

This nation's current plan for survival in the event of nuclear attack depends on moving a major portion of the population into marked and stocked fallout shelters. Benton and Franklin Counties do not have enough fallout shelters. The population of Franklin County is approximately 28,000; they currently have 7,931 fallout shelter spaces marked and stocked. Benton County's population is estimated at 68,000; they currently have 21,167 fallout shelter spaces marked and stocked including 12,500 spaces at McNary Dam which Benton County shares with Umatilla County, Oregon, and 2,800 in the Federal Building in Richland. Franklin and Benton Counties have over 25,000 spaces unstocked due to circumstances such as used work areas, etc.

The above totals do not include the fallout shelter spaces which are marked and stocked within the plant area. These shelters were designated in accordance with the Office of Civil Defense Memorandum 83-62m dated December 18, 1962. The memorandum recognized "an equivalent local defense authority" such as the Manager of an Atomic Energy Commission installation and, due to his mission or security requirements, gave him the authority to perform the functions of civil defense within the confines of his installation. The memorandum defined "sensitive facilities" as those housing equipment and other activities which, because of their nature, must be kept closed to the public to prevent dissemination of information that could endanger the safety and welfare of the United States.

On March 12, 1963, the Richland Operations Office received approval to mark and stock fallout shelter spaces within the "Controlled Area" and exclude the general public. RL was advised by the State of Washington that we would be identified as the Hanford Special Area—Zone 1 within the state civil defense organization. There are 9,784 fallout shelter spaces marked and stocked within the plant area including 4,062 spaces located in the 200 Areas, 5,487 spaces located in the 100 Areas, and 235 spaces located in the 300 Area. Each shelter location has

sufficient food, water, and medical supplies to support shelter occupancy for 14 days. RL has installed radios in main shelters in each of the operating areas. Communications are direct to the Emergency Relocation Center. With this capability, RL intends to control shelter emergence into the post-attack environment. Each main shelter is connected by telephone to other shelter locations within their respective areas and the Emergency Relocation Center. RL operating contractors have qualified supervisory personnel as Shelter Managers and other individuals as Radiological Defense Monitors in accordance with the standards established by the Office of Civil Defense. Present RL planning calls for providing shelter to the plant work force, including construction and transient personnel working in the 100-200 Areas.

Since there are only 235 shelter spaces in the 300 Area which has a work day population of approximately 2,000, personnel who work in the 300 Area and Richland would be expected to seek shelter in the city or county.

RL considers plant fallout shelters only as an interim protection in the event that sufficient warning time is not available.

RL Chapter 0526,

Radiological Assistance Program

The Interagency Radiological Assistance Plan (IRAP) designates the Atomic Energy Commission as the coordinating agency for eleven Federal Agencies. The AEC instructed their Regional Radiological Assistance Offices to organize the IRAP in their respective regions restricted only by the broad objectives of IRAP and adapted to the existing participating agency capabilities of the region. A meeting of Region 8 (Alaska, Oregon, and Washington) Federal and State representatives at Richland, November 29, 1966, resulted in a plan (IRAP-8) designating the Richland Operations Office as the coordinating office for Region 8. RL maintains an IRAP-8 CAPABILITY LIST that shows for each agency the responsible official; his night and day phone number; emergency equipment including transportation, radiation monitoring, construction, laboratory, medical, and communications; specially trained personnel; types of incidents about which each agency wants to be notified. "Contacts" are listed for thirty-five subagencies of the three states and twelve major federal agencies in Region 8. State agencies include law enforcement, health, civil disaster, and universities.

Each state has a coordinating agency. The AEC RL Security Division is the AEC night and day Regional coordinating office contact. For possible coordination between agencies outside Region 8, accidents are reported to AEC Headquarters and the AEC-DOD Joint Nuclear Accident Coordination Center in Albuquerque, New Mexico. Cooperation has been excellent particularly with state agencies in planning and in response to the few minor incidents to date.

RL 06R1

Procedures for Plant Engendered Emergencies

The procedures outlined in this chapter are applicable to control of and recovery from onsite emergencies. They are concerned with emergency measures to protect onsite and offsite populations and property. Incidents not originating on the Hanford site but resulting from RL-controlled and other radioactive material at offsite locations are handled as provided in AEC and RL Chapters 0526, including the IRAP-8.

Warning of onsite emergencies may come from various sources, including Civil Defense warnings from without the plant or from automatic alarms within the plant which are activated by some emergency event. In all cases, the personnel of the plant will be warned or notified through standard signals which will indicate a particular action on their part regardless of the cause of the signal. Actions within the plant will conform to plans, practices, and capabilities developed by the contractor responsible for the plant and approved by RL. These actions will include the proper notifications to points outside of the plant and, in the instances requiring it, the evacuation of plant personnel to a predesignated point, such as a parking lot, from which the ECC (Emergency Control Center) will direct evacuees as to a route for further evacuation. Before release, all plant personnel shall have been accounted for.

The notifications from the plant will activate emergency notifications necessary to bring together AEC and contractor emergency specialists and management, usually to the ECC. Individuals have predesignated functions to perform. The RL Emergency Chairman will direct other emergency operations as appropriate.

Affected contractors will be expected to take all appropriate emergency plant recovery actions, subject to change by the RL Emergency Chairman. The RL Emergency Chairman, assisted by the RL Emergency Committee, will have command of all emergency operations onsite and of all precautions and actions taken offsite to protect the population which is or may be threatened by plant conditions. Under his command, action normally will be taken according to preconceived plans and by predesignated

groups. However, the RL Emergency Chairman may assign additional functions to other contractors not in such groups for the duration of the emergency.

The RL Emergency Chairman will order the initiation of offsite notifications to the appropriate agencies and areas in cases of events which may endanger population and property offsite or cause public relations problems. The ranking contractor management on duty advises the RL Chairman when an offsite area is obviously immediately critically endangered by crucial levels of toxic materials. Such instances which may require evacuation at distances over five miles within a few minutes are considered possible but not probable.

Offsite notifications for mutual assistance pertaining to toxic atmospheric release may include City, County, and State law enforcement offices; county, state, and federal health agencies; State Civil Defense or Disaster Offices; Bureau of Reclamation and Irrigation Districts; U.S. Department of Agriculture; Corps of Engineers; the Bonneville Power Administration; and, radio, television and other news media. Notifications for releases of toxic material to the Columbia River would involve notification of most of the above agencies in addition to the U.S. Coast Guard station at Kennewick, municipal water plants, and state and federal pollution control agencies.

The objective of notification for a toxic cloud release is to instruct those possibly in its path (as predicted by BNW Meteorology personnel) to take cover or evacuate. If dangerous quantities of toxic material are accidentally released to the Columbia River, it would be cleared of swimmers, fishermen, and boaters. Time studies have determined rate of movement of dissolved material in the river at various flow rates. Pumping from the river would be stopped.

Contacts with officials of cooperating agencies for periodic updating of telephone call lists provides an opportunity to orient them as to what will be expected of them in an emergency situation.