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EDMC#:	0000003
SECTION:	1 OF 11
DOCUMENT #:	DOE/EIS-0113
TITLE:	Final EIS Disposal of Hanford Defense High-Level, Transuranic and Tank Wastes

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START

VOLUME 1

FINAL ENVIRONMENTAL IMPACT STATEMENT

DISPOSAL OF HANFORD DEFENSE HIGH-LEVEL, TRANSURANIC AND TANK WASTES

Hanford Site
Richland, Washington

DECEMBER 1987

U.S. DEPARTMENT OF ENERGY

COVER SHEET

RESPONSIBLE AGENCY: U.S. Department of Energy

TITLE: Final Environmental Impact Statement, Disposal of Hanford Defense High-Level, Transuranic and Tank Wastes, Hanford Site, Richland, Washington

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ABSTRACT: The purpose of this Environmental Impact Statement (EIS) is to provide environmental input into the selection and implementation of final disposal actions for high-level, transuranic and tank wastes located at the Hanford Site, Richland, Washington, and into the construction, operation and decommissioning of waste treatment facilities that may be required in implementing waste disposal alternatives. Specifically evaluated are a Hanford Waste Vitrification Plant, Transportable Grout Facility, and a Waste Receiving and Packaging Facility. Also an evaluation is presented to assist in determining whether any additional action should be taken in terms of long-term environmental protection for waste that was disposed of at Hanford prior to 1970 as low-level waste (before the transuranic waste category was established by the Atomic Energy Commission but which might fall into that category if generated today).

The following alternatives are considered in this EIS: 1) in-place stabilization and disposal, where waste is left in place but is isolated by protective and natural barriers; 2) geologic disposal, where most of the waste (by activity and to the extent practicable) is exhumed, treated, segregated, packaged and disposed of in a deep geologic repository; waste classified as high-level would be disposed of in a commercial repository developed pursuant to the Nuclear Waste Policy Act; transuranic waste would be disposed of in the Waste Isolation Pilot Plant near Carlsbad, New Mexico; 3) a reference alternative, where some classes of waste are disposed of in geologic repositories and other classes of waste are disposed of by in-place stabilization and disposal; 4) the preferred alternative, in which double-shell tank wastes, strontium and cesium capsules, and retrievably stored TRU wastes are disposed of according to the reference alternative, and in which decisions are deferred on disposal of single-shell tank wastes and on further remedial action for TRU-contaminated soil sites and pre-1970 buried suspect TRU-contaminated solid wastes (except the 618-11 site) until additional information is obtained on waste characterization, retrieval methods, and performance of near-surface disposal systems; and 5) a no disposal action alternative (continued storage).

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DOE/EIS-0113 (VOL. 1 of 5)

FINAL ENVIRONMENTAL IMPACT STATEMENT

DISPOSAL OF HANFORD DEFENSE HIGH-LEVEL, TRANSURANIC AND TANK WASTES

Hanford Site
Richland, Washington

DECEMBER 1987

U.S. DEPARTMENT OF ENERGY
ASSISTANT SECRETARY FOR DEFENSE PROGRAMS
WASHINGTON, D.C. 20545

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FOREWORD

This environmental impact statement (EIS) provides analyses of environmental impacts for the selection and implementation of final disposal strategies for the high-level (HLW), transuranic (TRU) and tank wastes generated during national defense activities and stored at the Hanford Site near Richland, Washington. Also an evaluation is presented to assist in determining whether any additional action should be taken in terms of long-term environmental protection for waste that was disposed of at Hanford prior to 1970 as low-level waste (before the transuranic waste category was established by the Atomic Energy Commission (AEC) but which might fall into that category if generated today). This document also addresses environmental impacts associated with the construction, operation and decommissioning of waste treatment facilities that may be required to implement the waste disposal alternatives.

Several previous documents have addressed environmental aspects of the management of defense waste at the Hanford Site. The first comprehensive one, The Final Environmental Statement for Hanford Waste Management Operations (ERDA-1538), was issued in 1975. In that statement, waste management practices at Hanford were shown to protect the public health and safety and the environment on an interim basis. Those practices, however, were not and are not intended as final solutions for long-term isolation and disposal of high-level, TRU and tank wastes.

In 1977, the Energy Research and Development Administration (ERDA) issued the report Alternatives for Long-Term Management of Defense High-Level Radioactive Waste (ERDA-77-44), which included preliminary cost estimates and analyses of near-term risks associated with alternatives considered. That document examined 27 variations on four options for the processing and disposal of Hanford HLW, encompassing numerous final waste forms and storage and disposal modes.

In 1978, the National Research Council of the National Academies of Science and Engineering issued a report entitled Radioactive Wastes at the Hanford Reservation: A Technical Review, concluding that there has not been in the past, and is not at the present, any significant radiation hazard to public health and safety from waste management operations at Hanford. The Council recommended that long-term isolation and disposal of Hanford high-level waste become the main focus of waste management research and development.

The need to include retrievably stored TRU waste within the scope of wastes to be disposed of, and concerns about potential environmental impacts of wastes disposed of before 1970 as low-level wastes (before the Atomic Energy Commission established the TRU waste category but which might be classed as TRU if generated today), led to enlarging the earlier plan that was to issue an EIS covering high-level waste only. Accordingly, on April 1, 1983, the Department of Energy (DOE) published in the Federal Register (48 FR 14029) a Notice of Intent (NOI) to prepare an EIS on Disposal of Radioactive Defense High-Level and Transuranic Wastes at Hanford.

Eighteen comment letters were received in response to the Notice of Intent to prepare this EIS. Ten of the letters only requested copies of the draft EIS when issued; eight

contained comments regarding its preparation. The draft EIS was published during March 1986, and its availability was published in the Federal Register on April 11 (51 FR 12547). During the 120-day agency and public comment period on the draft EIS, which began on April 11, 1986, 243 letters were received that provided about 2000 substantive comments on the draft EIS. In addition, oral testimony was heard on the draft EIS in public hearings held during July 1986, in Richland, Washington; Portland, Oregon; Seattle, Washington; and Spokane, Washington.

Excluded from consideration in this EIS are low-level radioactive wastes in liquid and solid disposal sites at Hanford (see ERDA 1538). These waste sites are presently being reviewed under hazardous-waste regulations. Also excluded are wastes generated by decontamination and decommissioning of surplus or retired facilities after the year 1983 (other than for those facilities directly associated with waste disposal). Those operations will be the subject of other National Environmental Policy Act (NEPA) reviews.

The Defense Waste Management Plan (DOE/DP 0015) states of the Hanford wastes: "Immobilization of new and readily retrievable high-level waste will begin about 1990 after sufficient experience is available from Savannah River's vitrification process. Other waste will be stabilized in place in the 1985-2015 time frame if, after the requisite environmental documentation, it is determined that the short-term risks and costs of retrieval and transportation outweigh the environmental benefits of disposal in a geologic mined repository."

It is necessary to understand the major differences between civilian and defense wastes and the programs to effect their disposal. Both types of waste include fission products and transuranic waste elements. On the other hand, the quantities of these elements, the physical and chemical forms of the wastes, and the technically sound alternatives for their disposal are markedly different. In all cases, for both civilian and defense, the final methods selected will have to meet the Environmental Protection Agency (EPA) standards (40 CFR 191) for the disposal of spent fuel and high-level and TRU wastes. The Nuclear Waste Policy Act of 1982 mandates a procedure to select the potential repository sites for detailed characterization.

A comparison of the Hanford waste inventory resulting from chemical processing of about 100,000 metric tons of nuclear reactor fuel with that of a commercial repository containing 70,000 metric tons of spent fuel elements is enlightening. In this comparison, the waste inventory from 100,000 metric tons of Hanford reactor fuel contains about 4% as much of the readily transportable (geohydrologically) isotopes ^{14}C, ^{99}Tc, and ^{129}I as is contained in 70,000 metric tons of commercial spent fuel. It contains only 1% as much ^{90}Sr and ^{137}Cs and about 0.1% as much of the primary transuranics ^{239}Pu, ^{240}Pu, and ^{241}Am. The volume of the Hanford wastes is markedly larger than the civilian wastes cited above--410,000 m^3 of Hanford wastes as compared to 29,000 m^3 of commercial spent fuel.

The physical and chemical characteristics of existing and potential waste forms considered in this EIS are highly diverse: liquid waste in double-shell tanks, vitrified/canistered wastes (from processed double-shell tank wastes); sludge and salts in the single-shell tanks; strontium and cesium capsules that are further protected with a

handling container; previously disposed of pre-1970 wastes in various forms and containers; and finally, low-level waste products, from the processing of double-shell-tank waste, in the form of grout.

In accordance with the requirements of NEPA, as amended, and implementing regulations of the Council on Environmental Quality (CEQ) published in the Code of Federal Regulations as 40 CFR 1500, this EIS was written early in the decision-making process to ensure that environmental values and alternatives are fully considered before any decisions are made that might lead to adverse environmental impacts or limit the choice of reasonable alternatives. This process will also help ensure that the public is fully informed and is involved in the decision-making process.

To comply with the NEPA's requirement for early preparation of environmental documentation, this EIS has been prepared early in the disposal decision process. As with any major action, it is expected that once a disposal decision is made, subsequent detailed engineering may enhance specific waste retrieval, treatment, handling, immobilization and/or disposal processes evaluated in the EIS. However, the processes evaluated in this document have been chosen such that, when finally implemented for any of the options, the processes would not be expected to result in environmental impacts that significantly exceed those described here. The DOE believes that bounding analyses performed in this EIS meet the requirements of CEQ regulations for analysis of all reasonably forseeable significant adverse impacts.

Implementation of defense waste disposal under the alternatives described in this EIS will be done in compliance with the letter and spirit of applicable federal and state environmental statutes, regulations and standards. To ensure that impacts of specific processes used during disposal implementation do not differ significantly from the results of the analyses set forth in this document, DOE will conduct environmental reviews of the specific processes as finally proposed. On the basis of these reviews, DOE will determine in accord with agency guidelines what additional NEPA documentation is required. The DOE anticipates that a supplemental EIS will be prepared prior to a decision on a disposal option for single-shell tank waste.

This document is not intended to provide the environmental input necessary for siting or constructing a geologic repository. For analysis of environmental impacts of alternatives involving geologic disposal, generic designs for either an offsite or onsite repository were used. Detailed environmental documentation required by the Nuclear Waste Policy Act of 1982 will be prepared before a geologic repository is sited, constructed and operated. A future EIS to address site selection is expected to include a discussion of cumulative impacts of the repository program at all candidate sites, including Hanford.

Other NEPA documentation relevant to this EIS includes the supplement to ERDA-1538, Double-Shell Tanks for Defense High-Level Radioactive Waste Storage at the Hanford Site (DOE/EIS-0063), and the Final Environmental Impact Statement--Operation of PUREX and Uranium Oxide Plant Facilities (DOE/EIS-0089). (The draft PUREX EIS with an addendum constituted the final PUREX EIS.)

Environmental considerations regarding disposal of Hanford's retrievably stored TRU waste at the Waste Isolation Pilot Plant (WIPP) (except for retrieval, processing, packaging, certification and transportation of waste from Hanford to WIPP, which are discussed in this EIS) are based on the Final Environmental Impact Statement--Waste Isolation Pilot Plant (DOE/EIS-0026). Environmental considerations associated with waste disposal in geologic repositories are based on information from the Final Environmental Impact Statement--Management of Commercially Generated Radioactive Waste (DOE/EIS-0046F). Alternatives to disposal of high-level waste in geologic repositories were described in that document.

Environmental considerations associated with borosilicate glass as a waste form for repository disposal of waste and with the construction and operation of a plant to provide vitrified waste are based in part on information developed in three previous DOE documents: Final Environmental Impact Statement--Defense Waste Processing Facility Savannah River Plant, Aiken, South Carolina (DOE/EIS-0082); Environmental Assessment--Waste Form Selection for SRP High-Level Waste (DOE/EA-0179); and Analyses of the Terminal Waste Form Selection for the West Valley Demonstration Project (WVDP-100 DOE).

The EIS has been structured to conform as closely as possible to the format described in CEQ Regulation 40 CFR Parts 1502.1 through 1502.18. To provide more information for the reader than can be reported within the text of Volume 1, more detailed information is included in 22 appendices (Volumes 2 and 3). Figure 1 in the Introduction to the Appendices (Volume 2, p. xxiv) shows the purpose of each appendix and how appendices relate to each other and to the text of Volume 1. Lines in the margins of Volumes 1, 2 and 3 indicate the areas where revisions were made. Volume 4 contains agency and public comments received and responses to them as well as the indication of location where revisions were made to the draft EIS. Volume 5 contains a reproduction of all of the comment letters received.

The final EIS is being transmitted to commenting agencies, made available to members of the public, and filed with the EPA. The EPA will publish a notice in the Federal Register indicating that the DOE has filed the final EIS. A DOE decision on proposed actions will not be made earlier than 30 days after the EPA has published the Federal Register notice for the final EIS. The DOE will record its decision in a publicly available Record of Decision (ROD) document published in the Federal Register.

EXECUTIVE SUMMARY

This environmental impact statement (EIS) examines the potential impacts calculated for alternatives for the final disposal of existing defense wastes stored at Hanford since 1943 and future wastes (those produced after October 1983). Wastes excluded from the scope of this EIS are previously disposed-of low-level wastes and those associated with the decontamination and decommissioning of surplus or retired Hanford facilities after 1983, the latter of which will be the subject of other National Environmental Policy Act (NEPA) reviews. Included, however, are those wastes from decontamination and decommissioning of future facilities such as the Hanford Waste Vitrification Plant (HWVP) that might be built and operated in direct support of disposal actions addressed herein. While existing and future wastes lend themselves to the same type of treatments afforded commercial nuclear wastes, the older tanks, cribs, and burial sites contain a variety of wastes in various forms that may require specialized treatment and recovery operations.

For purposes of analysis, the wastes under the scope of this EIS are divided into six classes; four of these consist of waste presently stored or future waste to be placed in interim storage pending disposal. The other two classes are wastes previously disposed of as low-level waste. Because of their transuranic (TRU) content, these two were reexamined to assist in determining whether any additional protection is justified. The classes are as follows:

1. Existing Tank Wastes--This class is further subdivided because of physical differences in tanks and chemical differences in their contents:
   - Single-shell tanks containing mostly solid wastes not readily retrievable
   - Double-shell tanks containing liquids and suspended solids that are readily retrievable by pumping and sluicing.
2. Future Tank Wastes--Tank wastes generated from PUREX[a] operations after October 1983 will be stored in double-shell tanks as liquids and suspended solids that are readily retrievable by pumping and sluicing.
3. Strontium and Cesium Capsules--The capsules will be held in water basins. After their useful life these byproducts will be returned for disposal. These wastes are double-encapsulated in stainless steel or Hastelloy®.
4. Retrievably Stored and Newly Generated TRU Wastes--These wastes consist of solid TRU waste produced since 1970, packaged, labeled and stored pending final disposal. Future TRU wastes are also included in this class.
5. TRU-Contaminated Soil Sites--These sites consist of soil contaminated by disposal of liquid wastes in cribs, ditches, trenches, settling tanks, French drains, and

(a) Plutonium URanium EXtraction.
® Hastelloy is the registered trademark of Cabot Wrought Products Division, Cabot Corporation, Kokomo, Indiana.

reverse wells (also known as injection wells). Although previously disposed of, these wastes were reexamined to determine whether additional environmental protection is warranted.

6. Pre-1970 Buried Suspect TRU-Contaminated Solid Wastes--These consist of general trash and failed equipment disposed of by burial in trenches prior to 1970. Although disposed of, these wastes were also reexamined to determine whether additional protection is warranted.

Of the disposal alternatives studied, three were considered to be reasonable for detailed analysis. Also a preferred alternative was identified for the final EIS. A highly abbreviated description of the features of each of the alternatives follows below.

1. Geologic Disposal--Essentially all wastes (by activity) are removed to a deep geologic repository; a low-activity fraction is disposed of as grout in near-surface vaults specifically designed to meet long-term performance requirements and those of the Resource Conservation and Recovery Act of 1976. High-level wastes (HLW) are sent to a commercial repository for disposal; transuranic (TRU) wastes are sent to the Waste Isolation Pilot Plant (WIPP). Protective barriers are installed over tank residuals and grout vaults. A marker system is installed.

2. In-Place Stabilization and Disposal--All wastes are stabilized in place and left at Hanford. Protective barriers are installed over all waste sites. A marker system is installed.

3. Reference (Combination Disposal)--Essentially all (by activity) present and future high-level waste in double-shell tanks is sent to a commercial deep geologic repository, and the low-activity fraction is disposed of as a grout in near-surface vaults. The vaults are specifically designed to meet long-term performance requirements and those of the Resource Conservation and Recovery Act of 1976. Encapsulated strontium and cesium wastes are sent to a commercial geologic repository, and retrievably stored and future TRU wastes are sent to WIPP. In order to consolidate TRU waste on the 200 Areas plateau, TRU waste from the pre-1970 buried suspect TRU-contaminated solid waste site (618-11, the only TRU waste site outside of the 200 Areas plateau) is retrieved, processed and sent to a geologic repository. All other wastes are stabilized in place. Protective barriers are installed over all waste sites. A marker system is installed.

4. Preferred Alternative--Essentially all (by activity) present and future high-level waste in double-shell tanks is sent to a commercial deep geologic repository, and the low-activity fraction is disposed of as a grout in near-surface vaults. The vaults are specifically designed to meet long-term performance requirements and those of the Resource Conservation and Recovery Act of 1976 and are covered by a protective barrier and marker system. Encapsulated strontium and cesium wastes are sent to a commercial geologic repository; retrievably stored and future TRU wastes are stored until disposed of in the WIPP facility; and, as in the reference alternative, TRU waste from the pre-1970 buried suspect TRU-contaminated solid

waste site (618-11) is sent to a geologic repository. Decisions on disposal of all other wastes are deferred until additional development and evaluation are completed. In the interim, DOE would continue storage and maintenance of those wastes. When sufficient data to support further decisions become available, DOE would prepare additional documentation for public review and comment, such as a supplemental EIS for disposal of single-shell waste or documentation of remedial investigation/feasibility studies under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). Figure i illustrates the general process for proceeding with disposal of defense wastes under the preferred alternative.

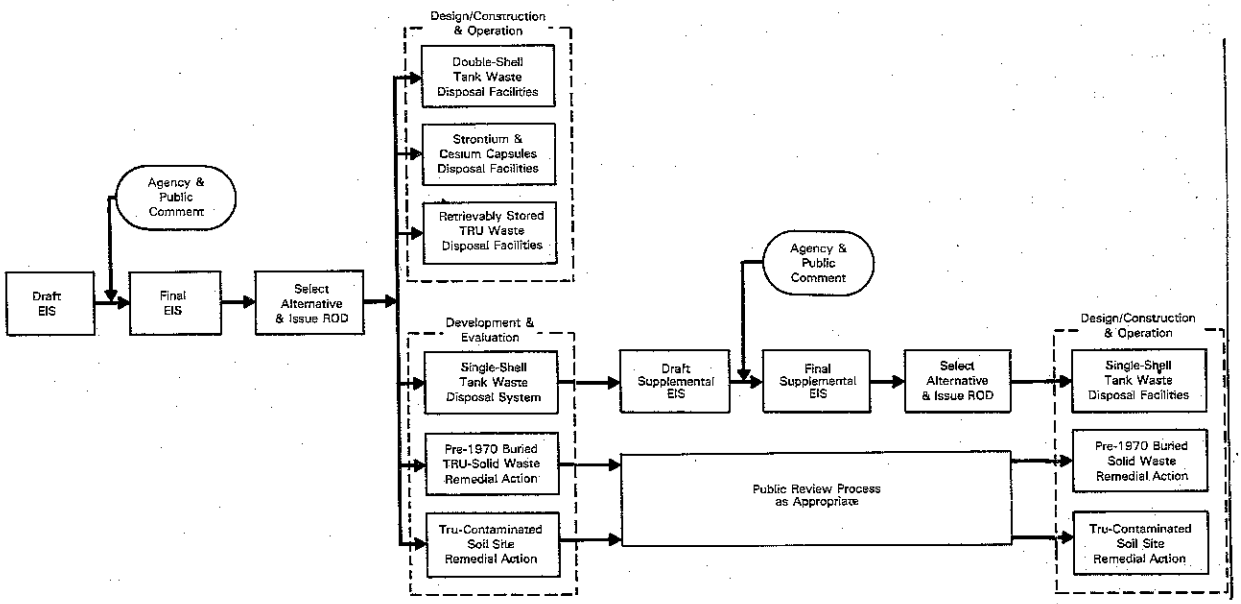

FIGURE i. Process of Hanford Defense Waste Disposal under the Preferred Alternative (EIS-Environmental Impact Statement; ROD-Record of Decision; NEPA-National Environmental Policy Act)

5. No Disposal Action--Storage of wastes continues, but no disposal action is taken. No protective barriers and no marker systems are installed. This case is included to comply with the Council on Environmental Quality requirements for a no action alternative. Most of the impacts arise as a result of loss (assumed) of active institutional control in the year 2150, which is assumed for all alternatives. These impacts are not representative of continued waste management practices.

The preferred alternative was developed following agency and public review of the draft EIS. Although it was recognized that disposal of single-shell tank waste, the pre-1970 buried suspect TRU-contaminated waste and TRU-contaminated soils is no less important than disposal of double-shell tank waste, capsules and retrievably stored TRU waste, consensus focused on proceeding with disposal of those wastes that could be most readily disposed of

(particularly liquid waste) and deferring disposal decisions on the other wastes. There would appear to be no conflict between implementation of the disposal actions of the preferred alternative and any federal or state regulations.

It was also recognized that because the radioactive wastes in single-shell tanks have been reduced from liquid to sludge and semisolids, there is little threat from further leakage and no urgent need to effect disposal despite a large inventory of waste in those tanks. Similarly, the pre-1970 buried suspect TRU-contaminated solid waste and TRU-contaminated soil sites have remained stable, and again, there is no urgency for election of further remedial action. Moreover, possible application of RCRA and CERCLA to these latter classes of waste suggested the need for further characterization of the wastes (including chemicals) and review for compliance with applicable hazardous-waste regulations.

Waste treatment and disposal facilities such as the Hanford Waste Vitrification Plant, the Transportable Grout Facility, and the Waste Receiving and Processing facility would be required for the geologic disposal, reference and preferred alternatives. These facilities are described in appendices to this EIS, and impacts from construction and operation are included with the presentation of other operational impacts. It is intended that this EIS provide the NEPA documentation for those facilities.

The environmental impacts (both short- and long-term) calculated for the alternatives generally are low and show no marked differences among the disposal alternatives except for intrusion scenarios. In some instances the no disposal action alternative might result in potential releases that numerically exceed Environmental Protection Agency release standards in Subpart B of 40 CFR 191, promulgated on September 19, 1985.(a)

The short-term cumulative total-body radiation doses(b) resulting from implementing each alternative are shown in Table i. Although these doses are small compared to the estimated 2,500,000 man-rem the same offsite population would receive from natural background during the 60-year operational period, they do show some significant differences among alternatives. For example, geologic disposal results in increases by factors of four to eight in occupational exposures due to increased doses from the extensive retrieval and processing operations. Likewise, transportation doses are higher for the geologic, reference and preferred alternatives, which involve transportation, when the shipments of the high-level wastes are made to an offsite repository as compared to an onsite repository.

(a) The U.S. Court of Appeals for the First Circuit vacated and remanded the 40 CFR 191 regulations back to EPA (Civil Action 85-1915). Subsequently, the court order was amended to reinstate Subpart A of 40 CFR 191. Nevertheless, prior to disposal of any of the wastes subject to 40 CFR 191, compliance with 40 CFR 191, as eventually promulgated by the EPA, will be demonstrated. Analysis and discussion of 40 CFR 191 requirements are based on this regulation as promulgated on September 19, 1985.

(b) In accordance with common practice, the term "dose," when applied to individuals and populations, is used for brevity in the HDW-EIS instead of the more precise term "dose equivalent" as defined by the International Commission on Radiation Units and Measurements (ICRU). See Appendix F for a description of radiation doses used in the HDW-EIS.

TABLE i. Comparison of Collective Operational Radiation Doses (1990-2050) from Implementing Alternatives, man-rem

Exposure Classification	Geologic Disposal	In-Place Stabilization and Disposal	Reference Alternative	No Disposal Action	Preferred Alternative
Occupational	15,000	2,400	3,800	1,900	3,800 - 15,000
Offsite Population	50	1	1	2	1 - 50
Transportation					
HLW Onsite, TRU to WIPP	45	0	40	0	40 - 45
HLW Offsite, TRU to WIPP	85	0	43	0	43 - 85

Nonradiological injuries, illnesses (lost time) and fatalities for workers are shown in Table ii for each alternative. Calculated differences are only slight for the case in which the high-level fraction is disposed of in an onsite repository and the TRU shipped to WIPP. For example, calculated transportation fatalities (for the geologic disposal alternative) are reduced from two to one when high-level wastes are disposed of in an onsite repository.

TABLE ii. Summary of Nonradiological Injuries and Illnesses and Fatalities to Workers from the Various Alternatives[a]

Operation	Geologic Disposal	In-Place Stabilization and Disposal	Reference Alternative	No Disposal Action	Preferred Alternative
Waste Processing and Stabilization	520/2	110/0	150/0	NA[b]	150/0 - 520/2
Transportation[c]					
HLW Onsite, TRU to WIPP	13/1	NA	10/1	NA	10/1 - 13/1
HLW Offsite, TRU to WIPP	21/2	NA	10/1	NA	10/1 - 21/2
Repository Emplacement	380/2	NA	72/0	NA	72/0 - 380/2
Continued Operations	NA	NA	NA	130/0	NA

(a) Numbers in table are shown as injuries(and illnesses)/fatalities.
(b) Not applicable.
(c) Includes public.

Costs vary considerably among alternatives, as can be seen in Table iii. Due to recovery, processing and shipping operations, the costs of the geologic alternative and the upper end of the preferred alternative (geologic) are five to seven times those of the other

TABLE iii. Comparison of Costs for Implementing Alternatives, Millions of $1987[a]

Geologic Disposal			Reference			No Disposal Action	
HLW Onsite, TRU to WIPP	HLW Offsite TRU to WIPP	In-Place Stabilization	HLW Onsite, TRU to WIPP	HLW Offsite TRU to WIPP	Preferred Alternative	First 100 yr	Each Additional 100 yr
16,900	17,500	2,400	3,900	3,900	3,900-16,400	1,800	1,300

(a) Costs were revised from the draft EIS to reflect increased proposed repository fees. Since the above costs were calculated, further, increased repository fees have been proposed. If put into effect, these additional increases would raise the cost of the geologic alternative by 20%, the reference alternative by 5% and the preferred alternative by 5 to 20%. Although these changes do not affect the relative cost comparison of alternatives, they do widen the cost difference between the geologic and preferred alternative and the other alternatives. However, the increase has not changed DOE's choice of a preferred alternative. Additional changes in estimated repository fees may be expected in the future.

disposal alternatives. Costs associated with the no disposal action (continued storage) alternative are shown to be the lowest at $1.8 billion for the first century. However, costs of no disposal action are estimated to be an additional $1.3 billion for each succeeding century. Costs are higher than in the draft EIS, primarily because of increased estimated cost of repository emplacement.

In the absence of intrusion into the waste sites, long-term environmental impact analysis for the general population indicates no major differences among the disposal alternatives, but the no disposal action, under some scenarios, exceeds 40 CFR 191 release limits applicable to disposal alternatives. With either the present climate, or with the average precipitation doubled and combined with a disruptive barrier failure scenario, the current analysis indicates that the general public would be protected in all disposal alternatives. Downstream users of the Columbia River would incur, at most, one health effect associated with the disposed-of waste over 10,000 years. However, where it was assumed in the no disposal alternative that active institutional control was lost in 2150 (loss of active institutional control is assumed solely to permit a parallel analysis with the disposal alternatives), 400 to 4,000 health effects were calculated to occur among the public as a result of repopulation of the Hanford Site. This may be compared to the 300,000 to 3,000,000 health effects estimated (using the same factors) for the same population and time period from exposure to natural background radiation over the 10,000-year period. For further comparison, about 50,000,000 cancer deaths would occur from other causes in the same population over the same time period.

Virtually all radioactive waste substances yielded in the process of producing or utilizing special nuclear material are contained, dissolved or suspended in nonradioactive chemical media. Some of these nonradioactive media may be classed as hazardous waste. In all of the disposal alternatives, the nonradioactive hazardous waste would be disposed of near

surface (in single-shell tanks, grout vaults or left in place in the soil). Under the geologic, reference and preferred alternatives, the low-activity fraction of double-shell tank waste would be treated to destroy chemical complexants before its disposal near surface.

The release of selected chemicals associated with the Hanford wastes (nitrate ion, cadmium, fluoride, chromium, and mercury) was analyzed. For the disposal alternatives the calculated concentrations at a well 5 km from the waste were well below limits established by the EPA drinking water standards (40 CFR 141). The no disposal action alternative under some conditions showed calculated chemical concentrations up to 1,000 times these standards. In no case was the standard exceeded in the Columbia River water. Additional chemical characterization data is necessary to permit assessment of potential impacts of other hazardous chemicals associated with the wastes. These and other needed data such as geochemical transport parameters would be collected and used to perform additional impact assessment and a regulatory compliance assessment prior to implementing a final disposal alternative.

No impacts to the general public were found from the previously disposed of TRU-contaminated soil sites or the pre-1970 TRU buried solid waste sites, whether they were left as disposed or additional protection was provided. Additional remedial action such as the protective barrier and marker system is being considered for protection of sites from inadvertent intrusion into these wastes. These sites are also presently being evaluated by DOE for possible remedial action under CERCLA.

Several scenarios were analyzed to determine what impacts might be expected to intruders who might drill or farm in the marked waste area on the 200 Areas plateau or to those individuals on the Hanford Site who might farm below the plateau out of site of the markers in the absence of active institutional control. When the various intrusion scenarios are weighted for their probability, no more than one health effect is expected over 10,000 years. If records and markers were destroyed or ignored, estimated impacts of intrusion would be zero health effects for residual wastes disposed of near surface according to the geologic disposal alternative, 130 for in-place stabilization and disposal, 64 for the reference alternative, 0 to 64 for the preferred alternative, and 120 for the no disposal action alternative. In a scenario in which some 65 farms were postulated to be established on the Hanford Site along the Columbia River, at most two health effects were calculated for any of the disposal alternatives over a 10,000-year period. For the no disposal action, with a loss of institutional control in 2150 and subsequent resettlement and groundwater use, from 10 to 300 health effects were calculated (which could be repeated if knowledge of the event were lost).

All of the disposal alternatives have low environmental impacts. The geologic alternative shows the lowest impacts in terms of releases to the environment but the highest exposures to workers and the public, as well as markedly higher costs than in the other disposal alternatives. The reference alternative has intermediate costs, low releases and exposures, and complies with the current policy of disposing of readily retrievable high-level and stored TRU defense wastes in a geologic repository. Costs and impacts of the preferred alternative would be between those for the geologic and reference alternatives. However, the

preferred alternative would defer disposal decisions for some wastes for an estimated 10 to 15 years until enough additional waste characterization and information on waste disposal system performance is available for final waste disposal decisions. The no disposal action could result in the lowest short-term costs, but in the long term the total costs may exceed the total costs of the other alternatives. If active institutional control were ever lost, the no disposal action alternative could lead to the highest environmental impacts due to assumed resettlement of the site.

This EIS is both a programmatic EIS intended to support broad decisions with respect to the disposal strategies for the Hanford waste addressed in this EIS and an implementation EIS intended to provide project specific environmental input for decisions on moving forward with certain disposal activities and facilities. The objective of the Hanford Defense Waste Program is to dispose of the Hanford high-level, transuranic and tank wastes in a safe, environmentally acceptable and cost-effective manner.

At present there is insufficient information with which to prepare a complete post-disposal compliance analysis in accordance with EPA's Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Waste, 40 CFR 191, for any of the alternatives. The management portion of the standard would not be expected to impact any of the alternatives since the estimated doses from operations were shown (Section 3.4.1.1) to be substantially below the specified limits. It appears that the Assurance Requirements portion of the standard would be met for all the waste classes and alternatives except for retrievably stored TRU for the in-place stabilization and disposal alternative (additional barriers might be required).

Application of RCRA as amended and CERCLA as amended to Hanford radioactive wastes is in its beginning stages. While these Acts are not seen as precluding any of the alternatives, requirements for leachate collection systems (which would be impractical for existing large underground tanks) might result in the need for variances or certain design features in the waste vitrification facilities in the case of near-surface disposal. Preliminary identification of CERCLA sites has been made; however, additional characterization is required because of the diverse chemicals that have been used at Hanford.

Consideration of licensing by the Nuclear Regulatory Commission of commercial repositories is outside the scope of this EIS. However, for wastes to be disposed of in situ in the in-place stabilization and disposal alternative or reference alternative, the NRC noted when responding to the draft EIS that "...establishing the feasibility of such disposal as technically adequate to protect public health and the environment will be exceedingly difficult and may not be achievable."

Other laws, standards and regulations are applicable primarily during operational phases. Operational experience suggests that the ability to comply with these other laws and regulations would not be affected significantly regardless of the alternative selected. In any event, DOE intends to meet all applicable laws, standards and regulations for the protection of public health and the environment.

VOLUME 1 CONTENTS

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FIGURES

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CHAPTER 1.0

GENERAL SUMMARY

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1.0 GENERAL SUMMARY

This section provides a general summary of this environmental impact statement (EIS). It is an overview of the five-volume final EIS itself, which details the proposed federal action, the issues involved, the decisions that need to be made, and the comments made regarding the draft EIS.

WHAT IS THE ISSUE?

The Department of Energy (DOE) is making a comprehensive effort to identify and select the means for permanently disposing of existing and future defense wastes at the Hanford Site near Richland, Washington. The DOE has examined a wide range of methods for permanently disposing of those Hanford defense wastes at the Site that are termed high-level, transuranic or tank wastes; DOE, in the draft EIS, identified three principal disposal alternatives (or options) from a larger number of possibilities. These options--geologic disposal, in-place stabilization and disposal, and reference (or combination) alternatives--were evaluated in the draft EIS, which was subjected to an extensive review and comment process. A no disposal action (continued storage) alternative was also examined, as required by the Council on Environmental Quality's (CEQ's) regulations for implementing the National Environmental Policy Act (NEPA). A preferred alternative was added for the final EIS.

The proposed action to which the EIS provides environmental information is to select and implement a final disposal plan for these wastes generated and stored at Hanford. The EIS also evaluates whether there is need for further protective action regarding certain wastes previously disposed of at the Hanford Site. The purpose of the proposed action is to dispose of these Hanford defense wastes in such a way that public health and safety and the environment are protected. Implementation of defense waste disposal under the alternatives described in this EIS will be done in compliance with the letter and spirit of applicable federal and state environmental statutes, regulations and standards.

This EIS discusses defense waste only. The disposal of wastes from commercial reactors and the selection of the Hanford Site for detailed characterization as a potential site of a commercial repository are being evaluated in other documents by the Basalt Waste Isolation Project.

To dispose of these Hanford defense wastes is of prime importance. The wastes are already on the Hanford Site. The challenge is to protect public health and safety and the environment in a cost-effective way.

HOW HAS THE PUBLIC PARTICIPATED IN THE DECISION-MAKING?

For all proposed major federal actions significantly affecting the quality of the human environment, the National Environmental Policy Act (NEPA) of 1969 calls for a process such as that depicted in Figure 1.1. This process focuses on preparation of an EIS and on review and comments by the public and by government agencies. Such a procedure is followed to help ensure that all reasonable alternatives and environmental issues are addressed and carefully

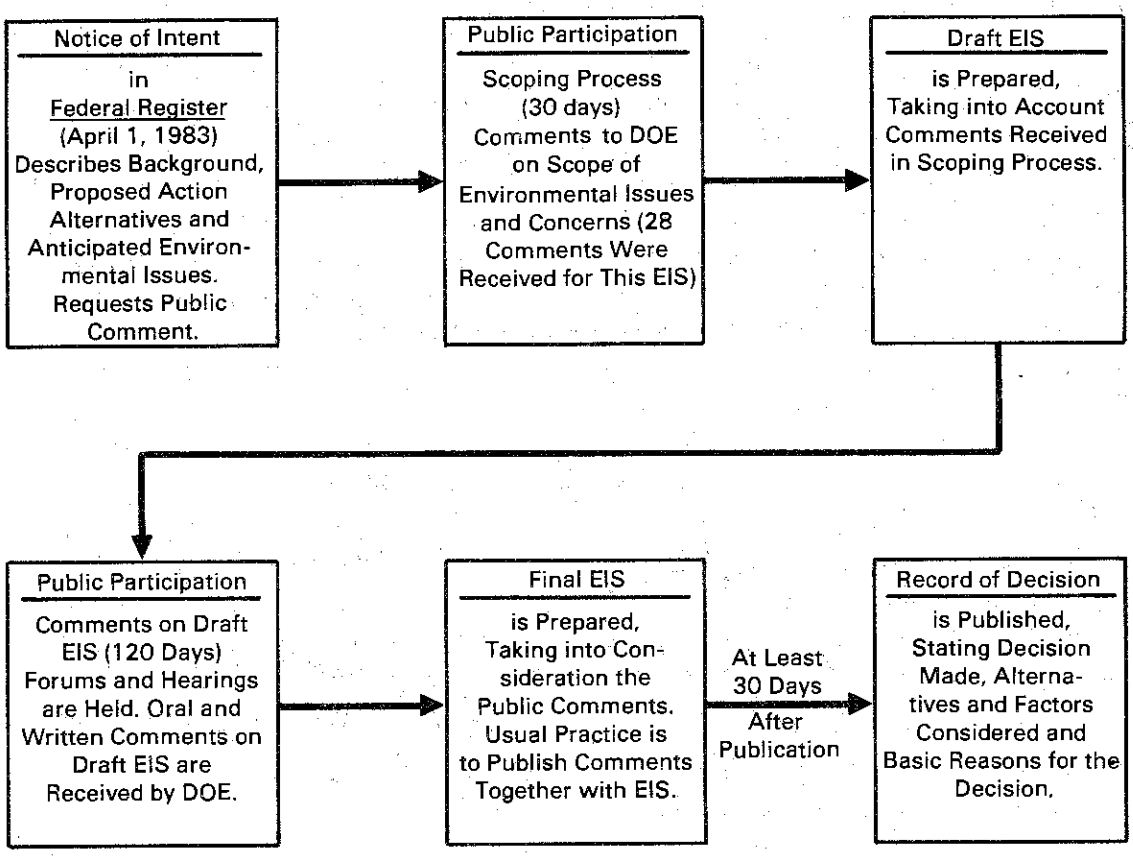

FIGURE 1.1. NEPA Process as Followed for Proposed Disposal of Hanford Defense Wastes

considered before a decision is made. With the release of this EIS, we are now in the period of 30 days or more preceding the Record of Decision. This final EIS includes consideration of the comments on the draft EIS by the Environmental Protection Agency, Nuclear Regulatory Commission, Departments of Commerce and Interior (including the U.S. Geological Survey), and interested groups and individuals; as well as comments from the states of Washington and Oregon, Indian organizations and the Northwest Citizens Forum on Defense Wastes.

A final decision regarding activities evaluated in an EIS may not be made, in accord with regulations issued by the Council on Environmental Quality, sooner than 30 days after notice of availability of the final EIS is published by the Environmental Protection Agency (EPA). Before beginning activities that have been evaluated in an EIS, a Record of Decision is published that sets forth the decision made; identifies all alternatives considered in reaching the decision; specifies the alternative considered environmentally preferable and other factors in the decision; and states whether all practical means to avoid or minimize environmental harm from the alternative selected have been adopted and if not, why they were not.

WHAT AND WHERE IS THE HANFORD SITE?

In 1943 the U.S. Army Corps of Engineers selected an area of about 600 square miles, in semiarid southeastern Washington, for producing nuclear materials, mainly plutonium, in support of the United States' effort in World War II. This area, the Hanford Site (Figures 1.2 and 1.3), has been dedicated ever since to the production of nuclear materials and electricity, to diverse research, and to waste management activities. Hanford facilities, first built and run by the Corps of Engineers (Manhattan Project), have been operated by the Atomic Energy Commission (AEC) (1947-1974) and its successors, the Energy Research and Development Administration (ERDA) (1974-1977) and the Department of Energy (since 1977).

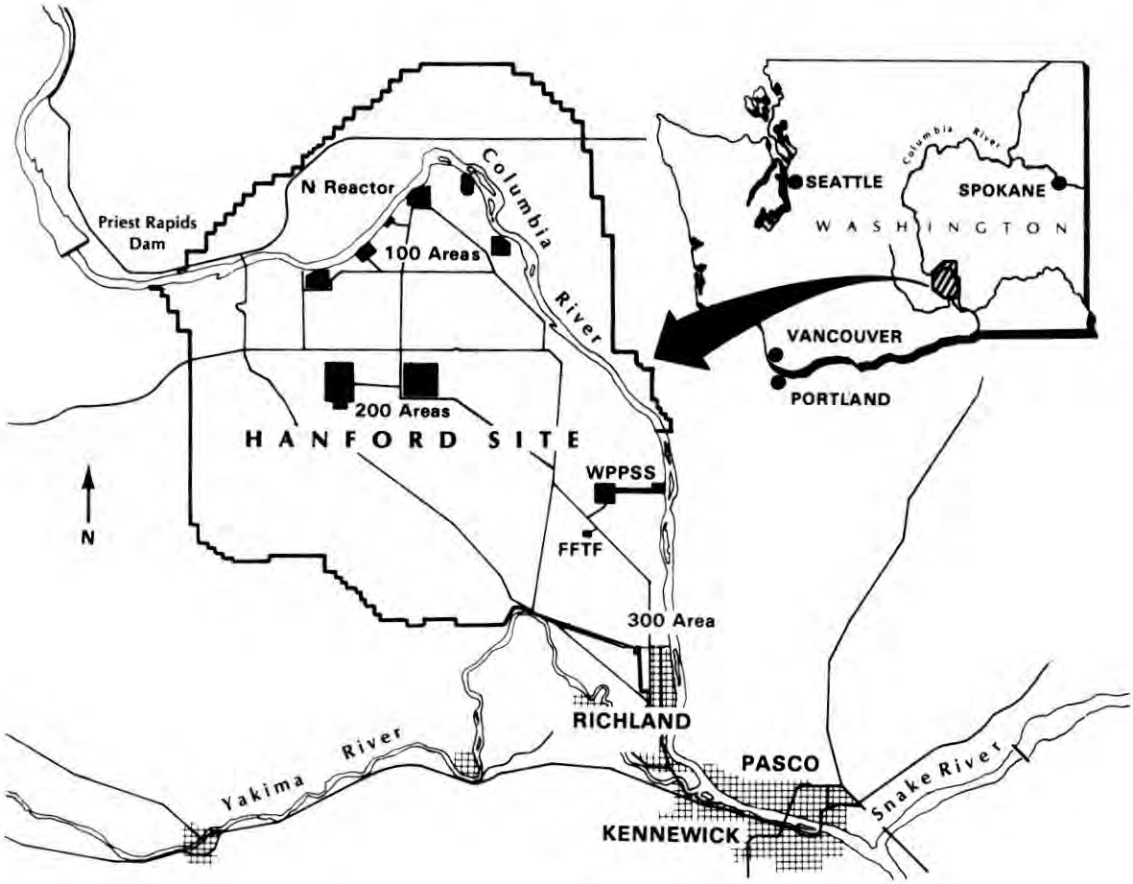

FIGURE 1.2. Location of the Hanford Site

WHERE DID THE WASTES COME FROM?

Eight reactors were built (in the 100 Areas) in the 1940s and 1950s and produced plutonium until the last one was shut down in 1971. One plutonium production/steam generation (dual-purpose) reactor (N Reactor) began operation in 1963 and continues to operate. The steam is used by Washington Public Power Supply System to generate electricity. Companion fuel fabrication plants (300 Area), chemical processing plants (the 200 Areas), and waste management facilities were constructed and operated.

FIGURE 1.3. Typical Terrain of the Hanford Site

Irradiated uranium discharged from the reactors has been processed to recover uranium and plutonium. This processing has resulted in the accumulation of a wide variety of radioactive and chemical wastes.

Since the 1940s, most of the Hanford Site's nuclear defense wastes have been stored near surface on a remote plateau, well away from the Columbia River and well above groundwater. Most waste volumes are large, but they have a relatively low concentration of radioactive material. Some wastes, such as encapsulated strontium and cesium, are highly concentrated.

The categories of waste dealt with in this EIS are high-level, transuranic, and tank wastes. High-level waste is highly radioactive, emits penetrating radiation, and generates a lot of heat. Thus it must be handled remotely, that is, with no human contact. Strontium and cesium (taken from tank waste to remove heat) have been solidified, sealed in capsules, and stored in water basins. Transuranic wastes come mostly from processing plutonium to produce special nuclear materials for national defense. Transuranic waste consists of the elements that have atomic numbers greater than that of uranium, for example, certain isotopes of neptunium, plutonium, americium, and curium. Transuranic solid wastes were either buried as low-level wastes before 1970 or stored retrievably on storage pads since 1970. Tank wastes began with the nuclear defense program in the 1940s. Until the early 1970s most of

the reprocessing waste at Hanford was stored in underground, reinforced concrete, single-shell steel tanks. Since 1970, underground reinforced concrete, double-shell steel tanks (Figure 1.4) have been used for storage of active liquids. These wastes have been processed and transferred among tanks to the point where some might be classed as high-level and some might not.

The radioactive wastes are the result of chemical processing of reactor fuel, and they contain many chemicals, some of which may be classed as hazardous.

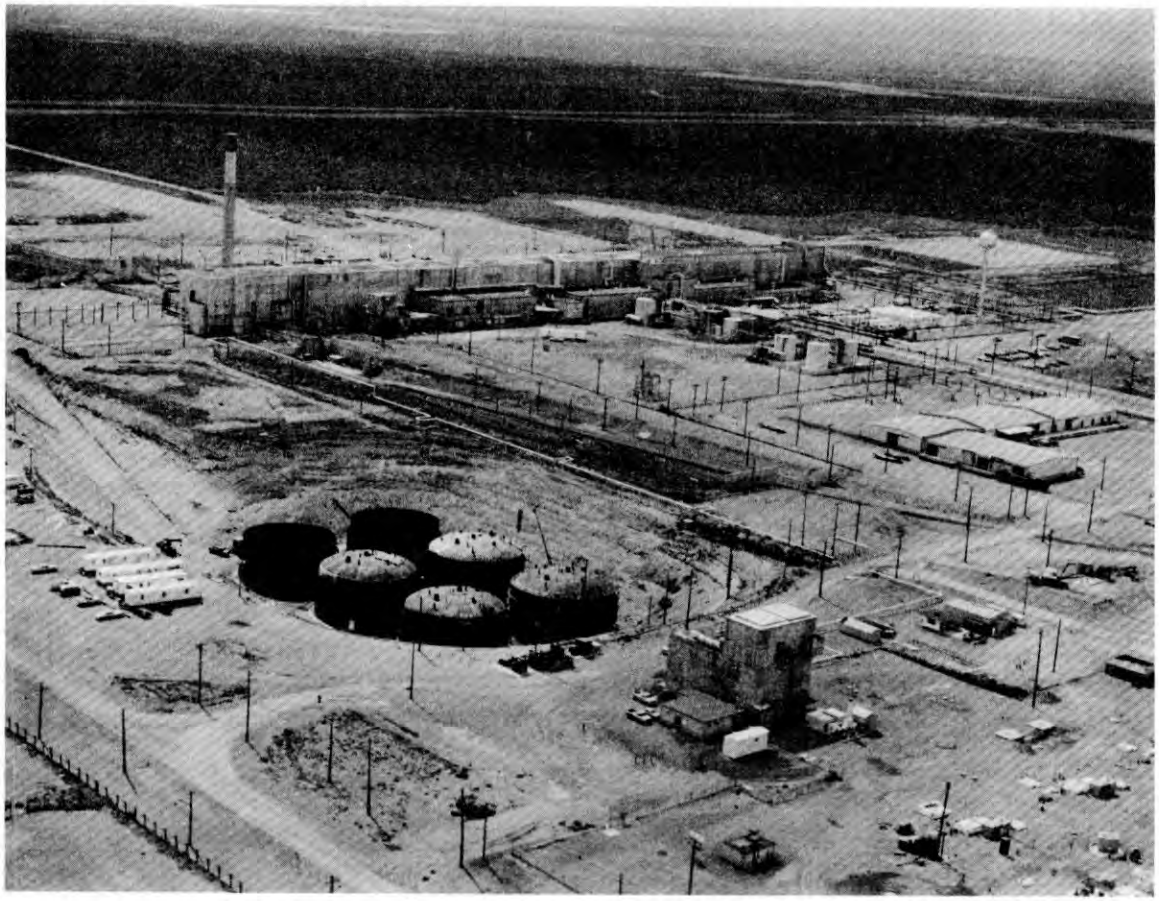

FIGURE 1.4. Six Storage Tanks Under Construction in the 200 Area. When completed, they were covered by eight feet of earth.

HOW SAFE IS CURRENT STORAGE?

Present storage practices provide a high level of public protection while final, long-term systems of containing the waste are planned, developed and built. Although wastes at the Hanford Site are now being held in these interim facilities, none has posed danger to the general public. Monitoring and sampling have shown that nearly all of the wastes that leaked from single-shell tanks early in the program, before adoption of double-shell tanks and other changes in waste management practices, were absorbed by the arid soil next to the tanks.

Monitoring studies have continually shown that radiation doses to people in the communities near Hanford have been well below the levels established for public health and safety. Also, in 1986 the total population dose around the Hanford Site was estimated to amount to less than one-tenth of one percent of that received from natural background radiation. At Richland, Washington, the first downstream community using the Columbia River as a source of drinking water, the maximum organ dose was calculated to be about one percent of EPA's standard in 40 CFR 141 of 4 mrem/yr for drinking water alone.

THEN WHY MOVE TOWARD PERMANENT DISPOSAL NOW?

The present protective levels of containment for wastes stored now or to be stored in the future cannot be expected to continue indefinitely. Some stored nuclear wastes will remain radioactive for centuries to thousands of centuries; certain chemical components of the wastes retain their toxicity forever. Thus DOE's task is to implement permanent disposal methods that will provide protection of public health and safety and the environment over extremely long periods of time.

The intent is to proceed with permanent disposal rather than continue to store the waste and defer responsibility for disposal to future generations. The DOE considers that adequate engineering and environmental information is available to select a specific disposal strategy for selected classes of waste.

Selection of a disposal strategy accords with the Defense Waste Management Plan (DOE/DP-0015) submitted by the President to the Chairmen of the House and Senate Armed Services Committees on June 16, 1983. The Plan, developed by DOE to comply with Public Law 97-90, the Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1982, describes reference plans for permanent disposal of high-level and transuranic waste resulting from atomic energy defense activities. These plans call for selecting, developing, testing and implementing systems for the disposal of Hanford defense waste.

ARE HIGH-LEVEL NUCLEAR WASTES FROM DEFENSE PRODUCTION AND SPENT FUEL FROM COMMERCIAL POWER PRODUCTION DIFFERENT?

The present Hanford high-level defense waste differs significantly from spent fuel assemblies from commercial power reactors. In the year 2000, the cumulative volume of waste stored at Hanford is expected to be about 10 times greater than the cumulative volume of spent fuel removed from commercial nuclear power reactors. However, the radioactivity in Hanford's waste is projected to be about 80 times lower than the commercial waste produced through the year 2000 (Figure 1.5). In addition, commercial spent fuel is mainly in solid form, while Hanford's defense waste is in many forms, from liquid to solid. Although defense and commercial high-level wastes differ in characteristics, both must be isolated from the human environment for thousands of years.

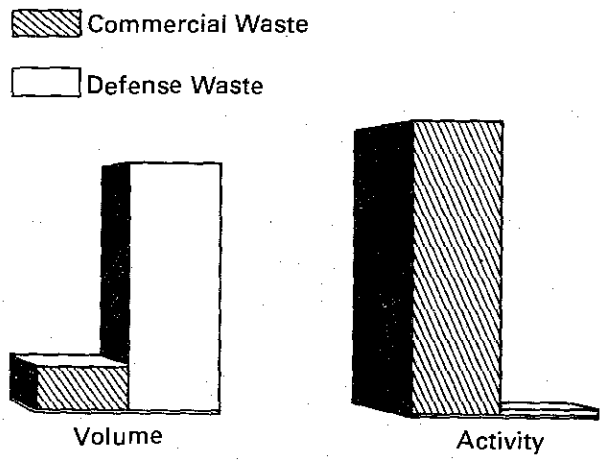

FIGURE 1.5. **Comparison of Hanford Defense Wastes and Commercial Wastes** (Cumulative total through the year 2000)

DO THESE DIFFERENCES INFLUENCE CHOICES ABOUT DISPOSAL METHODS?

Decisions about commercial high-level waste and the siting of a commercial repository are being reached in processes separate from the Hanford defense waste decision.

Commercial spent fuel assemblies stored temporarily in water basins at nuclear power plants can be readily retrieved and packaged for shipment to a repository. The compact form facilitates disposal.

Although double-shell tank wastes and future wastes at Hanford will be readily retrievable and, once the high-level fractions are solidified in borosilicate glass, can be managed much like commercial wastes, much of the older waste presents greater difficulties. The older single-shell tanks contain wastes that may require specialized, costly, and potentially hazardous recovery operations.

Difficult retrieval and lower radioactivity suggest that sending most of the Hanford wastes to a geologic repository after they have been immobilized in glass may not be justified when risk and cost are weighed against benefits. If it can be shown that in-place disposal can adequately protect public health and safety, including meeting EPA standards, that choice, or a combination of methods, may be appropriate.

HOW MUCH DEFENSE WASTE IS THERE AT HANFORD AND WHAT KINDS?

At Hanford about 440,000 cubic yards of high-level, transuranic and tank wastes have accumulated through 1983. Disposal is to also accommodate future defense wastes. For planning purposes, DOE estimates an additional 85,000 cubic yards of waste by 1999 at Hanford. To give a general idea of the total volume of this waste to be disposed of, it is depicted in Figure 1.6 as if it were all solidified and placed on a football field.

To facilitate analysis, the wastes within the scope of the EIS were divided into six classes; four of these consist of waste presently stored or future waste to be placed in

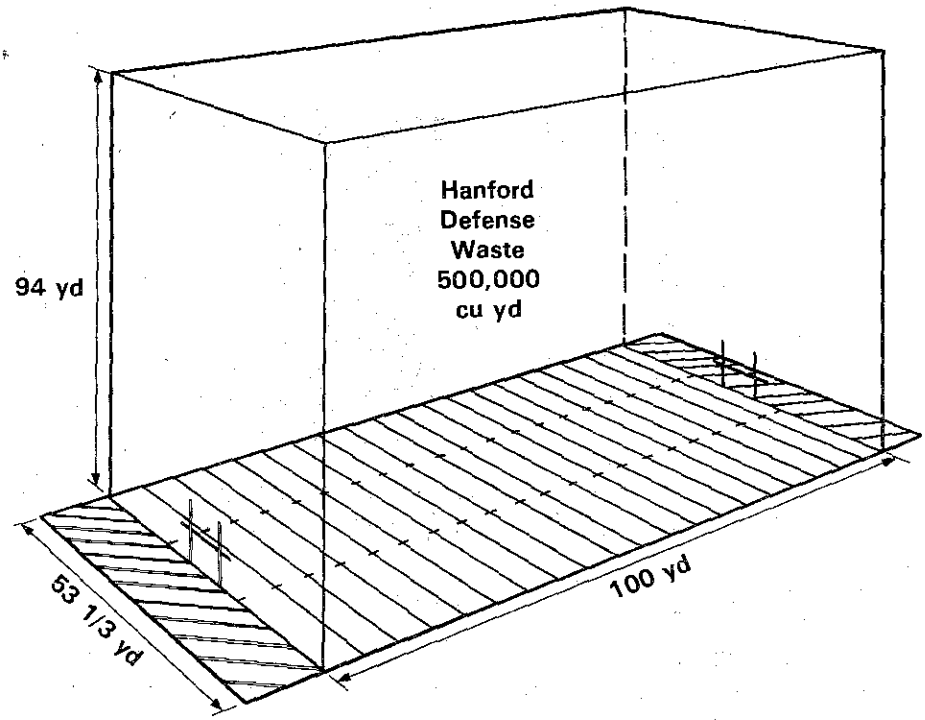

FIGURE 1.6. Approximate Volume of Existing and Future Hanford Defense Waste

interim storage pending disposal. The other two classes are wastes previously disposed of as low-level waste. Because of their suspected transuranic content, they were re-examined to determine whether additional protection is justified. The six classes are these:

1. **Existing Tank Wastes**--This class is further subdivided because of physical differences in tanks and chemical differences in their contents:
   - Single-shell tanks, 149 in number, contain moist sludge and salt cake not readily retrievable.
   - Double-shell tanks (Figure 1.7) are used for storage of existing liquids and sludge wastes that are readily retrievable by pumping. This type of tank has been used at Hanford since 1970. There are presently 28 double-shell tanks with plans for construction of additional tanks as necessary. For calculation purposes, 14 tanks are designated for existing tank waste.
2. **Future Tank Wastes**--Double-shell tanks (included above) are designated for storage of future liquids and sludge that are readily retrievable by pumping. For calculation purposes, 14 tanks are designated for future tank waste.
3. **Strontium and Cesium Capsules**--These are double-encapsulated and held in water basins. Some of these capsules have been leased for beneficial uses and will be returned for disposal.

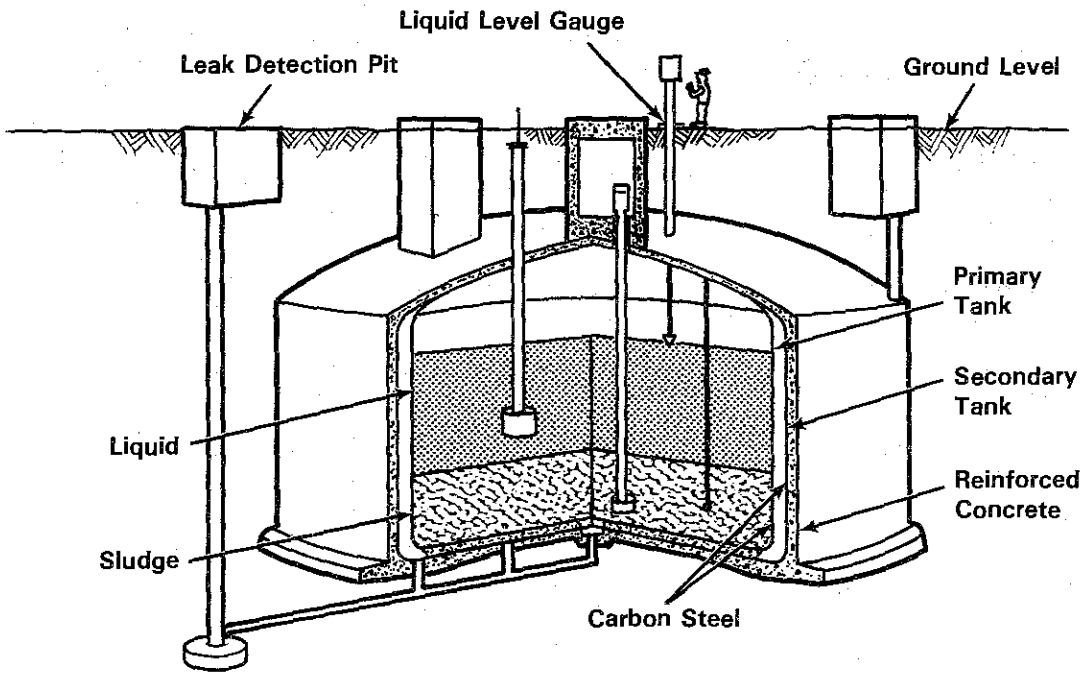

FIGURE 1.7. Double-Shell Tank

4. **Retrievably Stored Transuranic Wastes**--These consist of solid transuranic waste produced since 1970. Separated into combustibles and noncombustibles, packaged, and labeled, they are stored on asphalt pads, in caissons and in trenches. Future transuranic wastes are also included in this class.

5. **Transuranic-Contaminated Soil Sites**--These are disposed-of wastes in ditches, trenches, cribs, and drains. Although previously disposed, they are to be re-examined to determine whether additional environmental protection is warranted.

6. **Pre-1970 Buried Suspect Transuranic-Contaminated Solid Wastes**--These are general trash and failed equipment disposed of in soil-covered trenches prior to 1970. Although previously disposed of, these are to be re-examined to determine whether additional environmental protection is warranted.

HOW DOES RADIOACTIVE DECAY CHANGE THE WASTE QUANTITIES?

Table 1.1, which lists only those constituents most important in the EIS analysis, shows the effects of radioactive decay. The radioactive elements decay with time; some, like strontium and cesium, disappear in a few centuries. However, as Table 1.1 shows, very long-lived radionuclides and the chemicals remain at the same quantity for over 100,000 years.

Because different radioactive materials possess different radiation properties, a hazard index (Table 1.2) accompanies this table of quantities. The health hazard index was adapted from support material the EPA used in developing its standards for environmental protection related to waste disposal. A similar index is not available for stable chemicals.

TABLE 1.1. Quantities of Selected Hanford Defense Waste Constituents, Tons

Waste Constituents	At Disposal	500 yr Later	1,000 yr Later	10,000 yr Later	100,000 yr Later
Radionuclides					
Carbon-14	0.001	0.001	0.001	0.0004	0
Strontium-90	1	0	0	0	0
Technetium-99	2	2	2	2	1
Iodine-129	0.4	0.4	0.4	0.4	0.4
Cesium-137	2	0	0	0	0
Uranium-238	1,900	1,900	1,900	1,900	1,900
Plutonium-239+240	2	2	2	2	0.1
Americium-241	0.1	0.06	0.03	0	0
Chemicals					
Cadmium	4	4	4	4	4
Chromium	100	100	100	100	100
Fluoride	2,000	2,000	2,000	2,000	2,000
Mercury	0.9	0.9	0.9	0.9	0.9
Sodium Nitrate	200,000	200,000	200,000	200,000	200,000

TABLE 1.2. Health Hazard Index for Selected Radionuclides[a]

Radionuclides	At Disposal	500 yr Later	1,000 yr Later	1,500 yr Later	10,000 yr Later	100,000 yr Later
Carbon-14	300	300	300	300	90	0
Strontium-90	3,000,000	20	0	0	0	0
Technetium-99	10	10	10	10	10	9
Iodine-129	5	5	5	5	5	5
Cesium-137	1,000,000	10	0	0	0	0
Uranium-238	10	10	10	10	10	10
Plutonium-239+240	6,000	6,000	6,000	6,000	4,000	300
Americium-241	20,000	10,000	5,000	2,000	0	0
Total (rounded)[b]	4,000,000	16,000	11,000	8,000	4,000	300

(a) Health hazard index is adapted from EPA analyses and is defined as the number of fatal cancers per curie of nuclide that is released to surface water times the inventory of that nuclide at the time shown.

(b) The health hazard index for the amount of original uranium ore, as found in nature, from which the waste was produced (assuming no recycling of uranium in fuel) would be 9,000 for each time shown in this table. For these Hanford defense waste constituents, this point is reached at about 1,500 years. After 1,500 years the hazard index of Hanford wastes is lower than that for the ore (106,000 t of initial reactor fuel) from which the wastes came.

As may be seen by comparing Tables 1.1 and 1.2, some radionuclides in large quantities by weight have a relatively smaller hazard index and vice versa. This illustrates the complexity of discussing hazards of radioactive materials having widely varying properties.

WHAT ARE THE ALTERNATIVES (OR OPTIONS) FOR DISPOSAL?

In the past, a wide range of options for managing nuclear wastes has been considered and studied by scientists around the world. These options have ranged from disposal beneath the sea floor to disposal in outer space. Most studies in recent years have focused on the most feasible and practicable options and have concluded that geologic disposal is the most feasible option, with current technology, for disposal of high-level waste. This large body of work has served as a foundation for current analyses of options for Hanford defense wastes.

Several alternatives were considered for disposing of Hanford wastes. Those chosen for detailed analysis were selected to bound the range of potential impacts and to present one possible combination-disposal alternative. Thus the disposal alternatives and no action alternative considered in the draft Hanford defense waste EIS were as follows:

- Geologic Disposal--Essentially all wastes (by activity) are removed to a deep geologic repository; a low-activity fraction is disposed of as grout in near-surface vaults specifically designed to meet long-term performance requirements and those of the Resource Conservation and Recovery Act of 1976. High-level wastes are sent to a commercial repository for disposal; transuranic (TRU) wastes are sent to the Waste Isolation Pilot Plant (WIPP). Protective barriers are installed over tank residuals and grout vaults. A marker system is installed.
- In-Place Stabilization and Disposal--All wastes are stabilized in place and left at Hanford. Protective barriers are installed over all waste sites. A marker system is installed.
- Reference (Combination Disposal)--Essentially all (by activity) present and future high-level waste in double-shell tanks is sent to a commercial deep geologic repository, and the low-activity fraction is disposed of as a grout in near-surface vaults. The vaults are specifically designed to meet long-term performance requirements and those of the Resource Conservation Recovery Act of 1976. Encapsulated strontium and cesium wastes are sent to a commercial geologic repository, and retrievably stored and future TRU wastes are sent to WIPP. In order to consolidate TRU waste on the 200 Areas plateau, TRU waste from the pre-1970 buried suspect TRU-contaminated solid waste site (618-11, the only TRU waste site outside of the 200 Areas plateau) is sent to a geologic repository, assumed for calculation purposes to be WIPP. All other wastes are stabilized in place. Protective barriers are installed over all waste sites. A marker system is installed.
- Preferred Alternative--Essentially all (by activity) present and future high-level waste in double-shell tanks is sent to a commercial deep geologic repository, and the low-activity fraction is disposed of as a grout in near-surface vaults. The

vaults are specifically designed to meet long-term performance requirements and those of the Resource Conservation and Recovery Act of 1976, and are covered by a protective barrier and marker system. Encapsulated strontium and cesium wastes are sent to a commercial geologic repository; retrievably stored and future TRU wastes are stored until disposed of in the WIPP facility; and TRU waste from the pre-1970 buried suspect TRU-contaminated solid waste site (618-11, the only TRU waste site outside of the 200 Areas plateau) is sent to a geologic repository, assumed for calculation purposes to be WIPP. Decisions on disposal of all other wastes are deferred until additional development and evaluation are completed. In the interim, DOE would continue storage and maintenance of those wastes. When sufficient data to support further decisions become available, DOE would prepare additional documentation for public review and comment, such as a supplemental EIS for disposal of single-shell waste or documentation of remedial investigation/feasibility studies under the Comprehensive Environmental Response, Compensation and Liability Act.

- No Disposal Action--Storage of wastes continues, but no disposal action is taken. No protective barriers and no marker systems are installed. This case is included to comply with the Council on Environmental Quality requirements for a no action alternative. Most of the impacts arise as a result of loss (assumed) of active institutional control in the year 2150, which is assumed for all alternatives. These impacts are not representative of continued waste management practices.

The disposal alternatives in no instance are truly discrete options; each one uses techniques that are employed in the others. For analysis these alternatives are considered separately, but a final strategy could be selected that uses the best features of each one.

The EPA, in 40 CFR 191, stated that performance assessments that address isolation of the wastes from the accessible environment shall not consider any contributions from active institutional controls for more than 100 years after disposal. Although 40 CFR 191 does not apply to TRU-contaminated soil sites or pre-1970 buried suspect TRU-contaminated solid wastes, this EIS analyzes uniformly the impacts for all alternatives as if active institutional control is absent from the Site 100 years after disposal. The year 2150 is assumed as the starting date for loss of active institutional control. This uniformity has permitted parallel, comparable analyses of long-term effects of all alternatives. The assumption of absence of control was adhered to because of the EPA mandate. DOE, however, has no intention of abandoning the Hanford Site and intends to maintain a policy of responsibility for waste management.

WHAT IS THE GEOLOGIC DISPOSAL ALTERNATIVE FOR HANFORD WASTE?

The geologic disposal alternative involves retrieval, processing, segregation, packaging, transportation, and placement of most of Hanford's defense wastes in a deep geologic repository (Figure 1.8). The repository may be located on or off the Hanford Site.

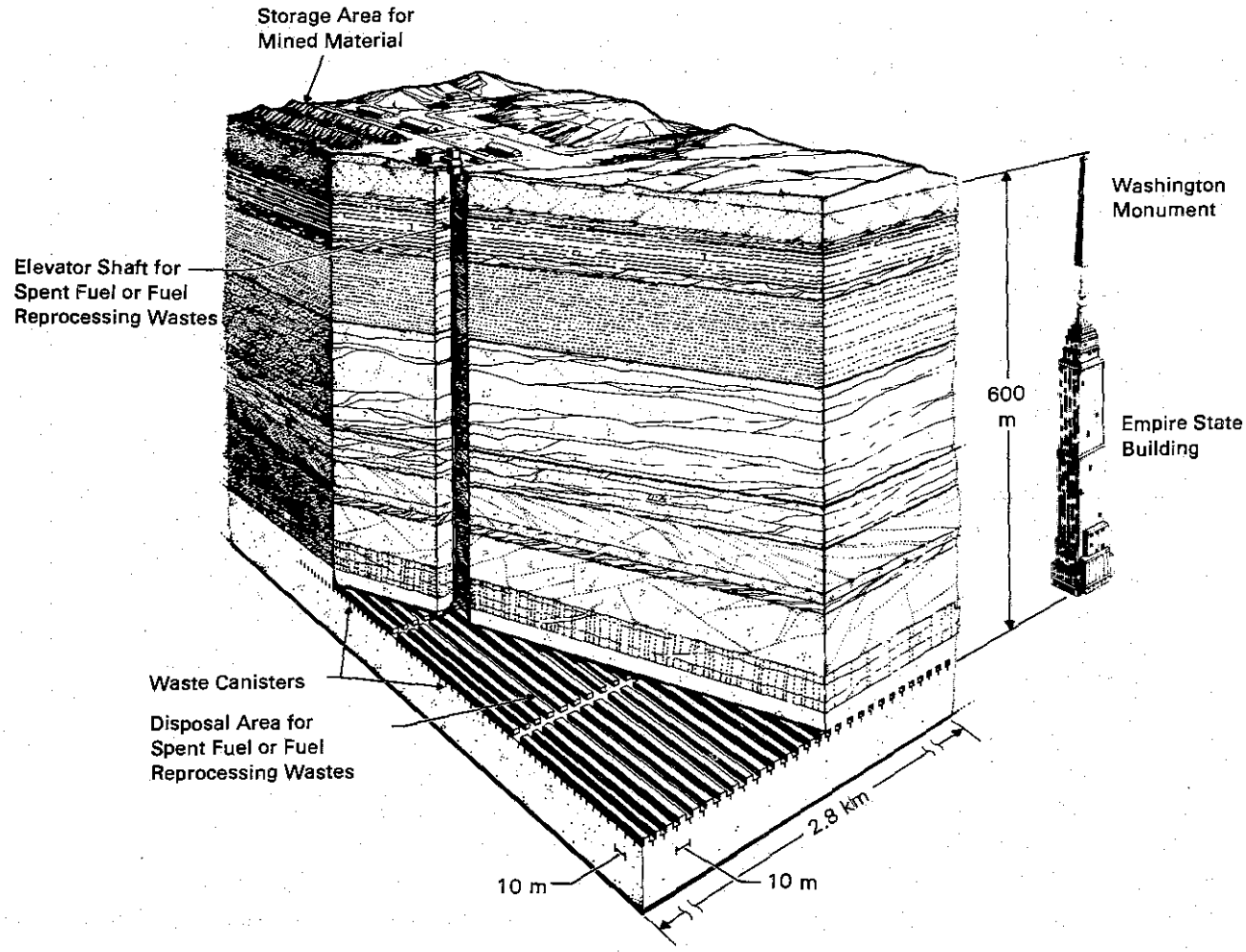

FIGURE 1.8. Conceptual Deep Geologic Repository

This EIS does not provide environmental input to the site selection nor to the construction of an actual geologic repository. It is assumed that any geologic repository for high-level waste would be sited, constructed and operated in accord with applicable provisions of the Nuclear Waste Policy Act of 1982 and would conform to all regulations for licensing and to all standards for protection of the environment. The cost of disposing of high-level defense waste in a commercial repository would be paid by the Department of Energy to the Nuclear Waste Fund.

Transuranic wastes are assumed to go to the Waste Isolation Pilot Plant (WIPP) site in New Mexico. An offsite geologic repository for high-level waste is assumed to be an unspecified location somewhere in the United States, about 3,000 miles from the Hanford Site. This latter repository location was chosen to bound all reasonable distances and therefore to bound possible impacts of shipping wastes to an offsite repository.

The geologic disposal alternative would dispose of high-level waste in deep geologic repositories and the remainder near surface at Hanford. For example, under this alternative, wastes in existing tanks would be separated into two fractions. A small-volume fraction, containing strontium-90, cesium-137, plutonium-239, and other nuclides, would be made into borosilicate glass, packaged and placed in a deep repository. The bulk of the waste, containing small quantities of carbon-14, iodine-129, and other residual radionuclides, would be made into a cement-based grout and disposed of in special, monitored vaults near surface on the Hanford Site. Strontium and cesium, currently double-encapsulated, would be put into a form to meet repository acceptance criteria and disposed of in a deep geologic repository.

A protective barrier, along with markers, (described later) would be placed over tank residuals and waste treatment residuals remaining near the surface.

WHAT IS THE IN-PLACE STABILIZATION AND DISPOSAL ALTERNATIVE?

The concept of this disposal alternative is to permanently fix in place all Hanford existing and newly generated high-level, tank, and transuranic wastes and to dispose of the wastes by isolation from the environment using a protective barrier and marker system.

There would be very little processing or treatment of wastes except for those stored in double-shell tanks. Double-shell tank waste would be treated by removing cesium, if necessary, to reduce grout temperature, to permit suitable grout formulation. Strontium and cesium capsules would be disposed of in near-surface drywells. Wastes in single-shell tanks would be dried, and some tanks would be provided with interim heat-removal systems to maintain temperatures within design specifications. Retrievably stored and newly generated transuranic waste would not be removed from its stored location. Pre-1970 buried transuranic solid wastes and transuranic-contaminated soil sites already disposed of would be further protected by adding barriers and markers.

All sites would be treated as needed to control subsidence and would be covered with a protective barrier and marker system.

Several unique features of the Hanford Site make this alternative reasonable:

- The waste is centrally located on a plateau well above groundwater and within a 570-square-mile federally controlled site.
- The waste is at an elevation that would not be reached by any reasonably postulated surface flood. The potential for flash floods reaching the vicinity of the wastes is remote.
- The region is semiarid. The average annual precipitation at the site is only 6 in. with extremes of record of 3 in. to 12 in. per year. Because of very low precipitation, high evaporation from the ground surface, and transpiration of moisture from plants, little or no water is available to infiltrate waste sites and move the waste materials.

What Is the Barrier? What Is Its Role?

The protective barrier and marker system (Figure 1.9), a concept yet to be more fully developed and tested, is believed to be an effective means for isolating wastes that are disposed of near surface from the environment. The protective barrier and marker system is planned for use at near-surface disposal sites in all the disposal alternatives but not for continued storage (no disposal action).

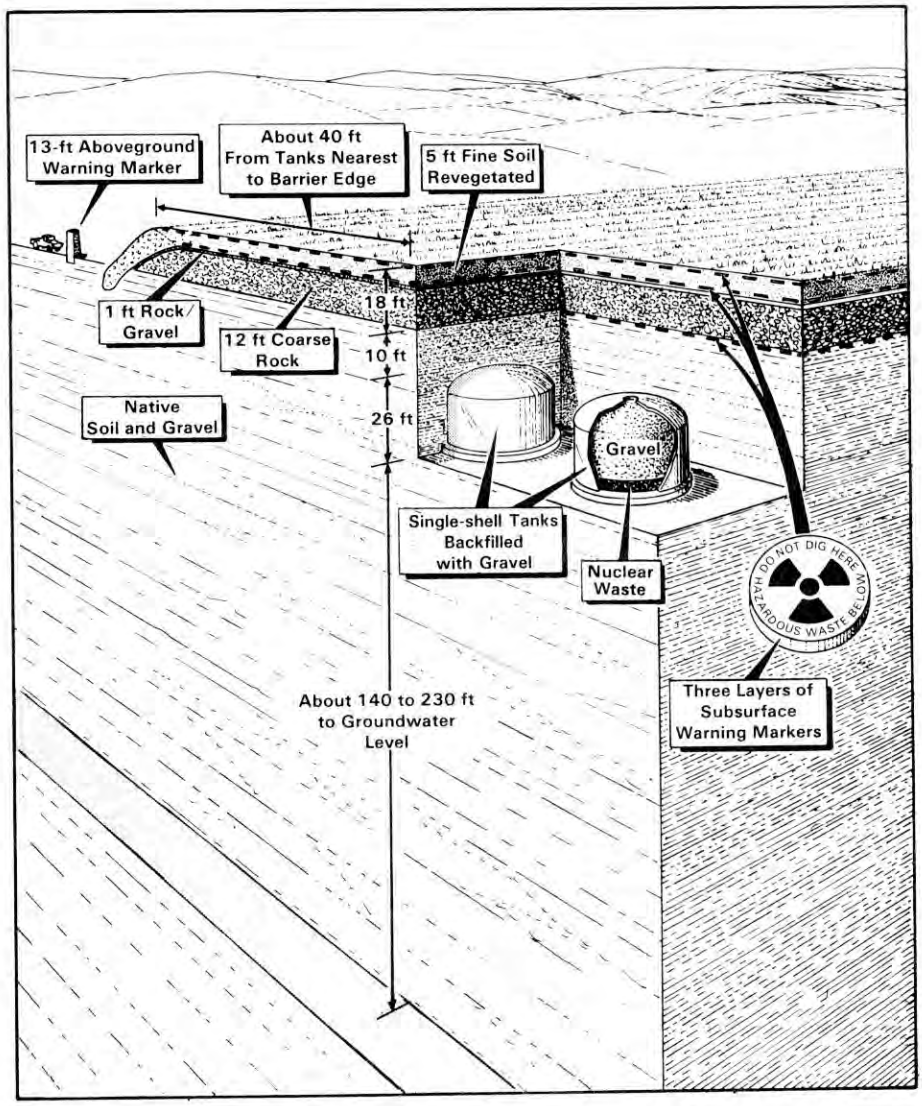

FIGURE 1.9. Conceptual Protective Barrier and Marker System Shown in Use with Single-Shell Tanks

A barrier would work much like a dry sponge to trap moisture (Figure 1.10). The effectiveness of the protective barrier concept is supported by examples both in archaeology and in nature. One example is the engineered barrier that has protected Silla Dynasty tombs in Korea for more than 1,500 years. The tombs are reported to be dry and their artifacts in good condition despite that area's 60 inches of rain annually. More remarkable is a

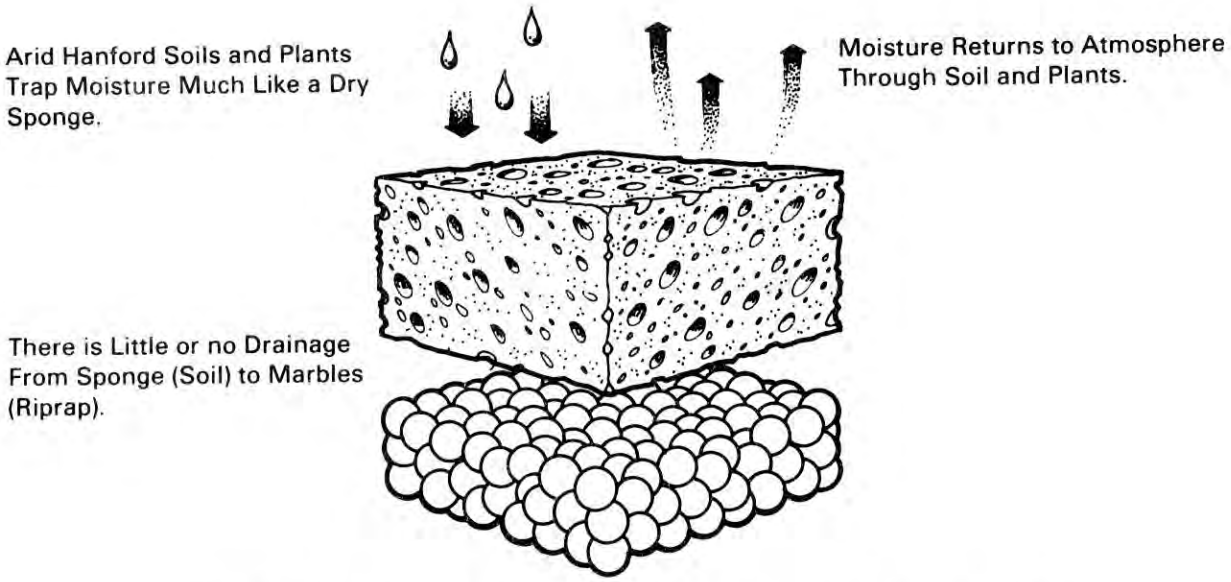

FIGURE 1.10. **Basics of How the Conceptual Protective Barrier Would Work**

2,100-year-old tomb that was protected by a multilayered barrier in the Hunan Province of China. The tomb contained the well-preserved body of a Chinese woman; not only were her skin and organs well-preserved, but also her silk garments were undamaged. The discovery shows that not only moisture but also air was excluded from the tomb for over 2000 years. The natural examples, gravel (or cobble) layers on the Columbia Basin plateau, are of special interest since distinct silt/cobble interfaces have persisted at Hanford for more than 12,000 years (Figure 1.11).

The protective barrier concept proposed for Hanford, shown in Figure 1.9, would consist of about 12 feet of basalt riprap covered by nearly 5 feet of revegetated fine soil. The top layer traps moisture until it can be removed by plants via evapotranspiration or by evaporation from the soil surface, and the riprap prevents upward or downward movement of water by capillary action. This is expected to keep precipitation from the waste sites even if the average precipitation at Hanford were to double present conditions to some 12 inches per year. The barrier's configuration would also prevent plant roots and burrowing animals from reaching the wastes. The performance of the protective barrier for wastes disposed near surface is a key issue of all the Hanford defense waste disposal alternatives discussed in this EIS.

What Is the Marker System?

As currently conceived, the boundary of the actual near-surface disposal area (about 4 by 8 miles) on the 200 Areas plateau would be permanently identified (as called for by EPA standards) by stone monuments engraved with messages such as "Radioactive and Hazardous Waste Disposal Sites Ahead." The marker system would also employ a series of tall monuments at each disposal site to warn of the presence of wastes. These monuments would so encircle the disposal areas that at least three monuments could be seen at once. Layers of subsurface

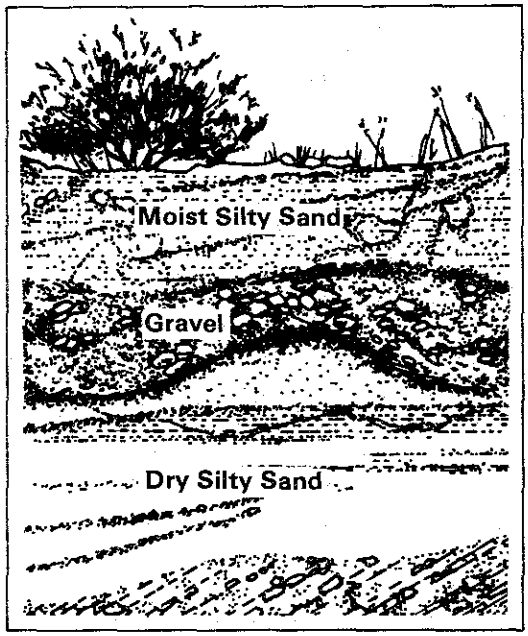

FIGURE 1.11. Natural Example of Barrier: Gravel and Sand Formation, About 12,000 Years Old, on 200 Areas Plateau

marker plates (such as those shown in Figure 1.9) embedded in the barrier would provide additional warning of wastes beneath if anyone were to excavate there.

Intrusion into a waste site would require that active institutional control be absent and that the person be unaware of or choose to ignore land-use records, boundary monuments encircling the area containing the waste sites, the warning monuments at the disposal site, the barrier itself, and the markers within it.

WHAT IS THE REFERENCE ALTERNATIVE?

The aim of the reference alternative (or combination disposal) is to provide a balanced, cost-effective disposal approach. Risks to populations over the long term would be low; yet the near-term risks and costs involved in disturbing difficult-to-retrieve wastes that are currently stable would not be incurred.

To some extent, the reference alternative combines two other alternatives: geologic disposal and in-place stabilization and disposal. Certain waste classes would, as appropriate, be treated the same as in either the geologic disposal or the in-place stabilization and disposal alternatives. Geologic disposal would be used for strontium and cesium currently in capsules, for high-level portions of existing double-shell tank waste and future tank waste (excluding ^{99}Tc), and for retrievably stored and newly generated transuranic solid waste. The cost of disposal of high-level defense waste in the commercial repository would be paid for by DOE via payments to the Nuclear Waste Fund.

Single-shell tank waste is not readily retrievable, and the short-term risks and the costs of its retrieval, preparation, transportation, and emplacement in a deep repository may outweigh any environmental benefits of disposal in a deep geologic mined repository. It would be disposed of by in-place stabilization and isolated from the biosphere with the protective barrier and marker system. The previously disposed-of transuranic-contaminated soil waste sites and pre-1970 transuranic buried solid waste sites would be further isolated by use of a protective barrier and marker system.

The transuranic waste in the pre-1970 site near the 300 Area would be removed to the waste site on the 200 Areas plateau, where transuranic wastes would be processed for disposal as solid transuranic waste in a geologic repository (assumed to be WIPP for calculation purposes). Residuals would be disposed of on the 200 Areas plateau. The rationale for retrieval of the 618-11 site is to consolidate TRU waste on the 200 Areas plateau where it can be protected from public access and potential flooding of the Columbia River.

The reference alternative would require a vitrification facility (for making waste-borosilicate glass), a grout facility, and a transuranic waste processing facility. But the vitrification facility would not need the capacity required in the geologic disposal alternative, in which single-shell tank waste would also be processed.

WHAT IS THE PREFERRED ALTERNATIVE?

The EIS was drafted without a preferred alternative because DOE had not chosen one and so that agency and public comments could be considered in the decision to propose such an alternative. As a result of public and agency comments, DOE has developed a preferred alternative that would dispose of the high-level fraction of double-shell tank waste, retrievably stored and newly generated transuranic waste, and strontium and cesium capsules as in the reference alternative. The pre-1970 buried suspect TRU-contaminated solid waste from one site (the 618-11 site) would be retrieved and taken to the 200 Areas for processing for disposal in a geologic repository (assumed to be WIPP for calculation purposes). The low-activity fraction of double-shell tank waste would be disposed of as grout in near-surface vaults covered (as in the reference alternative) by a protective barrier and marker system. Disposal decisions on single-shell tank waste, transuranic-contaminated soil sites, and the remaining pre-1970 buried suspect transuranic-contaminated solid waste would be deferred until further development and evaluation are completed.

The preferred alternative was developed following agency and public review of the draft EIS. Although it was recognized that disposal of single-shell tank waste, the pre-1970 buried suspect TRU-contaminated waste and TRU-contaminated soils is no less important than disposal of double-shell tank waste, capsules and retrievably stored TRU waste, consensus focused on proceeding with disposal of those wastes that could be most readily disposed of (particularly liquid waste) and deferring disposal judgment on the other wastes. There appeared to be no conflict between implementation of these disposal actions and any federal or state regulations.

It was also recognized that because the radioactive wastes in single-shell tanks have been reduced from liquid to sludge, there is little threat from further leakage and no urgent need to effect disposal despite a large inventory of waste in those tanks. Similarly, the pre-1970 burial suspect TRU-contaminated solid waste and TRU-contaminated soil sites have remained stable and, again, there is no urgency for election of further remedial action. Moreover, application of Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, or Superfund) to these latter classes of waste suggests the need for further characterization of the wastes (including chemicals) and review for compliance with applicable standards.

To implement the preferred alternative, the Hanford Waste Vitrification Plant would be constructed and operated to process existing and future wastes from the double-shell storage tanks. The high-level waste fraction would be processed into a glass waste form to be stored at the Hanford Waste Vitrification Plant until a deep geologic repository is built and is ready to receive this waste. The low-activity fraction would be solidified in cement-based grout and disposed of near surface in concrete vaults covered by the protective barrier and marker system and monitored according to regulations. The DOE would also proceed with design, construction and operation of the Waste Receiving and Processing facility. There, retrievably stored transuranic solid waste would be sorted and repackaged according to the waste acceptance criteria for the WIPP facility in Carlsbad, New Mexico. Once shipments are authorized, the waste would be sent for disposal to this defense-only transuranic-waste geologic repository. Strontium and cesium capsules would be packaged at the end of their useful life to meet repository acceptance criteria and sent to a deep geologic repository. Pre-1970 buried suspect TRU-contaminated solid waste would be retrieved from the 618-11 site, near the 300 Area, and taken to the 200 Areas for processing for disposal in a geologic repository (assumed to be WIPP for calculation purposes). For the three classes of waste for which disposal action is deferred, DOE would continue the present storage and maintenance activities until the development and evaluation and decision-making processes are completed and the final disposal action is implemented.

The DOE plans to work with the EPA and appropriate state agencies to establish mutually acceptable methods for dealing with the wastes, including the hazardous chemical components. The DOE will comply with applicable state and federal hazardous waste regulations, including RCRA and CERCLA (or Superfund).

WHAT WOULD NO DISPOSAL ACTION INVOLVE?

The no disposal action alternative is represented by continued storage of Hanford defense wastes. Analysis of a no action alternative is required by the Council on Environmental Quality regulations for preparing environmental impact statements. Except for modifications described here, present waste management practices would be continued. In this alternative, the waste storage sites would be monitored and maintained, but no disposal actions would be taken. Ongoing activities such as reduction of liquids in single-shell tanks would continue. It is assumed, as in the other options, that active institutional control of the Site is absent after the year 2150.

Under this alternative the following actions would be undertaken: 1) strontium and cesium capsules would continue to be stored under water at existing facilities until about the year 2010 and then would be transferred for storage in a near-surface drywell facility; 2) double-shell tank wastes would be retanked in new tanks as the older tanks approach their design life (at about 50-year intervals).

Previously disposed-of transuranic wastes would not be further stabilized; subsidence would be repaired if it were to occur. Sites would not be covered with the protective barrier and marker system.

HOW ARE IMPACT ANALYSES PERFORMED?

Basically, in analyzing the potential environmental effects of high-risk activities over long periods, agencies must disclose any lack of important information and also provide an analysis of the reasonably forseeable significant adverse impacts, based upon theoretical approaches generally acceptable in the scientific community, of proceeding without such information. Unequivocal proof is not expected or required because of the substantial uncertainties. This "rule of reason" encompasses what is called a "bounding analysis" that is based on available data and, in some cases, engineering estimates. A bounding analysis is made with a set of data, modeling assumptions, and accidental release scenarios which, totaled, compounds conservatisms so that the calculated (predicted) environmental impacts should exceed those actually expected. Figure 1.12 outlines the logic flow of the analysis.

The timing of NEPA impact statements necessitates an analysis of potential impacts before any major decision can be made. After such a decision, compliance analysis may be necessary before obtaining a permit, license, start-up of a plant, etc. Such analysis may entail developing experimental or engineering data and validating codes that enable the prediction of observed performance.

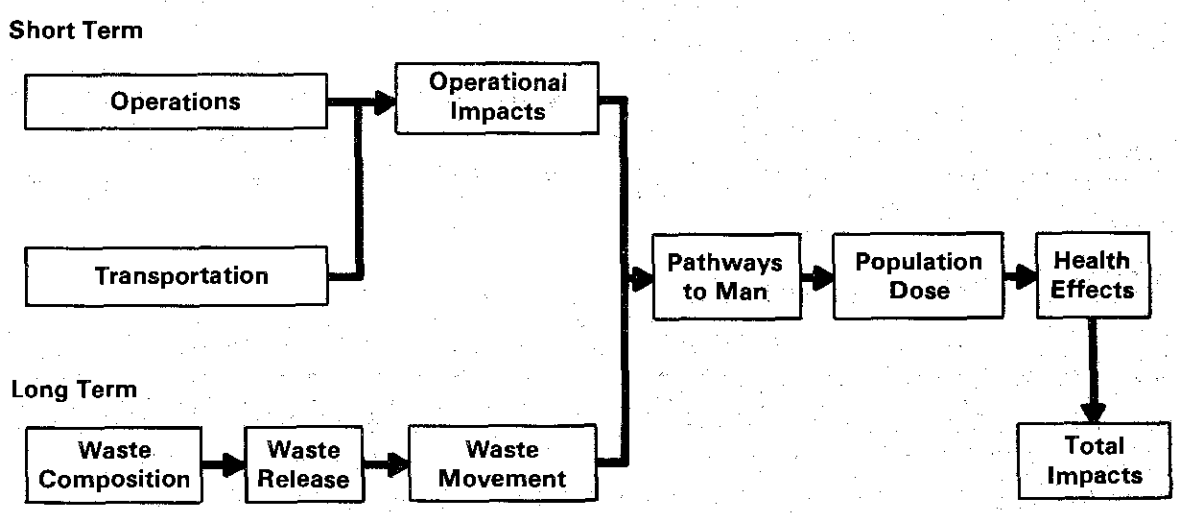

FIGURE 1.12. Major Components of the Analysis

WHAT IMPACTS WERE CALCULATED FOR THESE ALTERNATIVES?

Potential impacts of the disposal alternatives and the no disposal action alternative were carefully considered, analyzed and compared. Several important aspects were analyzed:

- public health and safety
- construction
- transportation
- ecology
- socioeconomics
- commitment of resources
- costs.

Tables 1.3 and 1.4 in this section summarize succinctly only the major projected impacts. In the absence of intrusion, the environmental impacts show little difference among

TABLE 1.3. Major Health and Safety Impacts. Number of projected health effects[a] over 10,000 years.

	Disposal Alternatives				
	Geologic Disposal	In-Place Stabilization and Disposal	Reference Alternative	Preferred Alternative[b]	No Disposal Action
Short Term					
Operations					
Radiological	2-15	0-2	0-4	0-15	0-2
Industrial-type Accidents	4	0	0	0-4	0
Transportation					
Radiological	0	0	0	0	0
Traffic Accidents	2	0	1	1-2	0
Long Term					
Radiological	0[c]	0	0[c]	0[c]	3-4,000
TOTAL	8-21	0-2	1-5	1-21	3-4,000

(a) Health effects are presumed radiation-induced fatal cancers and genetic effects. Safety impacts include industrial and traffic accident fatalities. Ranges result from the use of a range of climates and a range of dose-to-health effect conversion factors.
(b) Impacts would ultimately range from the low impacts associated with the reference alternative to the high impacts (because of waste retrieval and additional transportation) associated with the geologic alternative, depending on the decision for disposal of single-shell tank waste, TRU-contaminated soil sites and pre-1970 buried suspect TRU-contaminated solid wastes.
(c) Does not include long-term impacts resulting from wastes disposed of in geologic repositories (none would be expected; however, as many as 700 health effects could occur over 10,000 years and still meet the requirements of 40 CFR 191).

TABLE 1.4. Impacts of Intrusions[a] After Disposal. (Number of projected health effects[b] over 10,000 years.)

	Disposal Alternatives				
	Geologic Disposal	In-Place Stabilization and Disposal	Reference Alternative	Preferred[c] Alternative	No Disposal Action
Drilling into Waste					
Monuments, markers and records effective	0	0	0	0	
Monuments, markers and records absent or ignored	0	3	0	0	3
Habitation at Drilling Site[d]					
Monuments, markers and records effective	0	4	4	0-4	
Monuments, markers and records absent or ignored	0	130	64	0-64	120
Resettlement of Hanford Site[e]	0-4	0-2	0-2	0-4	300[f]

(a) All intrusions were assumed to occur during period of lethality, i.e., within about 400 years after disposal.
(b) The projected number of health effects (radiation-induced fatal cancers and genetic effects) is based in part on the area occupied by wastes, which is larger in the case of double-shell tank wastes in grout in the in-place stabilization and disposal alternative than where these wastes remain as liquids in tanks in the no disposal action alternative.
(c) Impacts would ultimately range from the higher impacts associated with the reference alternative to the lower impacts associated with the geologic alternative, depending on the decision for disposal of single-shell tank waste, TRU-contaminated soil sites and pre-1970 buried suspect TRU-contaminated solid wastes.
(d) It is assumed that a family of 4 is involved in each drilling/habitation event.
(e) The range shown includes the effects of a range in climate and dose-to-health effect conversion factors.
(f) Might occur more than once if knowledge of event were lost.

the disposal alternatives, but in some instances the no disposal action alternative shows distinctly greater impacts. Where intrusion is considered, the geologic disposal alternative has by far the least impact. Section 3.4 of the EIS contains detailed comparisons of the projected impacts for each alternative.

Expected (normal) and postulated (abnormal) impacts are explained and quantified at length in Chapter 5 of this EIS. Detailed information on analytical methods and the results are provided throughout Volumes 2 and 3, which contain appendices. Agency and public comments and responses are provided in Volume 4. Public comment letters are reproduced in Volume 5.

WHAT IMPACTS CAN BE EXPECTED IN THE NEAR FUTURE?

Radiation doses (occupational; offsite population; and transportation) resulting from each alternative were calculated and ranged from one to 15,000 man-rem.[a] Although these doses are small compared to the estimated 2,500,000 man-rem the offsite population would receive from natural background[b] radiation during the same period, they do show some significant differences among alternatives. For example, the geologic disposal alternative results in factors of six to eight increase in occupational exposures over the in-place stabilization and disposal and reference alternatives, primarily because of the extensive retrieval and waste processing operations.

Transportation doses are higher (for the geologic and reference alternatives, which involve transportation) when high-level wastes are shipped to an offsite repository as compared to an onsite repository. Shipments are made in massive containers that in tests under very severe conditions did not release radioactivity (Figure 1.13). Even though the

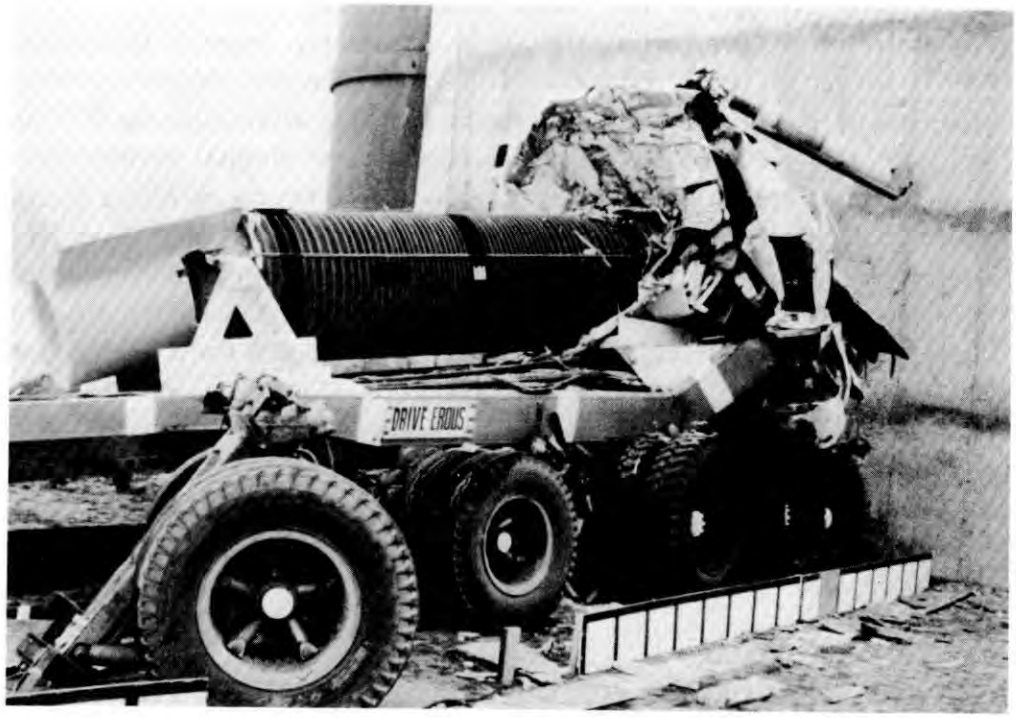

FIGURE 1.13. Photo of Intact Waste Cask Taken in a High-Speed Test Collision (Courtesy of Sandia National Laboratories.)

(a) Radiation impacts are expressed in rem, a unit of dose equivalent (or more simply, dose) to individuals, or in man-rem, a unit of collective dose equivalent (or population dose) for groups of people or populations--the product of the calculated dose to an individual and the number of individuals in the population receiving that dose.

(b) To place radiation impacts in perspective it is often helpful to compare them to the dose a person receives from natural background radiation, a dose of about 0.1 rem, or 100 millirem, per year. A population of 1 million would, then, receive a population dose of 100,000 man-rem/yr (1 million x 0.1 rem/yr) from natural background. (No contention is made that natural background radiation is or is not harmful.)

shipments are made in the safest possible way, traffic accidents are likely to occur in a few of the 3,100 shipments required for the reference alternative or 6,900 for the geologic alternative (or, for the preferred alternative, this range of shipments).

Nonradiological injuries, illnesses (lost time) and fatalities for workers were calculated and found to be highest for retrieval operations and repository emplacement. Calculated differences are only slight for the case in which the high-level waste fraction is disposed of in an onsite repository and the transuranic waste is shipped to WIPP. For example, calculated transportation fatalities (for the geologic disposal alternative) are reduced only from two to one when high-level wastes are disposed of in an onsite repository.

HOW ABOUT COSTS?

Costs vary considerably among alternatives. Due to recovery, processing and shipping operations, the cost of the geologic alternative (some $17 billion) is five to seven times those of the other disposal alternatives. Costs associated with the no disposal action (continued storage) alternative appear at first to be the lowest. However, they are estimated at $1.8 billion for the first century and $1.3 billion for each succeeding century. Therefore, depending on the length of storage, the cost of this alternative could be substantially larger. When this continued storage ceases, some type of disposal would probably be implemented and the costs would increase significantly. Costs for the reference alternative are estimated at $3.9 billion, and for in-place stabilization $2.4 billion. Costs for the preferred alternative show a range of $3.9 to $16.4 billion, reflecting the range of costs associated with the classes of waste for which decisions are being temporarily deferred. Costs are higher than in the draft EIS, primarily because of increased cost estimates for repository emplacement. These are shown in Table 1.5.

TABLE 1.5. Comparison of Costs for Implementing Alternatives, Millions of $1987[a]

Geologic Disposal						No Disposal Action	
HLW Onsite, TRU to WIPP	HLW Offsite, TRU to WIPP	In-Place Stabilization	Reference		Preferred	First 100 yr	Each Additional 100 yr
16,900	17,500	2,400	3,900	3,900	3,900 to 16,400	1,800	1,300

(a) Costs were revised from the draft EIS to reflect increased proposed repository fees. Since the above costs were calculated, further, increased repository fees have been proposed. If put into effect, these additional increases would raise the cost of the geologic alternative by 20%, the reference alternative by 5% and the preferred alternative by 5 to 20%. Although these changes do not affect the relative cost comparison of alternatives, they do widen the cost difference between the geologic and preferred alternative and the other alternatives. However, the increase has not changed DOE's choice of a preferred alternative. Additional changes in estimated repository fees may be expected in the future.

WHAT LONG-TERM IMPACTS CAN BE EXPECTED?

The analysis of long-term environmental impacts under normal conditions indicates no major differences among the disposal alternatives, but the no disposal action alternative, under some postulated scenarios and after assumed absence of institutional control, might exceed regulatory release limits. Impacts on limited groups of people from postulated disruptive scenarios, such as drilling into waste sites, are substantially different among the alternatives.

With the present climate, or even if the average precipitation were doubled and a barrier failure occurred, the general public would be protected in all disposal alternatives. Downstream users of the Columbia River would incur at most one health effect associated with the disposed-of waste over the 10,000 years. (Health effects are presumed radiation-induced fatal cancers, as well as presumed radiation-induced genetic effects.) However, where it was assumed in the no disposal alternative that institutional control was lost at the Site in the year 2150 (assumed solely to permit a parallel analysis with the disposal alternatives), up to 4,000 health effects could occur to the public. This may be compared to the 300,000 to 3,000,000 health effects estimated for the same population and time period from exposure to natural background radiation.

The release to groundwater of several key chemicals associated with the Hanford wastes (sodium nitrate, fluoride, cadmium, chromium, and mercury) was analyzed. For the disposal alternatives the calculated concentrations were well below the EPA drinking-water standards. The no disposal action alternative, in the absence of institutional control, however, showed calculated chemical concentrations at a nearby well on the Site up to 1,000 times these standards. In no case was the drinking-water standard in the Columbia River exceeded.

Several scenarios were analyzed to determine what impacts might be expected to persons who might drill or farm in the marked waste area on the 200 Areas plateau or to those who might farm on the Site below the plateau and out of sight of barriers and monuments. When the various intrusion scenarios are weighted for their probability (assuming that the barriers and marks are effective), no more than one health effect (fatal cancer and genetic effect) is expected over 10,000 years for all the disposal alternatives. If markers, monuments and records were absent or ignored, the calculated health effects would amount to zero for the geologic disposal alternative, 130 for the in-place stabilization and disposal alternative, 64 for the reference alternative, zero to 64 for the preferred alternative and 120 for the no disposal action alternative over the 10,000-year period. In a scenario in which some 65 farms were postulated to be established on the Site along the Columbia River, at most four health effects were calculated for any of the disposal alternatives over a 10,000-year period. For the no disposal action alternative, with a loss of institutional control in the year 2150, about 300 health effects would be expected during resettlement (which could be repeated several times over the 10,000-year period if knowledge of contamination were lost).

IN SUMMARY, HOW DO THE ALTERNATIVES COMPARE?

Where systems operate as planned, the disposal alternatives all have low impacts in terms of standards for protection of the environment. Although the geologic alternative shows the lowest in terms of long-term releases to the environment, it has the highest operational exposures to workers and the public, as well as markedly higher costs than the others. Total impacts for the preferred alternative would be determined by the disposal of the remaining three waste classes for which the decision is deferred, assuming that development and evaluation studies culminate in findings consistent with those of this EIS. The operational impacts could be as low as those for the reference alternative (if the remaining waste classes were all disposed of in place) or as high as those for the geologic alternative (if the remaining waste classes were all disposed of in a geologic repository). Similarly, long-term impacts would range from values as low as those for the geologic alternative to as high as those for the reference alternative. Disposal decisions on the remaining waste sites may be made on a site-by-site basis, with some wastes disposed of in a geologic repository and some in place; the resulting impacts would then be somewhere between (bounded by) these two extremes.

The geologic alternative has the highest costs and in-place stabilization has the lowest costs. The reference alternative has intermediate costs. Costs of the preferred alternative would also be bounded by those for the geologic and reference alternatives, depending upon the final disposal actions for the remaining waste classes. The no disposal action could result in the lowest short-term costs, but over an extended time could be more costly. The no disposal action alternative has low impacts as long as active institutional controls exist, but without them would have higher risks. Overall impacts of the alternatives may be higher once the chemicals are characterized and the impacts of their disposal are assessed.

WHY ARE THESE DECISIONS IMPORTANT NOW?

It is important to plan and implement disposal at Hanford that will not require the management and expense of a continuing active storage system. The goal of moving to final disposal as soon as practical is strongly supported by the states of Washington and Oregon, the National Research Council of the National Academies of Science and Engineering, the Northwest Citizens Forum on Defense Wastes, and other groups and individuals. A clear, timely decision will permit sound plans that focus on a path toward disposal of these wastes. This will allow time to do the necessary development and careful evaluation of systems that will protect public health and safety and the environment in a manner that is cost-effective and technically sound.

CHAPTER 2.0

PURPOSE AND NEED

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2.0 PURPOSE AND NEED

The proposed action, to which this EIS provides environmental input, is to select and ultimately implement a final disposal plan for high-level and tank waste and retrievably stored (since 1970) and newly generated transuranic (TRU) wastes produced as a result of national defense activities at the Hanford Site; also an evaluation is made of suspected TRU waste previously disposed of at Hanford to assist in determining whether any additional action should be taken in terms of further long-term environmental protection.

The proposed action also includes construction, operation and decommissioning of waste treatment facilities that would be required in the course of implementing disposal alternatives. Facilities which are evaluated in this EIS include a Hanford Waste Vitrification Plant, a Transportable Grout Facility, and a Waste Receiving and Processing Facility.

The purpose of the proposed action is to remove certain classes of Hanford defense waste from actively controlled and monitored storage and to dispose of the wastes permanently in such a way that long-term protection of public health and safety and the environment can be achieved in a cost-effective and technically sound manner.

The need for the proposed action is based on the Department of Energy's (DOE) responsibility under the Atomic Energy Act and DOE's commitment to manage and dispose of this waste properly. Moreover, the proposed action is in accord with the Defense Waste Management Plan (DOE 1983) prepared by the DOE and submitted by the President to the Chairmen of the House and Senate Armed Services committees on June 16, 1983. The plan was developed by DOE to comply with Public Law 97-90, the Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1982. It describes reference plans for the permanent disposal of high-level and transuranic waste resulting from atomic energy defense activities and calls for permanent disposal in a sequential mode based on technical priorities. Specifically, the Defense Waste Management Plan calls for disposal of readily retrievable high-level waste in a geologic repository[(a)] and disposal of stored TRU waste in the Waste Isolation Pilot Plant geologic repository in New Mexico.[(b)] The Defense Waste Management Plan states that: "immobilization of new and readily retrievable high-level waste will begin about 1990 after sufficient experience is available from Savannah River's vitrification process. Other waste will be stabilized in place in the 1985-2015 time frame

(a) On January 7, 1983, President Reagan signed into law the Nuclear Waste Policy Act of 1982 (PL 97-425). Section 8 of that law requires that the President evaluate the use of the disposal capacity at one or more commercial repositories for the disposal of high-level radioactive waste from atomic energy defense activities. In a letter to the Secretary of the Department of Energy, the President concluded that no basis appeared to exist for a defense-only repository and directed the Secretary to proceed with arrangements to dispose of defense waste in a commercial repository in conformance with the Act (April 30, 1985).

(b) The plan is to operate the WIPP for a period of 5 years to demonstrate the safe disposal of radioactive wastes resulting from defense activities and programs. Following the 5-year demonstration period, a decision will be made on whether to leave the transuranic waste in the WIPP permanently.

if, after the requisite environmental documentation, it is determined that the short term risks and costs of retrieval and transportation outweigh the environmental benefits of disposal in a geologic mined repository."

The scope of the waste included in the proposed action encompasses radioactive waste at Hanford in the following classes. Some of these wastes will be classed as high-level.

- Existing Tank Wastes stored in single-shell tanks and double-shell tanks
  - Single-shell tank waste is in the form of salt cake, sludge, and interstitial liquors, and is not readily retrievable, i.e., pumpable. There are 149 single-shell tanks of varying sizes up to 3,800 m^3 capacity.
  - Double-shell tank waste is in the form of liquors and slurries, readily retrievable by hydraulic sluicing. There are presently 28 double-shell tanks, with plans for construction of additional tanks as necessary. For calculation purposes, 14 are designated for existing tank waste. Each double-shell tank has a capacity of 3,800 m^3 to 4,300 m^3.
- Future Tank Wastes include wastes from operation of the PUREX[(a)] Fuel Processing Facility, which restarted in November 1983. The PUREX Plant will process fuel irradiated in N Reactor and may process other fuels such as blankets from the Shippingport Naval Reactor and from Hanford's Fast Flux Test Facility fuel cores I-IV, which are also of defense program origin. Only double-shell tanks are designated to contain waste from ongoing and future Hanford operations. For calculational purposes 14 are designated for future tank waste.
  For extended operations of facilities past 1995, see Section 3.2.2.
- Strontium and Cesium Capsules consists of double-shell metal capsules containing strontium or cesium that are stored in water basins. This material may be used in byproducts programs prior to return to Hanford for disposal.
- Retrievably Stored and Newly Generated TRU Waste consists of solid TRU waste produced since 1970; it is packaged, labeled, and stored in buildings, on asphalt pads, in caissons, and in trenches. Also included in this class are future TRU wastes to be generated by ongoing and future Hanford operations.
- TRU-Contaminated Soil Sites consist of cribs, ditches, trenches, settling tanks, French drains, and reverse wells that have received liquid radioactive wastes. At the time these wastes were disposed of, they were considered to be low-level wastes; the TRU waste category had not yet been established by the AEC. The wastes in these sites were disposed of but are included in the scope of the EIS to assist in determining whether additional environmental protection is warranted.
- Pre-1970 Buried Suspect TRU-Contaminated Solid Waste consist of general trash and failed equipment disposed of in trenches. At the time these wastes were disposed of, they were considered to be low-level wastes; the TRU waste category had not

(a) PUREX: Plutonium URanium EXtraction.

yet been established by the AEC. Records indicate that these buried wastes might meet the current TRU waste definition (DOE Order 5820.2). For simplicity, in this document they are referred to as "pre-1970 buried TRU solid waste." Although the wastes in these sites were disposed of, they are also included in the scope of the EIS to assist in determining whether additional environmental protection is warranted.

Section 3.2 provides more detailed definition and characterization of these waste classes and identification of sites requiring disposal.

Excluded from the scope of the proposed action are the disposal of defense waste generated during decontamination and decommissioning activities associated with surplus or retired facilities at Hanford and the disposal of DOE low-level waste (except as generated as part of the disposal alternative). Since there is no proposal to process commercial reactor fuel or waste for plutonium, such activities are not addressed. Waste from operation of commercial power reactors is not considered in this EIS.

This EIS is both a programmatic EIS intended to support broad decisions with respect to the disposal strategies for the Hanford waste addressed in this EIS and an implementation EIS intended to provide project specific environmental input for decisions on moving forward with certain disposal activities such as construction of the Hanford Waste Vitrification Plant (HWVP) and the Waste Receiving and Processing (WRAP) facility. Supplemental NEPA documentation such as an EIS for single-shell tank waste or other public review documentation, as appropriate, would be issued for agency and public review.

2.1 REFERENCES

Department of Energy (DOE). 1983. The Defense Waste Management Plan. DOE/DP-0015, Washington, D.C.

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CHAPTER 3.0

DESCRIPTION AND COMPARISON OF ALTERNATIVES

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3.0 DESCRIPTION AND COMPARISON OF ALTERNATIVES

Radioactive wastes on the Hanford Site have been generated since 1944 as part of the program required to support national defense activities. Technology for processing nuclear fuel has changed markedly during this period, and waste management guidelines and practices have also changed. This long time period and these changes are reflected in the large amounts and varied nature of high-level, transuranic (TRU) and tank wastes currently stored at Hanford.

The present status, with a variety of types and locations of high-level, TRU and suspected TRU wastes, developed during the formative years of nuclear technology. Waste is contained in underground storage tanks, capsules of purified strontium and cesium, sites where liquid waste was discharged to the soil, buried solid waste sites, and stored solid waste sites. Current programs at Hanford result in generation of waste from the PUREX[a] Plant and other operating facilities.

In 1977, the Energy Research and Development Administration (ERDA) issued the report Alternatives for Long-Term Management of Defense High-Level Radioactive Waste (ERDA-77-44), which included preliminary cost estimates and an analysis of near-term risks associated with those alternatives. That document examined 27 variations on 4 plans for the processing and disposal of Hanford high-level waste, encompassing numerous final waste forms and storage and disposal modes. As explained in Section 3.3.7, not all of these plans were examined in detail. The disposal alternatives described in this environmental impact statement (EIS), are based principally on the Defense Waste Management Plan (DOE/DP-0015, DOE 1983b) prepared by DOE, and submitted by the President to the Chairmen of the House and Senate Arms Services Committees on June 16, 1983, pursuant to the Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1982, Public Law 97-90. These alternatives are believed to bound the range of reasonable strategies and the consequences of their implementation for disposing of Hanford defense wastes. Alternatives that were considered but not selected for detailed analysis are discussed only briefly.

This chapter is divided into four major sections. The first section provides the background of waste generation at Hanford. The second describes the six major classes of wastes, the waste sites and their estimated inventories. The third section describes the three disposal alternatives and the no disposal action alternative (continued storage) described in the draft EIS and also describes the preferred alternative, derived from those disposal alternatives after review of agency and public comments on the draft EIS, and in response to those comments. The fourth section compares the disposal alternatives and the no disposal action alternative with respect to operational and postdisposal impacts and costs.

(a) PUREX: Plutonium URanium EXtraction.

3.1 BACKGROUND OF WASTE GENERATION

Generation of radioactive waste at Hanford began in December 1944 when plutonium from the Hanford production reactors was first recovered by processing irradiated uranium in chemical processing plants. Recovery of plutonium for use in fabrication of nuclear weapons and in other national defense activities continued through 1972. At that time the backlog of spent fuel from shutdown Hanford production reactors had been processed and the PUREX Plant was placed in standby condition. The PUREX Plant was reactivated in November 1983 and is presently processing a backlog of spent fuel from operation since 1972 of N Reactor (the dual-purpose reactor that has produced steam for electricity generation as well as plutonium for defense and research purposes); it will also process fuel from current N Reactor operation and perhaps from other DOE sources such as fuel from the Fast Flux Test Facility (FFTF) and blankets from the Shippingport reactor.

The processes by which plutonium and uranium were obtained from the reactor fuel and the disposition of the resulting waste have previously been reviewed (ERDA 1975) and are described briefly below.

3.1.1 Bismuth Phosphate Separations Process (B and T Plants)

Early in Hanford operation, the B and T Plants separated plutonium from uranium and the bulk of the fission products in irradiated fuel by co-precipitation with bismuth phosphate ($BiPO_4$) from a uranyl nitrate solution. The plutonium was then further separated from fission products by successive precipitation cycles using bismuth phosphate and lanthanum fluoride (LaF_3). The plutonium was isolated as a peroxide and, after dissolving in nitric acid, was concentrated as plutonium nitrate.

Waste containing the uranium from which the plutonium had been separated was made alkaline (neutralized) and stored in underground single-shell tanks. Other acid waste (which included much of the fission products) generated by this process was neutralized and stored in other single-shell tanks. The specific volume of neutralized waste stored in single-shell tanks was large, up to 40 m^3/t of irradiated uranium processed. B Plant was constructed between August 1943 and February 1945 and was operated until 1952. T Plant was constructed between June 1943 and October 1944 and operated until 1956.

3.1.2 Uranium Recovery Process (U Plant)

Uranium in waste from the $BiPO_4$ process was first stored in single-shell tanks. Later it was mined by sluicing, dissolved in nitric acid, and processed through a solvent extraction process using a solvent consisting of tributyl phosphate (TBP) in kerosene. The process was similar to that used later in the PUREX process (see below) except that plutonium was not recovered. The acid waste from the uranium recovery process was made alkaline and returned to single-shell tanks. The recovery process, which operated from 1952 to 1958, resulted in an increase in nonradioactive salts and a small increase in waste volume.

U Plant was originally built as one of three bismuth phosphate process facilities, but it was not used for that purpose. It was extensively modified and used for the uranium

recovery process described above. The main canyon is used for storage of failed equipment. Another nearby building is currently used in reducing liquid uranium nitrate to powdered uranium oxide.

3.1.3 REDOX Process (S Plant)

The REDOX[a] process was the first process to recover both plutonium and uranium. It used a continuous solvent extraction process to extract plutonium and uranium from dissolved fuel into a methyl isobutyl ketone (hexone) solvent. The slightly acidic waste stream contained the fission products and large quantities of aluminum nitrate that were used to promote the extraction of plutonium and uranium. This waste was neutralized and stored in single-shell tanks. The volume of high-level waste (HLW) from this process was much smaller than that from the $BiPO_4$ process, but larger than that from the PUREX process (see the next section).

The REDOX Plant was built between May 1950 and August 1951 and operated until July 1967.

3.1.4 PUREX Process (A Plant)

The PUREX process is an advanced solvent extraction process that uses a tributyl phosphate in kerosene solvent for recovering uranium and plutonium from nitric acid solutions of irradiated uranium. It is the process generally used worldwide for recovering uranium and plutonium. Nitric acid is used instead of metallic nitrates (e.g., aluminum nitrate) to promote the extraction of uranium and plutonium from an aqueous phase to an organic phase. Most of the nitric acid in the waste is recovered by distillation and reused. The waste, containing residual nitric acid, is neutralized and stored in underground tanks. Initially, single-shell tanks were used for this purpose. New tanks are double-shell and will be used for storing future PUREX Plant waste. The volume of HLW per unit amount of fuel processed by the PUREX process is small compared to that from earlier processes.

The PUREX Plant was built between April 1953 and October 1955 and then operated until 1972. It began operating again in November 1983.

3.1.5 Thorex Process

Special processing campaigns in the PUREX Plant recovered ^{233}U (a fissionable isotope of uranium) from thorium irradiated in the Hanford reactors. The thorium also was extracted and partially decontaminated. The waste composition was similar to that from the PUREX process except that it contained small quantities of thorium and ^{233}U instead of uranium and plutonium. Two campaigns were conducted between 1966 and 1971.

3.1.6 Plutonium Recovery and Finishing Operations (Z Plant)

This facility, now called the Plutonium Finishing Plant (PFP), began operations in late 1949 to process plutonium and prepare plutonium products. (Before 1949, all plutonium nitrate solutions had been shipped off site for further processing.) Waste from this plant contained only minor amounts of fission products but did contain low concentrations of

(a) REDOX: REDuction and OXidation extraction process.

plutonium and other transuranic elements, and was high in metallic nitrates. Initially this waste was discharged via cribs to soil columns, which sorbed the TRU elements and retained them close to the point of discharge. Later waste from Z Plant was stored along with other waste in underground tanks.

3.1.7 Waste Fractionation Plant (B Plant)

The radionuclides ^{90}Sr and ^{137}Cs and their decay products are the major sources of heat in Hanford high-level waste (HLW) after about 5 years' decay (ERDA 1975). Some of the strontium and cesium fission products were removed (fractionated) from the waste and separately isolated to reduce the heat generation in the tanks. B Plant, one of the original $BiPO_4$ process facilities, was modified in 1968 to permit removal of these fission products by a combination of precipitation, solvent extraction and ion exchange steps. The residual acid waste from the processing was neutralized and stored in single-shell tanks.

3.1.8 Waste Encapsulation and Storage Facility (WESF)

This facility converted solutions of strontium and cesium nitrates recovered at B Plant to strontium fluoride and cesium chloride solids that are doubly encapsulated in metal and stored in a water basin. Although these materials have potential beneficial use as heat and/or irradiation sources, they are considered, solely for purposes of this EIS, to be waste requiring disposal. That is, in the event of commercial use of these sources, they would at the end of their useful life be considered as wastes and would require disposal. This facility began operations in 1974.

3.1.9 Past Waste Management Experience

As a result of the several plutonium recovery processes used at Hanford and past practices in the management of tank waste, the chemical and radionuclide compositions of existing individual tank contents are quite varied. Volumes and compositions were strongly dependent upon the separations process used in generating the waste, as noted above. Methods for treating the waste in the tanks have had major impacts on the compositions of tank contents. These treatment methods have included:

- in-tank scavenging of strontium and cesium by the precipitation of strontium phosphate and cesium ferrocyanide to reduce the concentration of ^{90}Sr and ^{137}Cs in supernatant liquids and disposal of the supernatant liquids as low-level waste (LLW)
- removal of ^{90}Sr and ^{137}Cs at B Plant to reduce in-tank heat generation and allow concentration of the remaining waste
- concentration of tank contents by evaporation of water to crystallize the waste as a salt cake.

Mixing of tank contents was caused by transfers of solutions and slurries among tanks and tank farms during the above treatments.

Disposal of liquid and solid wastes created TRU-contaminated sites that are being considered for enhanced protection within the scope of this EIS.

3.2 WASTE CLASSES, SITES AND INVENTORIES

In this analysis, each particular waste site at Hanford for which disposal or remedial action is under consideration has been assigned to one of six waste classes, so that wastes with similar characteristics are classed together. Characteristics of waste composition or contamination and treatment requirements were the major factors used in this classification. Table 3.1 summarizes the six waste classes, showing the number of sites, areas and volumes involved, and inventories of the major radioactive contaminants of interest. Fission product radioactivity is shown in Table 3.1 both with and without short-lived daughters (short-lived daughters are accounted for in impact calculations). The engineering data in this section were obtained primarily from engineering support data provided by Rockwell Hanford Operations (Rockwell 1985, 1987)[a] Brief descriptions of each waste class follow. More detailed information, including that for chemicals, is contained in Appendix A.

The numerical information on waste inventories is the most accurate data available based on historical records. The basis for all inventories was the report by Rockwell (1985) wherein the rough, overall estimate of data accuracy is +50% to -30% and is believed to be adequate for generic waste class descriptions. Future characterization of wastes will be necessary to provide more detail, and in some cases is already under way (Rockwell 1987).

3.2.1 Existing Tank Waste

Existing tank waste includes all waste in underground storage tanks on the Hanford Site at the time the PUREX Plant resumed operations in November 1983. Most of this waste is in the form of salt cake, sludge,[b] and nonpumpable liquids currently stored in 12 tank farms (each considered a single site) containing a total of 149 tanks with single-shell[c] construction. For calculation purposes, it was assumed that residual liquids and slurries are contained in 14 newer tanks of double-shell construction. Fourteen double-shell tanks are also assumed for future waste storage.

Single-shell tanks contain various combinations of sludge, salt cake, and nonpumpable liquids. Present practice is to remove liquid (solution or slurry) waste from single-shell tanks to the extent practicable, and store it as a concentrate in double-shell tanks. However, due to a combination of physical properties (permeability, porosity, and capillarity), some liquids would remain in single-shell tanks that could not be removed by current pumping techniques. This residual moisture should not exceed 5% of the tank volume and is not

(a) Current inventories are available in the Integrated Data Base Report for 1987 (DOE 1987a).
(b) Sludge refers to the solids that precipitate when acidic liquid waste is neutralized. Salt cake is a damp solid formed by evaporation of the liquid that remains after the sludge settles out.
(c) Single-shell tanks are carbon-steel-lined concrete tanks. Double-shell tanks have a concrete shell and two carbon-steel liners with an annulus between the liners; this system provides for secondary containment and leak detection.

TABLE 3.1. Summary of Waste Classes

Waste Class	Number of Sites	Area, m^2	Volume, m^3	Mass, t	Quantity of Radioactive Materials[a] TRU, g	TRU, Ci	Fission[b] Products, Ci	Fission[c] Products, Ci
Existing Tank Waste[d]								
Single-shell (149)	12[e]	5.5×10^4[f]	1.4×10^5	2.2×10^5[a]	4×10^5	6×10^4	5×10^7	1×10^8
Double-shell (14)	5[e]	5.8×10^3[f]	4.5×10^4	7.7×10^4[a]	5×10^4	2×10^4	2×10^7	(g)
Total	17	6.1×10^4	1.9×10^5	3.0×10^5	5×10^5	7×10^4	7×10^7	
Future Tank Waste (14)	6[e]	5.8×10^3[f]	5.2×10^4	7.1×10^4[a]	2×10^5	3×10^5	2×10^8	4×10^8[g]
Strontium and Cesium Capsules	1	1×10^2	4.0	6.0	negligible	negligible	8×10^7	2×10^8
Retrievably Stored and Newly Generated TRU Waste	7	5×10^4	2.6×10^4	8.0×10^3	7×10^5	9×10^4	1×10^5	2×10^5
TRU-Contaminated Soil Sites	24	1.2×10^4	3.2×10^4	5.8×10^4	2×10^5	2×10^4	5×10^3	1×10^4
Pre-1970 Buried TRU Solid Waste	9	7.3×10^4	1.1×10^5	2.0×10^5	4×10^5	3×10^4	5×10^4	1×10^5
Total		2.6×10^5	4.1×10^5	6.3×10^5	2×10^6	5×10^5	4×10^8	7×10^8

(a) Listing by individual components is given in Appendix A. Decay calculated to 1995.
(b) Does not include activity of short-lived daughters in equilibrium with parent radionuclide. Short-lived daughters are accounted for in impact calculations.
(c) Includes activity of short-lived daughters. Current inventories are available in the Integrated Data Base for 1987 (DOE 1987a).
(d) Waste accumulated before November 1983.
(e) Number of tank farms. Some existing double-shell tanks (5 sites) as well as the recently constructed AP tank farm will be used for future wastes. Does not include recently planned AQ farm.
(f) Area cited is that of tanks alone.
(g) Double-shell tank waste includes all double-shell tank waste, both "existing" and "future."

expected to interfere with disposal operations. The need for drying of the residual solids is being considered as part of disposal operations (Appendix B).

Double-shell tanks contain residual liquids or slurries (called double-shell slurry). These include concentrated salt solutions that cannot efficiently be further concentrated using current operating facilities to produce a dried salt cake, and concentrates (called complex concentrates) containing soluble organic complexants. The double-shell tanks contain also a small amount of sludge. Because of fractionation and mixing, neither the single-shell nor the double-shell tanks contain waste typical of HLW as initially produced by the PUREX Plant.

Existing waste tanks will contain in 1995 about 70,000,000 Ci of the waste fission product and about 70,000 Ci (plus daughters) of TRU, including 400 kg of plutonium, in a total volume of 190,000 m^3. More details are given in Table 3.1 and in Appendix A.

3.2.2 Future Tank Waste

Operations since October 1983 to process spent fuel from the N Reactor and other potential DOE sources such as the Fast Flux Test Facility and the Shippingport Reactor will generate additional radioactive waste requiring disposal. Future waste stored (after November 1983) and to be stored in tanks will include the following:

- neutralized current acid waste (NCAW)--aqueous waste, resulting from the recovery of uranium and plutonium by solvent extraction, that has been neutralized by sodium hydroxide; it contains nearly all of the fission products processed through solvent extraction in the PUREX Plant
- cladding removal waste--the aqueous solution resulting from dissolution of the Zircaloy cladding from N Reactor fuel
- organic wash waste--waste from process solutions used to treat the solvent for recycle in the PUREX process
- miscellaneous sump waste--waste from the PUREX facility cells.

Of these, NCAW will be stored in double-shell tanks equipped with recirculators to permit storage of high-heat waste with a controlled rate of boiling. The cladding waste is neutralized with sodium hydroxide and stored in double-shell tanks. Organic wash solutions and miscellaneous sump wastes also are stored in double-shell tanks.

Waste from other Hanford facilities (e.g., N Reactor, Plutonium Finishing Plant) may be included in tank waste. As supernatant tank waste, this waste contains <100 nCi TRU/g, but after concentration in the tank farm the TRU concentration could exceed this value.

By the end of 1995, future tank waste is estimated to contain 300,000 Ci of TRU radionuclides and 200,000,000 Ci of fission products in a volume of 52,000 m^3. This waste, corresponding to the processing of 12,000 t of N Reactor fuel, is estimated to weigh 71,000 t and would be contained in about 14 double-shell tanks (Appendix A).

Extended Operations of Production Activities

As stated previously, future wastes for which disposal is considered in this EIS are future tank and newly generated TRU wastes expected to be produced in a reprocessing campaign, which began in November 1983 and is scheduled to end in 1996. About 12,000 t of irradiated uranium would be reprocessed, plus minor amounts (by comparison) of other materials as noted above. Any additional production of special nuclear material for defense programs would be in response to national defense or research and development needs. To account for the potential extension of production activities, the impacts of an additional assumed quantity of waste have been evaluated. It is assumed that this extension of special nuclear materials production activities would result in the reprocessing of an additional 20,000 t of irradiated uranium. Therefore, the impacts from this extended operation would approximate twice those that are calculated for the 1983-1995 campaign and are compared among the alternatives in this EIS in Section 3.4.3. The impacts from the 1983-1995 campaign have already been added to all tables in this EIS that present total impacts. For the extended production of special nuclear materials beyond 1995, the exposure and health impacts stated in Section 3.4.3 should be multiplied by two and added to all tables that present total impacts.

3.2.3 Strontium and Cesium Capsules

In 1972, activities began in the waste fractionation facility (B Plant) to remove and encapsulate the high-heat-generating isotopes ^{90}Sr and ^{137}Cs from the single-shell tank waste to permit solidification of waste in the single-shell tanks. These isotopes are currently contained in doubly encapsulated stainless steel or Hastelloy® capsules as SrF_2 and CsCl. There are no plans at present to separate strontium or cesium from future PUREX Plant waste; cesium would, however, be separated in the in-place stabilization and disposal alternative as described in Section 3.3.2.2. Some capsules may be removed from Hanford temporarily for beneficial uses (heat or radiation sources), but are likely to be returned to Hanford for disposal.

As of December 1985, approximately 40,000,000 Ci of ^{90}Sr and 70,000,000 Ci of ^{137}Cs (plus daughters) were contained in capsules stored in water basins adjacent to B Plant.

3.2.4 Retrievably Stored and Newly Generated TRU Waste

Since May 1970, solid waste classed as or suspected of being TRU waste has been packaged, labeled, and stored so as to be retrievable for at least 20 years. In 1973, the official level for segregation and storage became 10 nCi TRU/g of waste. Recently, however, the basis for classification as TRU waste was established as 100 nCi TRU/g.(a) Thus, some of the

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(a) Segregation and containment of material known or suspected to be contaminated with transuranic nuclides followed by 20-year retrievable storage were called for by Immediate Action Directive 0511-21 dated March 20, 1970, and applied to waste generated after April 30, 1970. Interim guidance promulgated that material contaminated to 10 nCi/g or more of transuranic nuclides should be placed in storage. This guidance appeared in AEC Manual Chapter 0511, September 19, 1973. TRU waste is now defined as those materials contaminated to 100 nCi of transuranic nuclides per gram of waste (DOE 1984).

waste now stored with TRU waste may actually be classed as low-level waste (LLW). Waste packages with surface exposure rates of 200 mR/hr or less are referred to as contact-handled; packages exceeding that value are referred to as remote-handled TRU. Most contact-handled waste is in 55-gal drums, but some is contained in large boxes constructed of steel, fiberglass-reinforced plywood, or concrete.

Some small items of TRU waste also contain high concentrations of fission products and generate dose rates exceeding 200 mR/hr. These require remote handling and have been packaged in 1-gal and 5-gal metal containers and stored in underground caissons.

Newly generated TRU solid waste from PUREX Plant operations and from other locations both on site and off site is included within this class, since its storage and disposal will be similar to that for the waste already retrievably stored. Some of it will be stored above grade in a retired plutonium storage vault.

Five sites covering a total surface area of 25,000 m^2 (Appendix A) have been used for retrievably storing TRU waste. Through the end of FY 1983, about 31,000 metal drums and 521 boxes of varying sizes containing 60,000 Ci of TRU elements (including 330 kg of plutonium), in a total volume of 12,900 m^3, have been stored. The total mass of waste is estimated to be 4,000 t. Projected newly generated TRU solid waste is expected to add an additional volume of 12,000 m^3 containing 33,000 Ci of TRU waste.

3.2.5 TRU-Contaminated Soil Sites

A TRU-contaminated soil site is one to which liquids (usually aqueous solutions classified as LLW at the time) have been released to soil. For purposes of this EIS, it is defined as a site at which the average concentration of TRU in the potentially contaminated soil volume at the site is estimated to exceed 100 nCi TRU/g (based on a soil density of 1.8 g/cm^3) or as a site that has received more than 80 g of plutonium per 100 m^2. This definition is based on characterization data that shows the TRU concentration to decrease rapidly at increasing depth because of the high adsorption characteristics of Hanford soils.

Waste in these sites is considered to have been disposed of; the sites are, however, being considered in this EIS because DOE is reviewing whether further action is warranted in terms of environmental protection.

There are 24 TRU-contaminated soil sites (Appendix A) covering a total surface area of 12,000 m^2 with an estimated total of 20,000 Ci of TRU (including 190 kg of plutonium) in 32,000 m^3 of contaminated soil. These sites consist of cribs, trenches, ponds, ditches, reverse wells, French drains, settling tanks and one unplanned release. The total mass of the contaminated soil is estimated to be 58,000 t.

3.2.6 Pre-1970 Buried Suspect TRU-Contaminated Solid Waste

Between 1944 and 1970, all solid waste (bulk quantities of trash, failed equipment, and laboratory and process waste contaminated with small amounts of TRU elements) was referred to as LLW and was routinely placed in designated shallow-land burial trenches at Hanford. Depending upon its source, the buried waste was contained in cardboard boxes, 55-gal steel drums, concrete burial vaults, or other containers. It was covered with about 1 m of soil to

reduce surface radiation levels and to provide protection from wind erosion, plant roots, and burrowing animals. Wastes with a surface dose rate above 200 mR/hr were placed in underground structures called caissons. Pre-1970 buried suspect TRU solid waste sites are like the above-described TRU-contaminated soil sites in that they are considered to have been disposed of but are being reviewed to determine whether further action is warranted in terms of environmental protection.

For this EIS a solid waste disposal site is defined as a TRU waste site if the concentration of TRU in some of the waste containers exceeds 100 nCi/g, averaged over the container volume. In those instances where only the total TRU content in the site is known, the peak container concentrations are assumed to exceed 100 nCi/g when the average TRU concentration in the site exceeds 10 nCi/g.

In the draft EIS, it was stated that the Hanford Site had 11 pre-1970 buried suspect TRU-contaminated solid waste sites. Review of waste site inventories revealed that two sites, 618-1 and 618-2, did not contain enough TRU material to qualify as TRU waste sites; thus, there are nine such sites at Hanford. These sites cover a total area of 73,000 m^2 (Appendix A). These sites contain an estimated 33,000 Ci of TRU (including 350 kg of plutonium) in a volume of about 110,000 m^3 of waste plus soil amounting to about 200,000 t of waste.

3.2.7 Chemicals Associated with High-Level, Transuranic and Tank Waste

Virtually all radioactive waste substances yielded in the process of producing or utilizing special nuclear material are contained, dissolved or suspended in nonradioactive chemical media. Considerable interest was expressed during review of the draft EIS for additional information regarding the existence, disposal and impacts from chemicals in Hanford radioactive defense waste. Moreover, concerns were expressed since some chemicals have been reported as having reached groundwater. The presence of nitrate and carbon tetrachloride as well as other chemicals in groundwater is addressed in Section 4.4.2.2.

3.2.7.1 Inventories of Chemicals

In the past, the main emphasis has been on tracking the radioactive components of waste and assessing their potential environmental impacts. It has been within just the last few years that the fate and impacts of chemicals have gained widespread interest. As a consequence, characterization of chemicals that are intermixed with the high-level, transuranic and tank wastes is somewhat behind that of radioactive species at the Hanford Site. Currently known inventories of chemicals in existing tank waste and projected inventories of chemicals in future tank waste are given in Tables A.3 and A.8, respectively. In addition, more-recent information on organic chemicals in neutralized cladding removal waste and double-shell slurry waste and in organic complexant waste is given in Tables A.6 and A.7, respectively. Quantitative chemical characterization for the four other waste classes has not been developed.

Additional efforts to further characterize chemicals in all waste classes are planned under ongoing programs and as a part of the development and evaluation work identified under

the preferred alternative discussed in Section 3.3.5. Hazardous-chemical disposal is discussed with respect to the preferred alternative in Section 3.4.6.

3.2.7.2 Management and Disposal of Chemical Wastes

Waste management and disposal practices for chemical wastes that will achieve compliance with applicable regulations for nonradioactive and mixed radioactive wastes will be addressed in the Hazardous Waste Management Plan (in preparation; 1988 publication planned). That plan will consider those federal regulations established pursuant to the Resource Conservation and Recovery Act and the Hazardous and Solid Waste Amendments of 1984. State regulations included are the Washington Dangerous Waste Regulations, established pursuant to the Washington Hazardous Waste Management Act of 1976.

The plan will entail a seven-step process: 1) establish regulatory criteria, 2) assess facilities and operations against these criteria, 3) identify areas of noncompliance, 4) identify necessary measures to correct noncompliance, 5) implement the identified measures, 6) ensure that compliance has been attained, and 7) establish measures to maintain compliance.

3.3 DISPOSAL OR MANAGEMENT ALTERNATIVES

The three disposal or enhanced protection alternatives initially selected for detailed analysis are the following:

- **Geologic Disposal**--Most (98% by activity) of the waste within the scope of this EIS would be retrieved (to the extent practicable) and processed, with some packaged and transported for disposal in either an onsite or offsite geologic repository. The remainder would be disposed of on site and isolated with a protective barrier and marker system.
- **In-Place Stabilization and Disposal**--Double-shell tank waste would be retrieved and grouted in near-surface vaults. Transuranic and single-shell tank wastes would be stabilized in their existing locations to the extent practicable and covered with a protective barrier and marker system (Appendix B). Encapsulated strontium and cesium would be retrieved from water basins, placed in an additional package, placed in a drywell storage facility, and isolated from the environment by a protective barrier and marker system.
- **Reference Alternative** (combination disposal)--Elements of the geologic disposal and in-place stabilization and disposal alternatives would be employed to provide a balanced disposal or enhanced protection approach that would give reasonable expectation that this alternative will limit risks to populations over the long term without incurring near-term risk due to disturbing wastes that are currently stable and difficult to retrieve. Readily retrievable waste would be processed for geologic disposal. Other waste would be disposed of in place. All wastes disposed of near surface would be isolated from the environment by a protective barrier and marker system.

A no disposal action alternative, which amounts to continued storage of the wastes, was also considered in detail. This alternative is not considered by DOE to be a viable long-term option based on current waste management policies, particularly in view of the large accumulated costs associated with maintaining the wastes in a storage mode for many centuries. The no disposal action alternative is analyzed in accord with Council on Environmental Quality (CEQ) regulations. In the short term (i.e., for periods less than 100 years), the no disposal action alternative can be considered as a "delay major action" alternative, after which time disposal alternatives could be considered. If DOE were to choose the no disposal action alternative, waste would remain as disposed of or continue to be stored indefinitely using existing storage practices with planned improvements to comply with RCRA and CERCLA requirements as applicable. Active administrative control would be provided. Federal ownership and presence on the Hanford Site is planned in perpetuity (but for comparative analyses in Chapter 5, loss of active institutional control is assumed to occur in the year 2150). It must be emphasized that this scenario was defined simply for comparing alternatives. Present disposal practices with active administrative control will not result in the impacts calculated for this scenario.

The preferred alternative was developed following agency and public review of the draft EIS and consists of a combination of the reference alternative for some classes of waste and a deferred decision for other classes of waste. Under this alternative, readily retrievable waste (double-shell tank waste, strontium and cesium capsules, and retrievably stored and newly generated TRU waste) would be processed for geologic and grout disposal, and other waste would be left in place until results of ongoing or planned development and evaluation are obtained.

Although it was recognized that disposal of single-shell tank waste, the pre-1970 buried suspect TRU-contaminated waste and TRU-contaminated soils is no less important than disposal of double-shell tank waste, capsules and retrievably stored TRU waste, consensus focused on proceeding with disposal of those wastes that could be most readily disposed of (particularly liquid waste) and deferring disposal judgment on the other wastes. There appeared to be no conflict between implementation of these disposal actions and any federal or state regulations.

It was also recognized that because the radioactive wastes in single-shell tanks have been reduced from liquid to sludge and semisolids, there is little threat from further leakages and no urgent need to effect disposal despite a large inventory of waste in those tanks. Similarly, the pre-1970 buried suspect TRU-contaminated solid waste and TRU-contaminated soil sites have remained stable and, again, there is no urgency for election of further remedial action. Moreover, application of RCRA and CERCLA to these latter classes of waste suggested the need for further characterization of the wastes (including chemicals) and review for compliance with applicable hazardous-waste regulations. After the ongoing or planned development and evaluation are completed in about 15 years, necessary NEPA documentation will be prepared for disposal of these remaining waste classes and a decision will be made as to implementation of their disposal. In the interim, DOE will continue the present storage and maintenance activities.

The following sections describe the implementation of each of the disposal alternatives and the no disposal action alternative for each of the waste classes (i.e., existing tank waste, future tank waste, strontium and cesium capsules, retrievably stored and newly generated TRU solid waste, TRU-contaminated soil sites, and pre-1970 buried TRU solid waste). Further details are provided in Appendix B.

In some cases, a proposed engineering method selected for analysis is representative; however, engineering design confirmation may be required in a number of cases. Examples of methods that might be applied for various process steps are radio-frequency drying to remove residual nonpumpable liquid from single-shell tanks, mechanical retrieval of waste from single-shell tanks, and heat removal by heat pipes. Other process steps that have a broad variety of options and would need to be optimized include onsite subsidence control and immobilization techniques for TRU wastes. One such option is in situ vitrification, in which the waste and surrounding soil would be converted to a highly durable glass material and left in place. (In situ vitrification could also facilitate waste removal if warranted.) Representative implementation methods were selected without attempting to optimize the details. Some changes from the implementation methods described in this EIS are likely as processes are optimized. However, the methods described are expected to bound the impacts of any optimized process. Results of ongoing and future research may provide additional enhancement of waste forms (e.g., glass and grout), and would be applied where appropriate.

An example of a selected engineering concept for which considerable latitude in final design details exists is the multilayer protective barrier and marker system proposed for all sites designated for such protection. The barrier is designed to discourage farming, root penetration, and animal burrowing; to minimize infiltration of water; and to enhance resistance to erosion. The surface and subsurface markers are intended to deter human intrusion. Several system designs are currently undergoing field tests, and in practice a range of designs might be employed on a site-specific basis. However, this conceptual system was chosen as a generic design, subject to future modification once results of field tests and consequences analyses are obtained (Appendices B and M).

The conceptual protective barrier used for purposes of analysis in this EIS would consist of a multilayer cover 5.4 m thick, the bottom portion of which would be a 3.6-m-thick layer of basalt riprap 12 to 25 cm in diameter. The riprap would be topped by a rock/gravel layer 0.3 m thick, which in turn would be covered by a 1.5-m-thick layer of fine-textured soil. The rock/gravel layer would be used to minimize the sifting of fine soil materials into the riprap below. The soil layer would be covered with native vegetation to remove water from the soil. A riprap-filled perimeter trench 1 m x 1 m would be used to control intrusion by burrowing animals.

The primary function of the layered design or capillary barrier is to reduce water infiltration into the waste. The coarse layer would act as a one-way check-valve system. Water from below could not be drawn to the surface because of the large rock texture. The fine-textured soil layer would act as a capillary barrier to downward flow. Subsurface markers would be distributed throughout the soil and riprap portions of the barrier to discourage

intrusion into the wastes. The performance of the protective barrier for wastes disposed of near surface is a key part of all the Hanford defense waste disposal alternatives discussed in this EIS.

Granite monoliths, about twice human size, placed around the site on the surface would denote the area within which the wastes are located. The faces of the surface markers would have warnings (in simple symbols and simple phrases) to alert anyone of the hazardous nature of the wastes.

Process methods and facilities for each alternative are described briefly in this section, but more detail is contained in Appendices B and M. Some process methods include chemical separation of selected radionuclides, which results in separation of nonradioactive components also. In general, nonradioactive metals (mercury, cadmium, chromium, etc.) are contained in the sludge layer of tank waste (Appendix A), and would remain with the sludge during the proposed chemical separations. Light alkali metals (sodium and potassium) together with most anions such as nitrate and nitrite ions would remain preferentially with the supernatant liquids during chemical separations.

Most process methods and facilities are described in Appendix B. Three major facilities for use with the reference, geologic and preferred alternatives have been developed in sufficient detail to facilitate quantification of impacts for construction, operation and decommissioning. These facilities are the Hanford Waste Vitrification Plant (HWVP), the Transportable Grout Facility (TGF), and the Waste Receiving and Processing (WRAP) facility. They are described in Appendices C, D and E, respectively.

3.3.1 The Geologic Disposal Alternative

The objective of the geologic disposal alternative is to remove from surface or near-surface storage or disposal on the Hanford Site essentially all (98% by activity) of the high-level/low-volume and TRU wastes (to the extent practicable) and place them in a deep repository for high-level waste and in WIPP for TRU waste. Disposal in a future onsite or offsite repository is considered in this alternative. The postulated onsite repository would be a mined basalt cavern approximately 900 m beneath the Hanford Site. For this EIS, the hypothetical offsite repository for tank waste is assumed to be about as deep but at a site about 5,000 km from Hanford to bound transportation impacts calculated for this alternative.

Waste would be retrieved from both single-shell and double-shell tanks and would be separated into a low-volume, high-level fraction that contained most of the fission products and TRU waste and a high-volume, low-activity fraction, containing the remainder. Geologic isolation of all retrieved waste was considered but rejected as impractical and unwarranted (Section 3.3.6). The high-level and TRU waste from tanks would be converted to a glass, packaged, and transported to a repository for disposal. The low-activity waste would be converted to a cementitious grout and disposed of on site.

Strontium and cesium currently in capsules would be put in a suitable form and sent to a repository for geologic disposal.

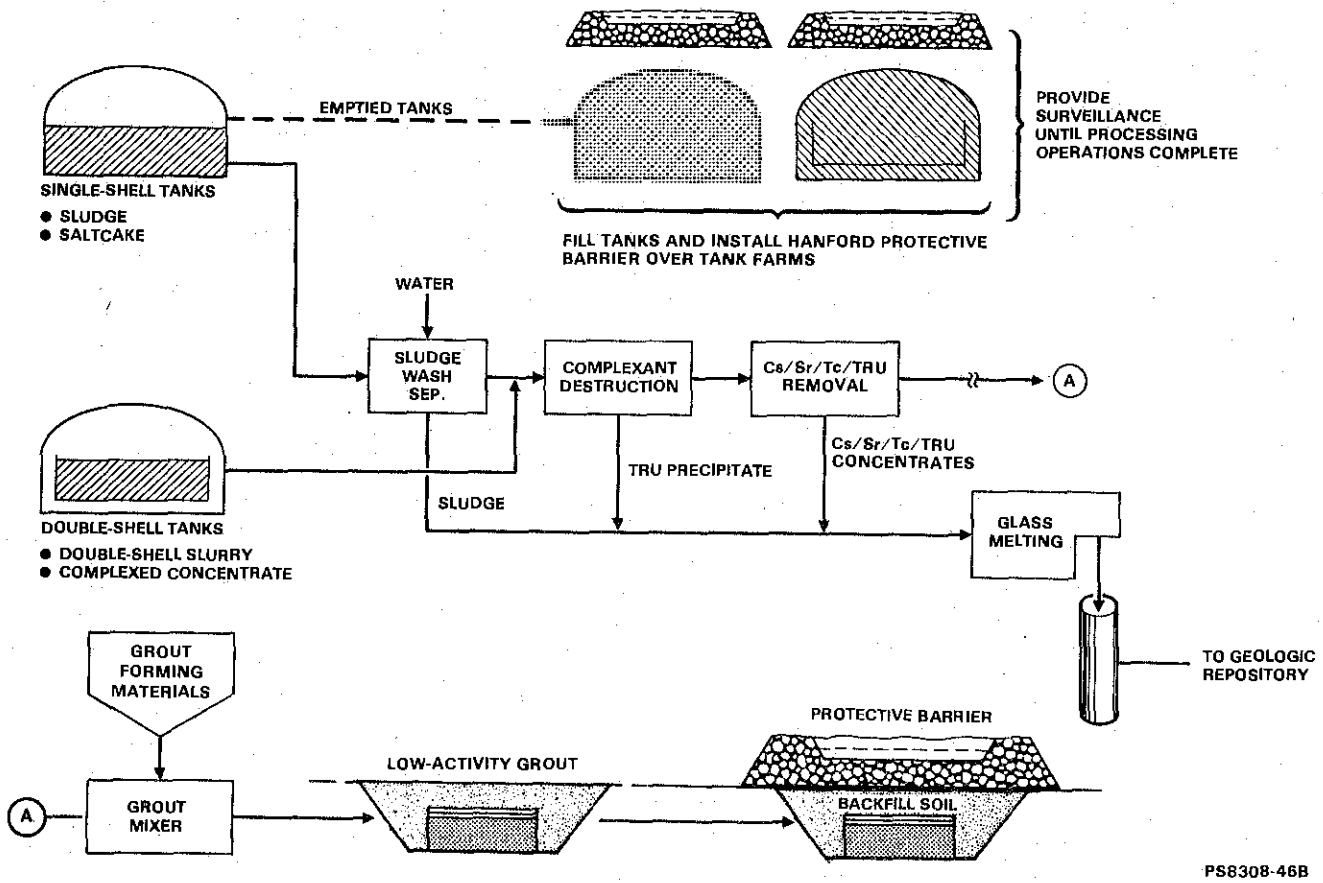

FIGURE 3.1. Schematic for the Geologic Disposal Alternative for Existing Tank Waste

Although the total amount of irradiated uranium processed and to be processed would amount to about 106,000 t, the commercial reactor equivalent (upon which the 70,000-t size of the first repository was based) would amount to about 3,100 equivalent metric tons of heavy-metal (eMTHM) fuel from a commercial reactor (DOE 1987b; see also Appendix S.1). Of the 3,100 MTU, approximately 1,000 MTU could be attributed to single-shell tank waste. This large difference comes about because of the short time during which defense fuel is in a reactor, compared to that for commercial fuel. Thus the defense waste described in this EIS, 3,100 eMTHM, could be accommodated in the first 70,000-t repository.

TRU-contaminated soil sites, pre-1970 buried solid TRU waste, and retrievably stored and newly generated TRU waste would be retrieved and converted to a stabilized form meeting repository acceptance criteria. In this analysis the stable form except for retrievably stored TRU is considered to be a slag, but other waste forms, such as cement-based grout, may be chosen later. Retrievable TRU waste may already be adequately stabilized or may be further stabilized by incorporation in cement, if required. The stabilized waste form would be packaged as solid transuranic waste to meet waste acceptance criteria and transported to a geologic repository (for calculation purposes assumed to be WIPP) for disposal.

Application of geologic disposal to each waste class is described briefly below. More details of process methods and facilities are given in Appendices B, C, D and E.

All defense waste to be disposed of in a civilian repository will meet repository acceptance criteria requirements, including those of NRC's 10 CFR Part 60, "Disposal of High-Level Wastes in Geologic Repositories," and performance requirements of EPA's 40 CFR Part 191, "Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes."

3.3.1.1 Geologic Disposal of Existing Tank Waste

As schematically shown in Figure 3.1, at least 95% of the salt, sludge, nonpumpable liquid and residual liquors would be mechanically retrieved from single-shell tanks, and 99.95% would be hydraulically sluiced from double-shell tanks. The fractions removed represent the most practicable available technology (Appendix B). The material removed would be transferred mechanically or hydraulically as appropriate to a processing facility. There it would be converted into two fractions: 1) a high-integrity solid (e.g., a glass) containing nearly all the radionuclides in a form suitable and acceptable for disposal in a geologic repository and 2) a decontaminated salt solution with residual radioactivity low enough for near-surface disposal after conversion to a cement-based grout. The tanks and their residual contents would be disposed of in place by filling with crushed rock, sand, soil, or grout to control subsidence and covered with a protective barrier to reduce potential for intrusion and infiltration of water into the waste. Piping and risers would be filled with grout to the extent practicable.

Removal of salt cake and sludge from single-shell tanks could be accomplished with a mobile mechanical retrieval system or other means. The waste tank contents would be excavated with an articulated mechanical arm, placed in an elevator bucket, and brought to the surface for loading into shielded shipping containers. The containers would be sealed and

placed on a trailer for transfer to an onsite radionuclide concentration facility currently planned to be B plant, where the contaminated waste volume would be reduced significantly.

A hydraulic system of sluicing and slurry pumping is proposed for retrieving the liquid slurry and sludge from double-shell tanks and transfer to the radionuclide concentration facility. Waste would be treated as required to destroy organic compounds.

In the radionuclide concentration facility, strontium, cesium, technetium, and TRU elements would be removed from soluble salts, combined with sludges and other streams containing high concentrations of fission products and TRU elements. This material would then be transferred to the HWVP and fed with glass-forming additives to a liquid-fed ceramic melter (LFCM) to produce a borosilicate glass waste form. One possible chemical separation system is described in Appendix B, but other chemical separations systems may be used if they are at least equally effective. For example, in an alternative processing step currently under development, recovered tank sludges would be dissolved in acid and treated by the Transuranic Extraction (TRUEX) solvent extraction process to remove transuranics. The small quantity of undissolved sludge that remains would be combined with the transuranics recovered by the TRUEX process. The transuranics, cesium, strontium and technetium recovered from the salt solution along with the transuranics and undissolved sludge from application of the TRUEX process would be sent to the melter in the HWVP. This alternative could result in a substantial reduction in the quantity of glass that must be made. The TRUEX process is a recent development in transuranics separation technology. Before a new process such as this would be implemented, impact calculations would be rerun, evaluated and compared to the bounding scenarios of this EIS to determine whether the impacts are significantly different from those presented in this EIS.

Borosilicate glass provides a waste form with properties of low dispersibility, low leachability, and high thermal stability (DOE 1982a,b; DOE 1983a). The glass product is further described in Appendix C. An estimated 19,800 canisters of glass would be produced, with a total volume of 12,300 m^3. Approximately 15,000 canisters would be attributed to single-shell tank waste.

Differences in the number of canisters containing glass will be seen between the reference or preferred alternatives and the geologic disposal alternative. This is due principally to large amounts of insoluble metal compounds (~5,000 t) in single-shell tank waste that reduces the efficiency of waste loading in glass in the geologic disposal alternative. In the reference alternative the waste containing this inventory of insoluble metal compounds is not processed into glass.

The plan for disposing of the decontaminated salt residuals is to incorporate them into 736,000 m^3 of cement-based grout in near-surface disposal vaults (covering about 25 ha) or partly in empty single- or double-shell tanks, with the balance disposed of in vaults, and covered with a protective barrier (see Appendix D).

The residual tank waste (less than 5% of initial quantities in single-shell tanks and less than 0.05% in double-shell tanks) and the tanks themselves would be disposed of in place. The single-shell and double-shell tanks, accessible pipes and risers, and the annulus

of double-shell tanks would be filled with grout, gravel, sand, soil, or other substances to control subsidence in the event of tank structural failure (dome collapse). This precaution would improve the stability of both the tank and barrier but would not constitute an impervious barrier.

Contaminated soil around and under tanks resulting from tank leaks in the past (ERDA 1975) would be left in place. The residues from leaks contain radioactivity equal to a small fraction of the 5% residual waste in single-shell tanks (ERDA 1975 Sections II.1.1.4.5 and III.2.2.2), and do not contain sufficient TRU to qualify as TRU-contaminated soil sites as defined in Section 3.2.5. Individual tanks or whole tank farms would be covered with a protective barrier.

Environmental impacts of removing the contents of all tanks are developed as above in the geologic disposal alternative, and the environmental impacts of leaving all in place are developed under the in-place stabilization and disposal alternative. Although it would be possible to develop impacts from selectively removing the contents of specific tanks, a clear basis for selection has not been established. That does not foreclose the option, after the completion of the tank characterization program, of developing a strategy of removing the contents of certain high-activity tanks and leaving the rest. The present analytical approach bounds the impacts by assuming that 1) essentially all of the tank contents would be removed, and 2) all contents would be left in place.

However, consideration was given to selectively removing portions of the TRU waste from single-shell tanks. Table 3.2 summarizes, as an example, the options in terms of projected TRU and number of tanks whose contents would be removed for geologic disposal (Rockwell 1987). Other tank selection criteria such as concentrations of hazardous chemicals or amounts of selected radionuclides other than TRU elements could be considered.

3.3.1.2 Geologic Disposal of Future Tank Waste

Most (by activity) future tank waste would be disposed of in a geologic repository. Figure 3.2 shows the conceptual processing scheme that would be used for geologic disposal of high-level and some transuranic fractions from future tank waste. The high-level waste (HLW) would be stored in double-shell tanks equipped to handle high-heat waste until a vitrification facility would be available in about 1995. The HLW would be retrieved and the solid and liquid fractions of the waste would be separated. The large inventories of strontium and cesium, the long-lived radionuclide technetium, and transuranic elements would be removed from the liquid fraction. New processes such as the TRUEX process described in Section 3.3.1.1 may also be applied to future tank waste. The separated radionuclides and the solid fraction of the waste would be vitrified and placed in 3,310 canisters with a total volume of 2,050 m^3 of glass for disposal in a deep geologic repository. Some other radionuclides would accompany the separated radionuclides, but ^{14}C and ^{129}I would remain in the liquid phase and go to grout.

The partially decontaminated liquid would be converted to grout, along with low-activity waste components of cladding waste, customer waste, and miscellaneous process waste. About

TABLE 3.2. Example of Selective Retrieval of Single-Shell Tank Contents (Rockwell 1987)

Case 1: Retrieval Based on Projected TRU Concentration

TRU Concentration (nCi/g) Used as Cutoff	Contents Retrieved: Number of Tanks
Geologic Alternative	149
100	78
200	61
500	29
1,000	15
Reference Alternative	0

Case 2: Retrieval Based on Total Projected TRU Inventory Removed

Percent of Total TRU Removed	Contents Retrieved: Number of Tanks
Reference Alternative	0
15%	1
20%	2
35%	5
50%	10
60%	17
70%	25
80%	33
90%	63
Geologic Alternative	149

99,000 m^3 of grout would be disposed of in near-surface disposal vaults covered with a protective barrier which would require about 3 ha.

The purpose of the Transportable Grout Facility (TGF) is to make a grouted waste form of wastes that would be classified as Class C waste according to 10 CFR 61. (These wastes would be designated for disposal in near-surface disposal sites located in the 200 East Area.) A grouted slurry would be formed by blending low-activity liquid wastes with grout-forming solids. The grout slurry would be pumped into disposal vaults where it would solidify into large monoliths.

The grout process would involve two facilities: 1) the Dry Materials Receiving and Handling Facility (DMRHF), where the grout-forming solids would be blended, and 2) the Transportable Grout Equipment (TGE) modules, where the blended solids would be mixed with liquid waste and the resulting slurry pumped to the disposal site. An existing 3,800 m^3 underground waste storage tank would be assigned to serve as the liquid feed tank for the grout process.

The Dry Materials Receiving and Handling Facility includes fixed equipment for storing and blending grout-forming solids such as Portland cement, blast furnace slag, fly-ash (waste product from coal-burning power plants), and clays. Equipment associated with the facility would include: railcar unloading station, storage silos, solids conveyers, solids blending system, and truck loading station. The DMRHF would be operated in a nonradioactive mode. Trucks would transport the blended grout-forming solids from the facility to the TGF.

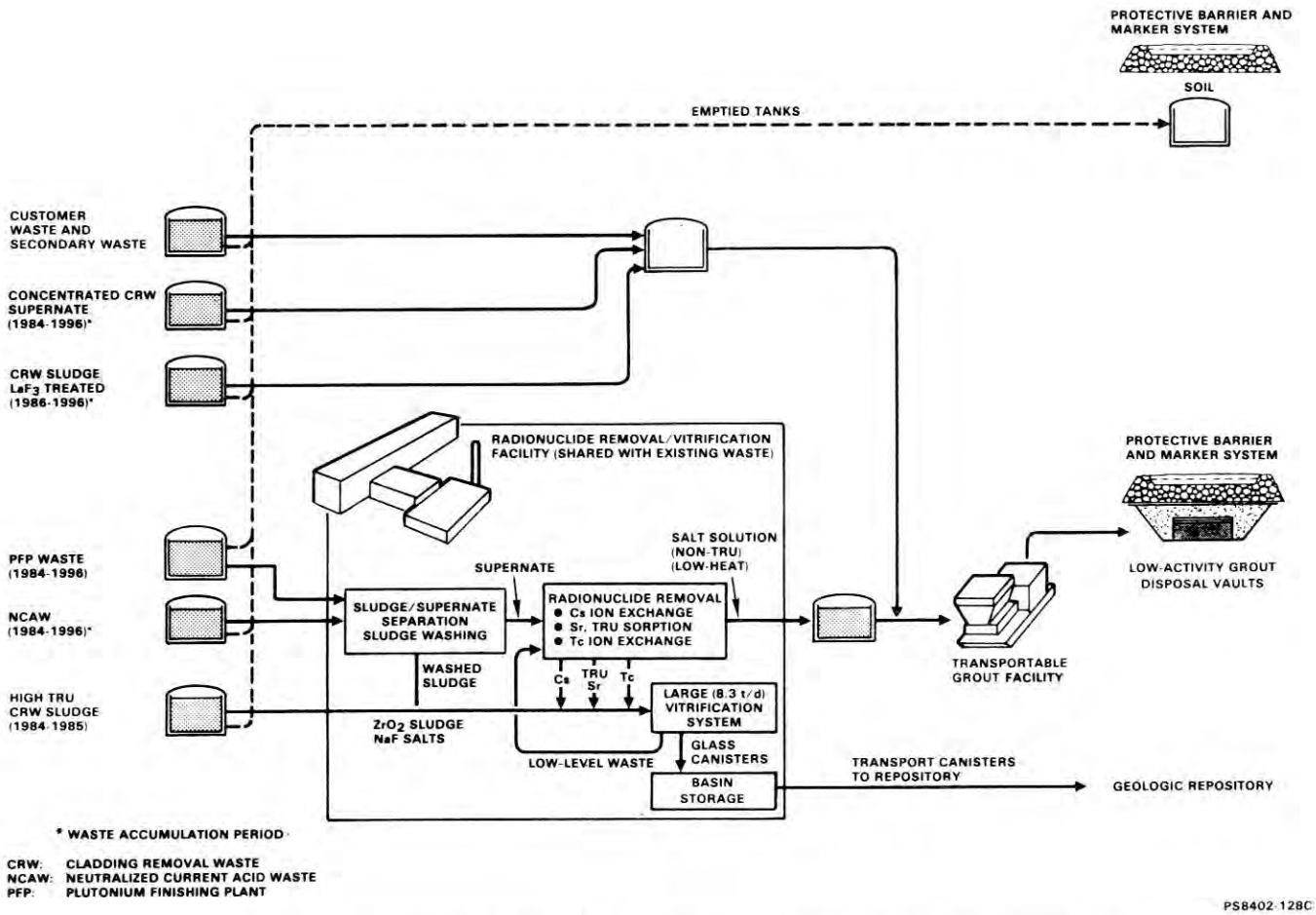

FIGURE 3.2. Schematic of the Geologic Disposal Alternative for Future Tank Waste

The transportable grout equipment would consist of modules that would mix blended solids with liquid wastes from current and future operations. The resulting slurry would then be pumped into the disposal sites. The system of modules would produce grout slurries safely and efficiently. The equipment would include: blended solids feed system, grout mixing and pumping system, off-gas exhausters and filters, tanks for additives and decontamination solutions, standby electric generators, and a control room.

Appendix D describes the facilities currently planned to be used for conversion of designated wastes into grout. Topics addressed in the appendix include: the facilities, their relationship to other Hanford facilities, the grouting process, waste feedstreams, resource needs, nonradiological emissions, radiological impacts, and cost.

Processing of future tank waste would be integrated with processing the large volume of existing waste to be treated and vitrified. The combined processing would require a large sludge-liquid separation and radionuclide removal facility, a vitrification facility (Appendix B), as well as the grout facility (see Appendix D). Vitrified waste would be shipped by rail or truck to an offsite repository or an onsite repository.

3.3.1.3 Geologic Disposal of Strontium and Cesium Capsules

The geologic disposal alternative would provide for continued storage of the strontium and cesium capsules in water basins until a repository becomes available. For the purpose of evaluation of impacts for this EIS, it was assumed that the strontium and cesium would be packaged in accordance with repository waste acceptance specifications and shipped to a commercial repository. An estimated total of about 509 canisters would be shipped for disposal. In actuality all of the cesium and some of the strontium is already committed to beneficial uses. It is planned, though, that this material will be eventually returned for disposal.

3.3.1.4 Geologic Disposal of Retrievably Stored and Newly Generated TRU Waste

All retrievably stored and newly generated TRU waste would be sent to WIPP for disposal. Any retrieved waste having a concentration of less than 100 nCi TRU/g would be classified as LLW and would be disposed of as such on site.

The current inventory of retrievably stored contact-handled TRU waste (exposure rates of less than 200 mR/hr) would be removed and transferred to a Waste Receiving and Processing (WRAP) facility. The facility is conceptually designed to support inspection and certification of contact-handled TRU waste for repository disposal. Processing and packaging capabilities for contact-handled TRU waste in 20-year retrievable storage will also be provided in the facility. All TRU waste must be inspected and certified to meet the Waste Isolation Pilot Plant (WIPP) Waste Acceptance Criteria (Westinghouse 1985). Accordingly, TRU waste generated after 1985 has been packaged and documented to be certifiable. In estimating process costs, emissions, and volumes of waste, it is projected that 45% of all retrievably stored contact-handled TRU waste would not be classified as TRU waste after the TRU waste content of each waste package is determined. The projected 45% of waste to be reclassified

is based on engineering judgment and historical records, and reflects the change in definition of TRU waste limits from 10 nCi/g to 100 nCi/g (DOE 1984).

The waste processes being considered include waste package inspection, assaying, repackaging, size reduction, sorting, shredding, and waste immobilization in cement. Incineration will be implemented as an additional process step between shredding and grouting if deemed appropriate. A conceptual process flow diagram for the Waste Receiving and Processing facility uses a shredding process without incineration.

The Waste Receiving and Processing facility is assumed for calculation purposes to be constructed in the 200 West Area during the 1990-1993 time frame. Operations are expected to begin in 1999 and to continue for about 20 years. The operational period required for handling newly generated TRU is dependent on future activities at Hanford. For this EIS, it was assumed that all retrievably stored and newly generated TRU waste (generated through 1996) will be processed between 1994 and the year 2005 (Rockwell 1985).

Appendix E describes the Waste Receiving and Processing facility, the waste treatment and packaging processes, the flow of materials through the facility and the associated waste feedstreams. It also summarizes the resource requirements, emissions, radiological impacts, and costs associated with the construction, operation, and decontamination and decommissioning of the facility.

Remotely handled TRU waste (exposure rates equal to or exceeding 200 mR/hr) in caissons would be mechanically removed using an airtight, double-shelled metal structure installed over the caissons. The remotely handled TRU waste would be placed in a cask and transferred by truck to the waste processing facility. There it would be processed with waste from TRU-contaminated soil sites and pre-1970 buried waste. Built as part of the geologic disposal alternative for this purpose, this waste processing facility would begin operation in about 1996. (See Appendix B for details.)

Until about 1994, newly generated TRU waste would be retrievably stored on pads or in buildings. Newly generated TRU waste would be retrieved and processed in the same manner as the existing retrievable TRU solid waste. After 1994 (when the Waste Receiving and Processing facility would begin operation), all contact-handled TRU waste would be processed directly in the facility and packaged to meet WIPP waste acceptance criteria.

3.3.1.5 Geologic Disposal of Previously Disposed-of TRU-Contaminated Soil Sites

Contaminated soil containing an average concentration of more than 100 nCi/g TRU would be retrieved until the TRU concentration in the residual soil would be less than 100 nCi/g. All removed material would be treated in a waste processing facility, packaged, and certified for transport to, and acceptance at, a geologic repository (assumed for calculation purposes to be WIPP). The waste product assumed allocated for cost estimation purposes to TRU-contaminated soil sites would be 13,000 m^3 of a slag, weighing about 36,000 t (reduction from 32,000 m^3). Excavated areas would be filled with clean soil, and all areas would then be maintained as LLW burial grounds. (See Appendix B for details of processing methods.)

3.3.1.6 Geologic Disposal of Previously Disposed-of Pre-1970 Buried Suspect TRU-Contaminated Solid Waste

Pre-1970 buried TRU solid waste and the surrounding contaminated soil that is defined as TRU waste would be retrieved and processed for enhanced protection in a geologic repository (assumed to be WIPP for calculation purposes). Retrieval procedures would be similar to those proposed for use at TRU-contaminated soil sites (see Appendix B). Retrieved waste (exceeding 100 nCi TRU/g) would be processed in the waste processing facility, certified as meeting WIPP waste acceptance criteria (Westinghouse 1985), and sent to WIPP. The final waste form was assumed to be a slag occupying about 45,000 m^3 (reduced from 110,000 m^3) and weighing about 130,000 t.

Residual waste (i.e., containing <100 nCi TRU/g) would be retained in the original, excavated burial site. The site would be backfilled and stabilized in the same manner as any other LLW site.

3.3.2 In-Place Stabilization and Disposal

The objective of the in-place stabilization and disposal alternative is to immobilize and stabilize all high-level, transuranic and tank wastes at Hanford and to dispose of the waste or provide enhanced protection by isolation from ecosystems using a protective barrier and marker system.

There would be very little processing or treatment of wastes except for those stored in double-shell tanks. Wastes in single-shell tanks would be dried and the tanks filled with suitable material to limit future subsidence and provided with interim systems for heat removal as needed. Strontium and cesium capsules would be placed in canisters for ease of handling and transferred to near-surface drywells for disposal. Retrievably stored or newly generated solid TRU waste would not be removed from its predisposal location. Wastes in TRU-contaminated sites, soil sites, and pre-1970 solid waste sites are already disposed of, but they would be further protected by the addition of the protective barrier and marker system.

The largest amount of processing would occur with waste stored in double-shell tanks. This waste would be processed for cesium recovery to remove a significant heat source that would otherwise constrain grout disposal options, the cesium would be encapsulated, and the capsules would be disposed of along with previously stored capsules. All other wastes in the double-shell tanks would be processed to destroy organic complexants if necessary to meet technical or regulatory requirements, converted to a grout, and disposed of in near-surface disposal vaults or in empty tanks.

All sites would be treated as necessary for subsidence control, and all sites containing high-level or TRU waste would be covered with a protective barrier and marker system.

Although in-place stabilization and disposal would be a permanent disposal action, and retrieval would not be contemplated, the fact that waste has been so disposed of does not preclude future generations from intentionally removing the waste (although with some difficulty) for resource recovery or to effect enhanced disposal by some other means if either ever appears warranted.

Processing steps for each waste class are discussed briefly below, and in more detail in Appendix B.

3.3.2.1 In-Place Stabilization and Disposal of Existing Tank Waste

As illustrated in Figure 3.3, single-shell tank waste would be immobilized as 140,000 m^3 of solids and disposed of in place. Residual liquor and other liquid waste from double-shell tanks would be retrieved hydraulically and treated (if necessary to meet technical or regulatory requirements) to destroy organic compounds.(a) Treated residual aqueous solutions would

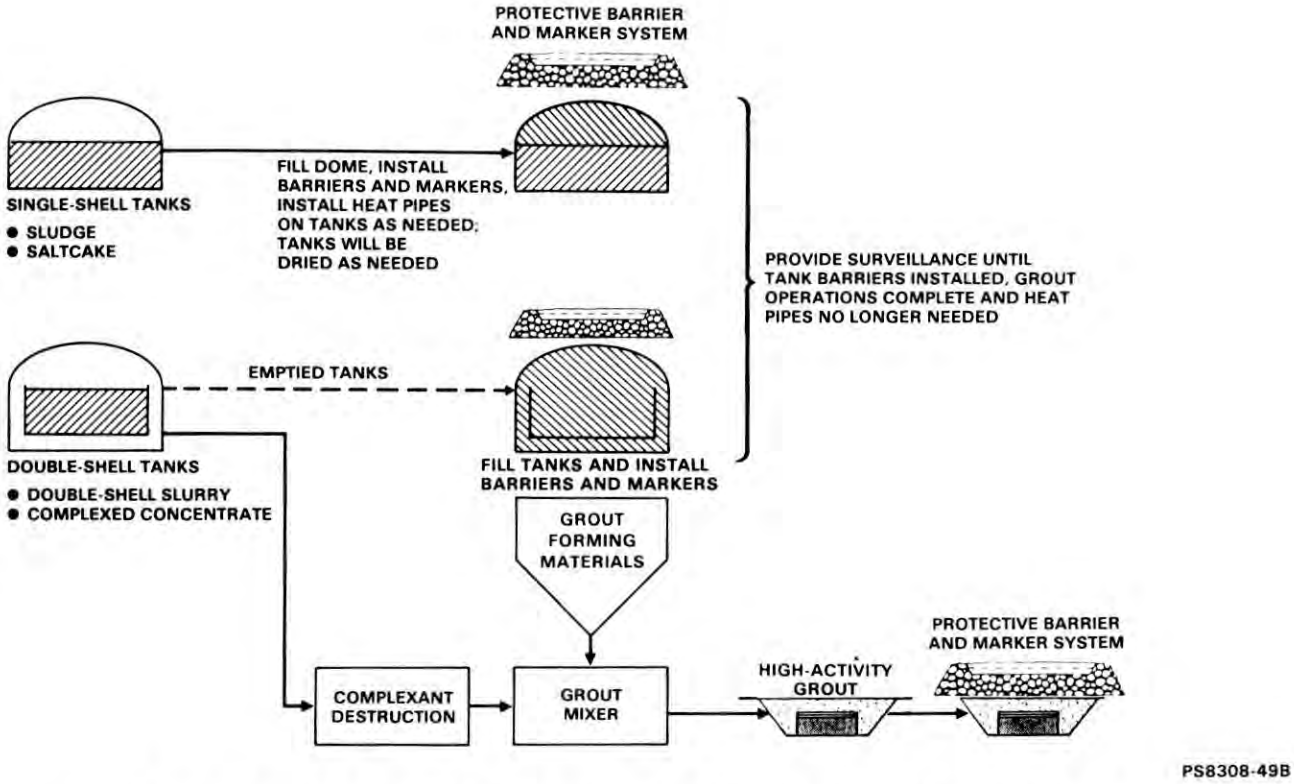

FIGURE 3.3. Schematic of In-Place Stabilization and Disposal for Existing Tank Waste

then be immobilized by converting them to a cementitious grout. The 173,000 m^3 of grout would be disposed of in near-surface disposal vaults (covering about 6 ha) or potentially in single- and double-shell tanks.

The tank dome voids in both the single- and double-shell tanks and the annular spaces in the double-shell tanks would be filled with gravel, sand, grout, or other substances (singly or in combination) to provide support to the tank walls during subsequent disposal operations

(a) Treatment would avoid potential complications from the presence of organic complexants during processing and long-term disposal. Organic complexants interfere with treatment processes to varying degrees, and some complexants have been shown to reduce the ability of soils to retard movement of some nuclides such as plutonium if complexes of these nuclides were to reach the unsaturated or saturated zone (groundwater).

and to control subsidence in the long term. The tanks with the lowest heat content would be filled first, and those with the highest heat content would be filled last. This order of filling controls thermal releases so that the temperature of concrete will not exceed present operating limits. Selected tanks (up to 12) may be equipped with passive heat pipes to help disperse the decay heat (for example, Tank 106-C would still generate about 20 kW in the year 2030). All tanks would be filled by the year 2030. All pipes and other entries to the tanks (except heat pipes and some inaccessible horizontal connections between tanks) would be filled with nonradioactive grout or other material, isolating the tanks and their contents from external liquids. Further details are given in Appendix B.

To further isolate the waste, each tank farm would be covered with a protective barrier and marker system (Appendices B and M). The barrier would protect against inadvertent human intrusion, water intrusion, wind erosion, and plant and animal penetration. The land area associated with tank farm disposal would be about 34 ha.

3.3.2.2 In-Place Stabilization and Disposal of Future Tank Waste

A conceptual processing scheme for in-place stabilization and disposal of future tank waste is depicted in Figure 3.4. Cesium would be removed from new HLW and encapsulated.[a] The cesium would be extracted from the liquid fraction of the waste by ion exchange and converted to solid cesium chloride for encapsulation. The new capsules would be stored in water basins along with existing capsules until all capsules were overpacked and disposed of in shallow drywells, as described in Section 3.3.2.3. An estimated 811 cesium capsules would be made.

After removal of cesium, the residual supernatant liquid would be concentrated by evaporation and converted into grout along with new cladding waste, organic wash waste, customer wastes, and miscellaneous low-level liquid process waste. The 99,000 m^3 of grout would be disposed of in near-surface disposal vaults covering 3 ha or be put back in single- and double-shell tanks and a protective barrier and marker system erected over the grout disposal sites. Emptied double-shell tanks would be filled with gravel or grout to prevent dome subsidence, and tank penetrations would be sealed and covered with soil. Appendix B gives a more detailed description of each process step.

3.3.2.3 In-Place Stabilization and Disposal of Strontium and Cesium Capsules

Storage of strontium and cesium capsules in the Waste Encapsulation and Storage Facility (WESF) water basins is assumed to continue until about the year 2010. This time allows decay for 20 to 40 years following the separation of the strontium and cesium. After this time the heat generated by these radionuclides would be low enough to permit passive cooling[b] of the encapsulated waste.

(a) Calculations showed that if neither cesium nor strontium is removed before incorporating the waste into grout, temperatures resulting from decay heat become excessive for maintaining a stable grout, or the thickness of a slab of grout would be restricted to such a thin layer that the land usage for grout disposal would become prohibitive. Cesium removal was selected because of process simplicity.

(b) Passive cooling means that no forced-convection cooling would be necessary or employed.

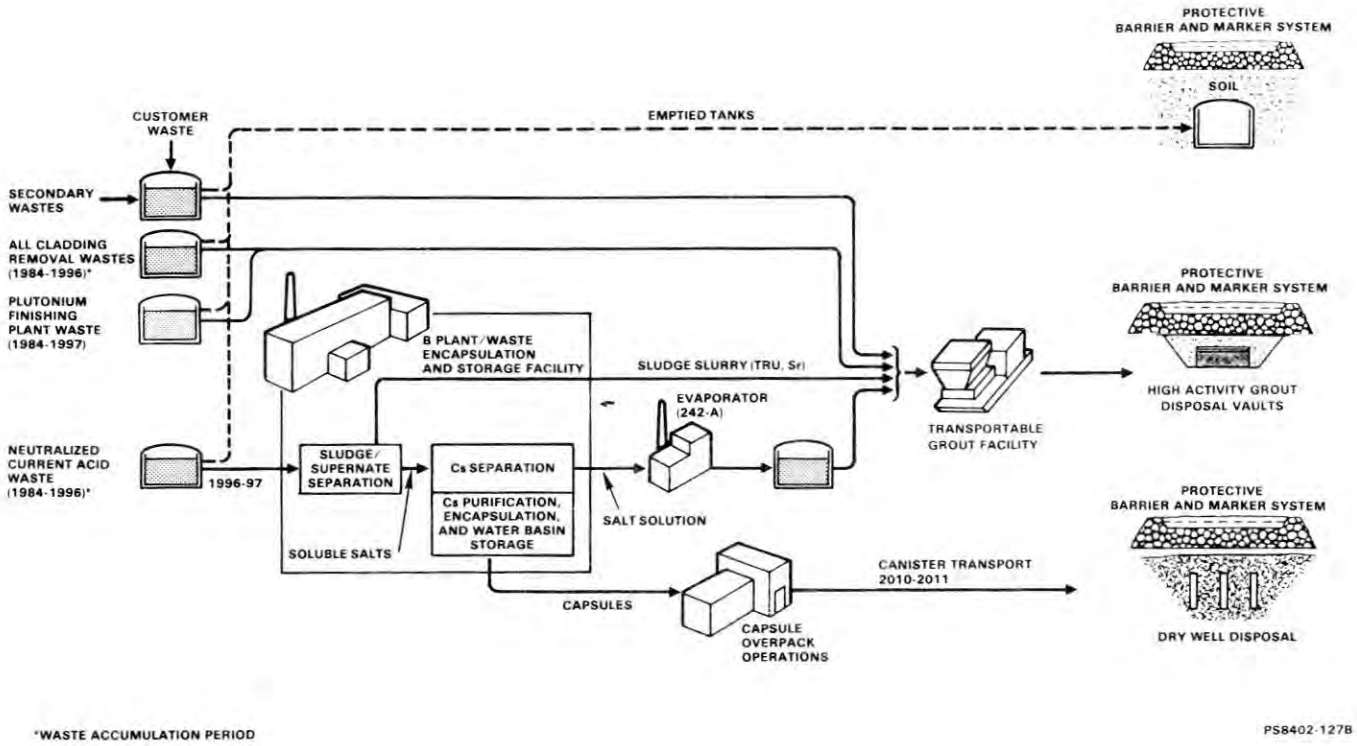

FIGURE 3.4. Schematic of In-Place Stabilization and Disposal for Future Tank Waste

Beginning in 2010, the strontium and cesium capsules would be removed from the WESF, transferred to a capsule packaging facility (CPF), packaged in canisters for ease of handling, and placed in the drywell storage facility (DWSF). Each of these steps is described in Appendix B.

The capsules would be removed from the water basins and transferred to an inspection cell. There they would be surveyed for removable (smearable) radioactivity that might have been caused by leaking capsules, decontaminated or repackaged if leaking, and checked for heat content. They would then be loaded into transfer casks and transferred by truck to a storage vault at the packaging facility until time for emplacement in drywells. The capsules would be placed into canisters containing about two strontium or four cesium capsules.

The canisters would be transferred to the drywells in a shielded-cask transporter vehicle, as described in Appendix B. This vehicle would also be used to place the canisters in the drywells and to fill the voids in the drywells with sand.

A protective barrier and marker system would be constructed over the site in the years 2013 to 2015. The barrier would cover an area of about 3.8 ha.

3.3.2.4 In-Place Stabilization and Disposal of Retrievably Stored and Newly Generated TRU Waste

Retrievably stored or newly generated TRU waste would be disposed of near surface and covered with a protective barrier and marker system, as shown in Appendix B.

TRU waste burial grounds with significant potential for subsidence would be compacted. One technology considered for accomplishing this utilizes a vibratory hammer interfaced with a heavy-duty crane to inject rods into the waste site, thus compacting the buried drums and other containers (Appendix B). The rods (piles) would be withdrawn for reuse unless during their withdrawal they were determined to be contaminated. If contaminated, the rods would be redriven for in-place disposal. Caissons containing TRU waste would be immobilized in place by being filled with grout or other stable filler.

3.3.2.5 In-Place Stabilization and Disposal Applied to Previously Disposed-of TRU-Contaminated Soil Sites

Sites would be surveyed to determine radiation and contamination status. Subsidence control would be initiated by completing a geophysical survey of the liquid waste sites with high subsidence potential to characterize them and identify grout-injection points.

Abandoned ponds, trenches, and ditches would be filled as needed. French drains, cribs, settling tanks, and reverse wells would be injected with cement-based grout. All sites would be covered with a protective barrier and marker system (Appendix B).

3.3.2.6 In-Place Stabilization and Disposal Applied to Previously Disposed-of Pre-1970 Buried Suspect TRU-Contaminated Solid Waste

All pre-1970 buried TRU solid waste would remain as disposed of and covered with a protective barrier and marker system.

TRU waste burial grounds with significant potential for subsidence would be compacted by using a vibratory hammer interfaced with a heavy-duty crane to inject rods into the waste site, thus compacting the buried drums and other containers (Appendix B). The rods (piles) would be withdrawn for reuse unless during their withdrawal they were determined to be contaminated. If contaminated, the rods would be redriven for in-place disposal. Caissons containing TRU waste would be immobilized in place by filling with grout or other stable material.

3.3.3 Reference Alternative

The objective of the reference alternative is to remove and process readily retrievable wastes for geologic disposal and to leave in place the wastes that are difficult and/or hazardous to retrieve. The principal basis used to classify waste as readily retrievable or difficult to retrieve is the potential for radionuclide dispersion during retrieval. Mechanical retrieval of solid waste not in packages (solids in single-shell tanks, soil sites, or pre-1970 solid waste burial sites) and mechanical retrieval of liquid waste (double-shell tanks) is considered to be hazardous, while mechanical retrieval of packaged solid waste (capsules, or post-1970 TRU solid waste) is not particularly hazardous. Hydraulic retrieval of waste in single-shell tanks is difficult since the tanks may leak, while hydraulic retrieval of waste in double-shell tanks is not difficult. The reference alternative would give a reasonable expectation that risks to populations over the long term will be limited without incurring substantial near-term risks by disturbing wastes that are currently stable and hazardous to retrieve.

To some extent, the reference alternative would combine portions of the geologic disposal and in-place stabilization and disposal alternatives. It would be the same as the geologic disposal alternatives for strontium and cesium capsules and portions of TRU solid waste. It would be the same as the in-place stabilization and disposal alternative for waste in single-shell tanks, TRU-contaminated soil sites, and most pre-1970 buried TRU solid waste sites.

For double-shell tank waste and retrievably stored TRU wastes, however, the reference alternative would be different. These wastes would be processed in facilities sized for the needs of the reference alternative, rather than being processed in the more extensive facilities required for the geologic disposal alternative. Waste in double-shell tanks would be processed so that the bulk of the activity would be sent to a geologic repository, but some of the waste would be disposed of in grout on site. Technetium is removed from tank waste and incorporated into glass in the geologic alternative but not in the reference alternative. Retrievable remotely handled TRU waste would be packaged, for geologic disposal in WIPP, rather than being processed to a slag.

Disposal actions for the reference alternative are described briefly below, and in more detail in the appendices. Three major facilities are described in considerable detail in Appendices C, D and E since they have been well defined. These facilities are: 1) Hanford Waste Vitrification Plant, 2) Transportable Grout Facility, and 3) Waste Receiving and Processing facility. Other processes and facilities are described in Appendix B.

3.3.3.1 Reference Alternative for Existing Tank Waste

Existing tank waste would be disposed of by a method that combines portions of the geologic disposal and in-place stabilization and disposal alternatives (see Figure 3.5).

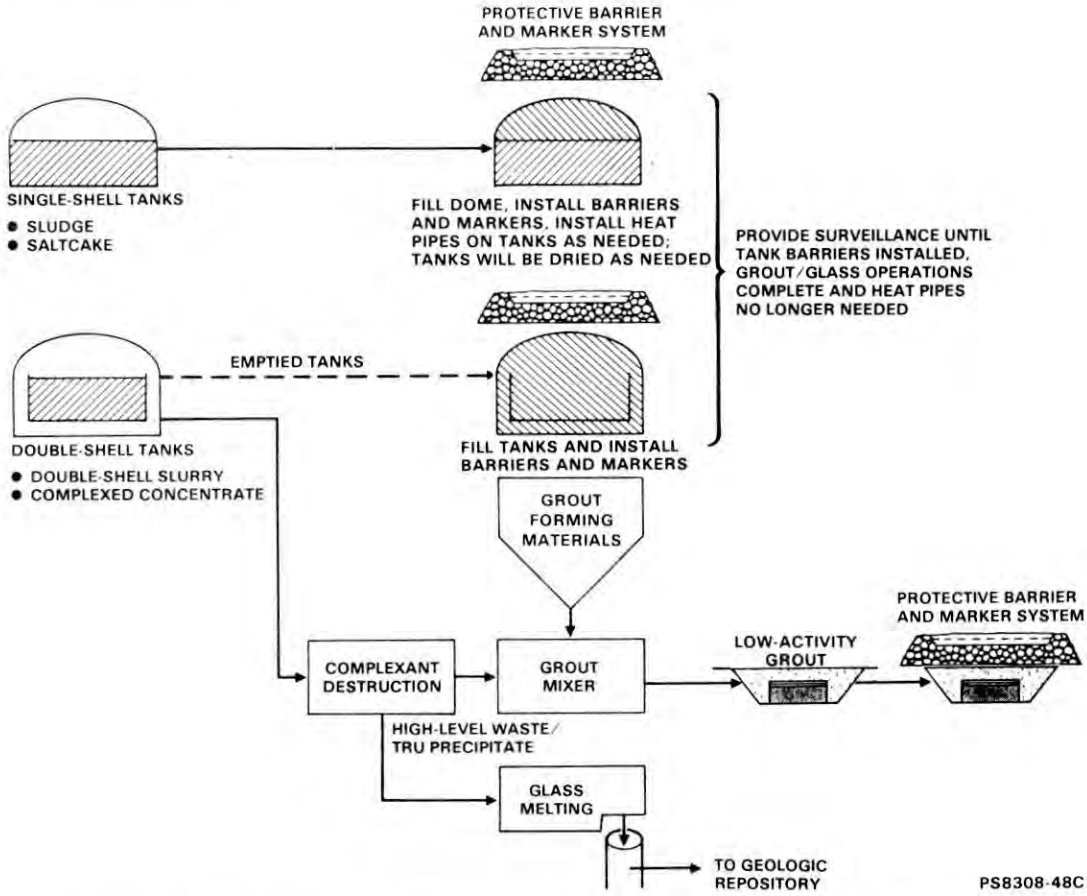

FIGURE 3.5. Schematic for the Reference Alternative for Existing Tank Waste

Waste in single-shell tanks would be left in the tanks and treated as described in the in-place stabilization and disposal alternative (Section 3.3.2.1).

Waste in double-shell tanks would be retrieved by hydraulic sluicing and treated to destroy organic compounds. The high-level and TRU components of the waste in these tanks would be concentrated and immobilized in the Hanford Waste Vitrification Plant (HWVP) to produce 473 canisters containing 293 m^3 of borosilicate glass that would be transported to, and disposed of in, a deep geologic repository either on site or off site. Other waste from the double-shell tanks would be treated to immobilize it (e.g., as 173,000 m^3 of cement-based grout) and placed in near-surface disposal vaults. A protective barrier and marker system would be erected over the grout disposal sites. Alternatively, the grout (Appendix D) could be disposed of in the void space of single- and double-shell tanks.

The purpose of the vitrification plant is to vitrify, package and temporarily store existing and future Hanford defense high-level and/or TRU waste from tanks prior to geologic disposal. The plant would operate for up to 20 years and would process nominally up to 150 canisters of vitrified waste per year. It would be similar to the Defense Waste Processing Facility (DWPF) at Savannah River Plant; however, it would be smaller, and the processed waste streams would be somewhat different (DOE 1982a).

Appendix C describes the vitrification plant currently planned under the reference disposal alternative. Also addressed in Appendix C are the facility description (Section C.1), its relationship to other facilities (Section C.2), process description (Section C.3), waste form (Section C.4), waste feedstreams (Section C.5), resource requirements (Section C.6), projected radiological impacts and emissions (Section C.7), nonradiological emissions (Section C.8), and cost estimates (Section C.9). The objective of the appendix is to provide conceptual information on the plant, its role in waste management operations, and general characteristics of the materials processed by the plant sufficient to allow an evaluation of environmental impacts resulting from its construction and operation.

All voids in empty and partially filled tanks (both single- and double-shell) would be filled as appropriate with gravel, sand, grout, soil or other solid material to avoid subsidence. All tank dome penetrations would be closed by filling with nonradioactive grout or other material. All single-shell tank farms would be covered with a protective barrier and marker system (Appendix B).

3.3.3.2 Reference Alternative for Future Tank Waste

The reference alternative for future tank waste, shown in Figure 3.6, involves geologic disposal, either on site or off site, for HLW. Only cesium would be removed from the supernatant liquid derived from HLW before incorporation of the supernatant liquid along with cladding waste, organic wash waste, and other streams into 99,000 m^3 of grout. The cladding removal waste (CRW) sludge and LaF_3 treated CRW sludge may or may not be blended prior to processing, contingent upon the efficiency of LaF_3 treatment and on results from agency review. If not blended, CRW sludge will be pre-treated similar to the neutralized current acid waste (NCAW). Removal of cesium would be required to reduce thermal degradation in the grout product; the supernatant liquid, after cesium removal, would be converted to grout for near-surface disposal. Cesium and sludge (containing strontium, TRU elements, and other fission product elements, such as rare earths and zirconium) would be processed in the vitrification plant (Appendix C). The product would be 369 m^3 of glass in 595 canisters. (The glass volume from future tank waste would be much less than in the geologic disposal alternative since in the reference alternative no cladding removal sludge would be vitrified and less-extensive chemical processing would be used.)

3.3.3.3 Reference Alternative for Strontium and Cesium Capsules

In the reference alternative, the strontium and cesium currently in capsules would be packaged and shipped to a geologic repository for disposal, as described in Section 3.3.1.3.

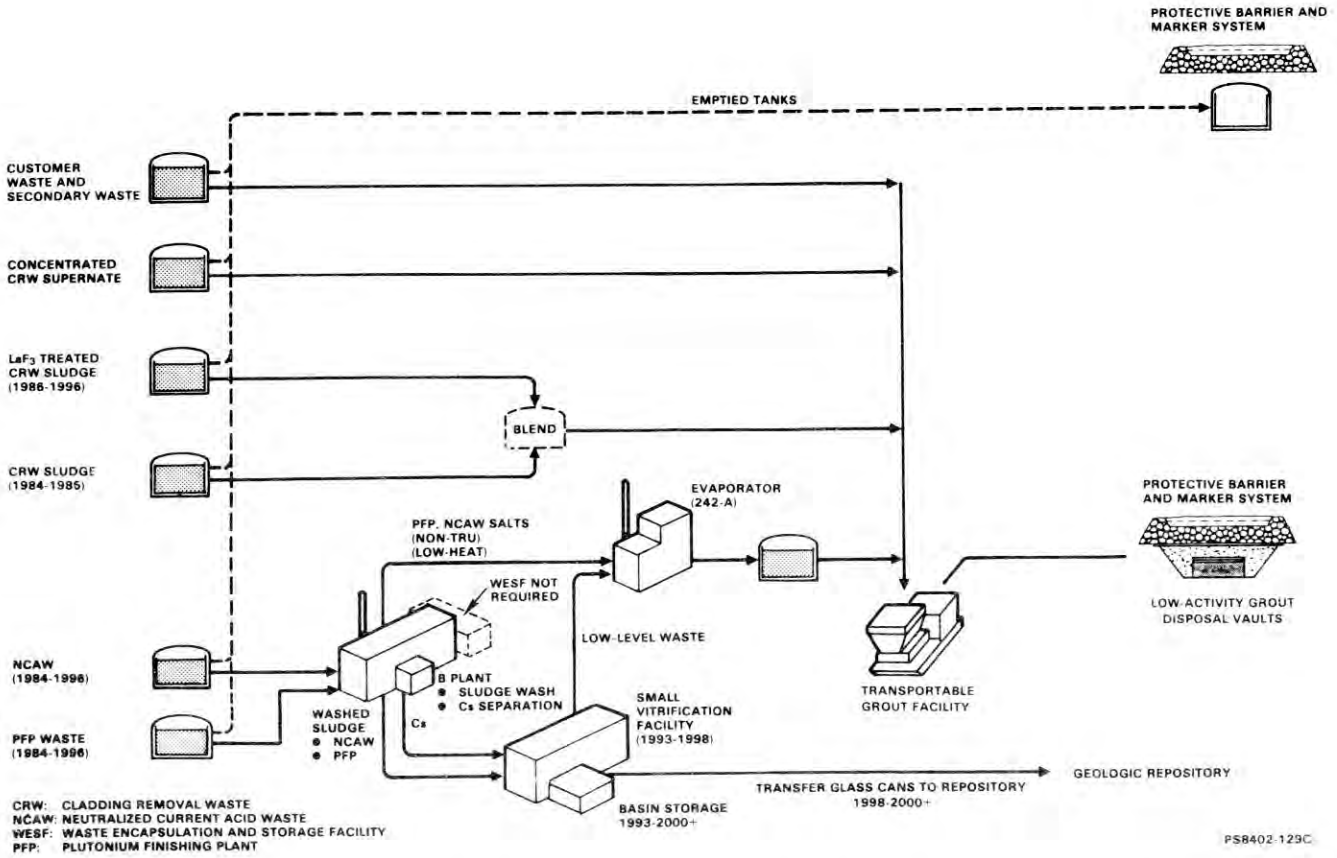

FIGURE 3.6. Schematic for the Reference Alternative for Disposal of Future Tank Waste

3.3.3.4 Reference Alternative for Retrievably Stored and Newly Generated TRU Solid Waste

In the reference alternative, retrievably stored and newly generated TRU solid waste would be sent to WIPP. The waste would first be processed and packaged in the same way as in the geologic disposal alternative (Section 3.3.1.4), except for remotely handled TRU waste. The waste processing facility proposed for the geologic disposal alternative would not be provided in the reference alternative since this facility would be sized for treatment of TRU-contaminated soil sites and pre-1970 TRU solid waste burial grounds (for a total of 1.4×10^5 m^3) as well as remotely handled TRU waste (500 m^3). In the reference alternative, the remotely handled TRU material would be processed on a much smaller scale, which favors use of a smaller facility using different technology. The waste would be processed in a new facility (or in a temporary facility, since such a small volume is involved) of suitable size, possibly as an addition to the Waste Receiving and Processing facility (Appendix E). A new facility to provide remote handling is assumed, containing hot cells for size reduction, immobilization, and packaging.

3.3.3.5 Reference Alternative for Previously Disposed-of TRU-Contaminated Soil Sites

The reference alternative for TRU-contaminated soil sites would be enhanced protection identical to the in-place stabilization and disposal alternative (Section 3.3.2.5).

3.3.3.6 Reference Alternative for Previously Disposed-of Pre-1970 Buried Suspect TRU-Contaminated Solid Waste

The reference alternative for previously disposed of pre-1970 TRU solid waste burial grounds in the 200 Areas would be enhanced protection identical to the in-place stabilization and disposal alternative (Section 3.3.2.6). However, TRU waste in the 618-11 site near the 300 Area would be retrieved. Retrieved waste would be packaged and processed the same as newly generated TRU solid waste (Section 3.3.3.4). This selective combination of in-place stabilization and geologic disposal would consolidate wastes at central locations (either the 200 Areas or WIPP), and would remove TRU waste from the sites near areas of habitation and potentially accessible to severe floods.

3.3.4 No Disposal Action (Continued Storage)

The "no action" alternative, required by Council on Environmental Quality (CEQ) guidelines, is in the context of this EIS a "no disposal action" and is analyzed in terms of continuing with the current course of waste management, including ongoing and future plans for improved storage. As described below, improved storage includes liquid removal, tank isolation, periodic replacement of double-shell tanks, passive storage for strontium and cesium capsules, and control of deep-rooted vegetation. Continuation of current waste management plans over the long term for wastes not already disposed of would be contrary to the DOE's mandate to provide safe permanent disposal of the waste (e.g., the Defense Waste Management Plan issued by the President in accordance with Public Law 97-90). Interpretation of the "no action" alternative as "walk away" or site abandonment is also unacceptable to the DOE.

Except for wastes in double-shell tanks, this alternative is similar to the in-place stabilization and disposal alternative with two important exceptions: 1) sites would not be stabilized, but if incipient subsidence were detected, those sites would be stabilized to prevent further subsidence, and 2) TRU and HLW sites would not be covered with a protective barrier and marker system.

Wastes in double-shell tanks would be monitored and maintained. However, because the tanks have a limited design life, new tanks would be provided about every 50 years to avoid leakage.

3.3.4.1 Continued Storage of Existing Tank Waste

Existing tank waste would continue to be stored in tanks. Improvements to enhance containment would consist of practices now under way: production of double-shell slurry from interstitial liquid, stabilization of salt cake and sludges, and isolation of the tanks (ERDA 1975). Liquid would be removed from salt cake now stored in single-shell tanks to the extent reasonable (to no more than 190 m^3 residual per tank). Liquid waste and slurries now stored in double-shell tanks would continue to be monitored and kept under surveillance. Spare double-shell tank space would continue to be maintained in condition to receive this waste in case of tank failure. Since the minimum design life of double-shell tanks is 50 years, all double-shell tank waste is assumed to be transferred to new tanks at that frequency. The liquids would be reconcentrated during transfer by evaporation of any water added for pumping or sluicing. The waste would occupy 190,000 m^3.

Structural analysis of tank design and laboratory testing of concrete samples from single-shell tanks show the probability of tank dome failure from deterioration or earthquake-induced forces to be slight. Nevertheless, dome elevations would continue to be monitored. In case of any evidence of dome deterioration or damage, empty tank space would be filled with gravel to minimize the potential for subsidence of the dome and overlying soil. This preventive measure is important because sudden collapse of the dome and overburden could release radioactivity as particulate matter from waste in the tank.

Surveillance would be provided appropriate to the degree of isolation of the tanks. Thus, surveillance would be continued at the current interim level until the year 2030, by which time the adequacy of isolation procedures should be confirmed. After 2030 only one of the single-shell tanks and three of the double-shell tanks containing future waste would require forced ventilation to remove heat due to radioactive decay. Surveillance would then be continued at a reduced long-term level. Site services (security, fire protection, environmental monitoring and utilities) would, however, be maintained at current levels.

3.3.4.2 Continued Storage of Future Tank Waste

The neutralized waste from the PUREX facility would be stored in double-shell tanks. This neutralized waste would be processed and treated in a manner similar to the current practices for handling existing waste, using only double-shell tanks. The tanks would contain strontium and cesium (unless they were separated from the waste for beneficial purposes), other fission products, and transuranic elements (except for that plutonium and

neptunium removed by the PUREX process). Radioactive decay heat would be sufficient to require storage in tanks with circulators for several decades to prevent excessive boiling. Part of the distillate from this high-heat waste would be returned to prevent the tanks from overconcentrating and exceeding their operating temperature and density limits.

Surveillance and monitoring of the stored waste in double-shell tanks would continue until a future decision is made to process and dispose of the waste. Since the tanks have a limited life, new ones would be provided and the waste transferred from old to new tanks every 50 years.

After decay of about 100 years, the supernatants from the tanks would be removed and be concentrated in an external evaporator. The concentrate would be returned to a double-shell tank for crystallization in accord with present practices (ERDA 1975). The waste would consist of 52,000 m^3.

Cladding removal waste, organic wash waste, and other low-heat waste from future PUREX Plant operations would be concentrated by evaporation, allowing the concentrate to crystallize to a salt cake for storage in double-shell tanks.

3.3.4.3 Continued Storage of Strontium and Cesium Capsules

The continued storage alternative for strontium and cesium capsules is the same as the in-place stabilization and disposal alternative discussed in Section 3.3.2.3 with one exception: a protective barrier and marker system would not be placed over the drywell storage facility. The canisters of strontium and cesium capsules would be stored in drywells indefinitely with continuing surveillance.

3.3.4.4 Continued Storage of Retrievably Stored and Newly Generated TRU Waste

The current inventory and any future TRU solid waste would continue to be stored retrievably for 20 years after generation. Current packaging and storage procedures would be followed (i.e., packaging in 55-gal drums and storage in designated TRU waste sites). A filled waste site would then be covered with soil so that the waste could be retrieved later if desired. After 20 years of storage, the waste might be reclassified as buried waste. Monitoring, surveillance, and maintenance of TRU solid waste would continue until a decision is made either to recover materials contained in the waste or to permanently dispose of the waste (ERDA 1975). Monitoring would include site surveys, groundwater analyses, atmospheric sampling, and biotic surveys. Based on monitoring results, maintenance activity would provide (as necessary) erosion and subsidence control, maintenance of observation wells, vents, etc., and control of plant and animal access.

3.3.4.5 Continued Surveillance of Previously Disposed-of TRU-Contaminated Soil Sites and Pre-1970 Buried Suspect TRU-Contaminated Solid Waste

Even without other disposal actions, by the year 2000 all TRU-contaminated soil sites and TRU solid waste burial grounds from pre-1970 operations are expected to have been surface-stabilized. Planned activities aimed at surface stabilization through the control of deep-rooted vegetation would have been implemented and completed by the year 2000. Extensive monitoring and surveillance practices (ERDA 1975) would continue at these sites. Monitoring

would include site surveys, groundwater analyses, atmospheric sampling, and biotic surveys. Based on monitoring results, maintenance activity would provide (as necessary) erosion and subsidence control, maintenance of observation wells, vents, etc., and control of plant and animal access.

3.3.5 Preferred Alternative

A preferred alternative for disposal of the Hanford high-level, transuranic and tank wastes has been developed following review of comments received during the agency and public review of the draft EIS. The preferred alternative as discussed below identifies preferred disposal actions for existing and future double-shell tank waste, retrievably stored and newly generated TRU waste, strontium and cesium capsules and one pre-1970 TRU solid waste site. The preferred alternative identifies additional development and evaluation work required on other waste classes prior to final disposal decisions. Supplemental NEPA documentation such as an EIS for single-shell tank waste, or other public review documentation, as appropriate, would be issued for agency and public review after the additional work is completed and proposed disposal alternatives identified for the remaining waste types.

The preferred alternative would combine a near-term decision for disposal of some of the waste consistent with the reference alternative from the draft EIS, and a future decision for disposal of other wastes. The preferred alternative would be the same as the reference alternative for existing tank waste in double-shell tanks, future tank waste, strontium and cesium capsules and retrievably stored and newly generated TRU solid waste. In addition, in order to consolidate TRU waste on the 200 Areas plateau where it can be protected from public access and potential flooding of the Columbia River, the pre-1970 buried suspect TRU-contaminated site, 618-11 (the only TRU waste site outside of the 200 Areas plateau), would be retrieved and processed for geologic disposal. The preferred alternative would require future decisions possibly on a site-by-site basis, for waste in single-shell tanks, TRU-contaminated soil sites, and pre-1970 buried TRU solid waste sites. Such decisions would be based on the results of the development and evaluation work. In the interim, pending completion of development and evaluation and the decision-making process, including additional NEPA or other public reviews, DOE would continue the present storage and maintenance activities for these three classes of waste.

It is estimated that at the present time there are more curies of both transuranic and fission products in the single-shell tanks than in the double-shell tanks, and some of the single-shell tanks have leaked. Therefore, it would seem counter-intuitive to treat and dispose of double-shell tank wastes before treating and disposing of single-shell tank wastes. However, the wastes in double-shell tanks are primarily in liquid form, whereas the wastes in single-shell tanks have largely been converted to sludges and semi-solids. Consequently, the potential risk from leakage from the double-shell tanks might be greater than from single-shell tanks. Further, the wastes in the double-shell tanks are better characterized than are the wastes in the single-shell tanks; these more mobile, better-characterized wastes should be treated and disposed of first. The strontium and cesium

capsules contain more curies than the fission products in both the single- and double-shell tanks, and in addition, they are well characterized and packaged. Therefore, it makes sense to process as necessary and dispose of these wastes. Finally, the curies of transuranic elements in the stored and future-generated transuranic wastes are a substantial part of the TRU inventory. Because there is also a repository (WIPP) which will shortly be able to receive such wastes, it makes sense to treat and dispose of them first.

Although it was recognized that disposal of single-shell tank waste, the pre-1970 buried suspect TRU-contaminated waste and TRU-contaminated soils is no less important than disposal of double-shell tank waste, capsules and retrievably stored TRU waste, consensus focused on proceeding with disposal of those wastes that could be most readily disposed of (particularly liquid waste) and deferring disposal judgment on the other wastes. There appeared to be no conflict between implementation of these disposal actions and any federal or state regulations.

It was also recognized that because the radioactive wastes in single-shell tanks have been reduced from liquid to sludge and semisolids, there is little threat from further leakages and no urgent need to effect disposal despite a large inventory of waste in those tanks. Similarly, the pre-1970 buried suspect TRU-contaminated solid waste and TRU-contaminated soil sites have remained stable and, again, there is no urgency for election of further remedial action. Moreover, possible application of RCRA and CERCLA to these latter classes of waste suggested the need for further characterization of the wastes (including chemicals) and review for compliance with applicable hazardous-waste regulations.

The other three classes of wastes, including their hazardous-chemical components, are poorly characterized. The efficacy of possible methods of treating and disposing of these wastes is not yet proven, and the consequences of such actions are not yet well-defined. Consequently, treatment and disposal of such wastes should be postponed until these issues are resolved.

3.3.5.1 Preferred Alternative for Existing Tank Waste

The high-level fraction of existing double-shell tank wastes would be disposed of in a geologic repository according to the reference alternative (Section 3.3.3.1), with the low-activity fraction being converted to a cementitious grout. The grout would be placed in preconstructed, lined concrete vaults (see Appendix D). For final disposal, the vaults would be covered with protective barriers. Until field data are finalized, the waste-loading criteria will be established assuming less-than-perfect performance of the barrier.

Existing and future double-shell tank waste will be characterized for hazardous chemical constituents, as well as other chemical constituents that might affect glass or grout formulation before processing. The formulations for both glass and grout will be determined, via laboratory tests, before processing, to ensure that release rates from the waste forms for hazardous constituents as well as radionuclides are within regulatory requirements. The final grout formulation, along with the design for the vault, monitoring system, etc., will

be reviewed by EPA and the appropriate state agencies before disposal. The grout disposal vaults will meet the requirements of the Resource Conservation and Recovery Act (RCRA), including permitting of facilities as required.

DOE would perform the following work as part of the preferred alternative for disposal of double-shell tank waste:

- Finalize glass waste formulation to ensure that it meets repository waste acceptance criteria.
- Finalize grout formulations to ensure that they meet processing, regulatory, and environmental protection criteria.
- Complete design and construction of the HWVP and pretreatment modifications necessary to the pretreatment facility, currently planned to be B Plant.
- Construct subsurface vaults for disposing of low-activity and mixed waste as grout.
- Before final closure of the grout site, develop a protective barrier that will meet the long-term environmental protection criteria. Before final demonstration of the protective barrier, mixed wastes will be grouted and disposed of in vaults with leachage collection systems and caps that conform to RCRA requirements.

Single-shell tank wastes would continue to be stored until sufficient information is available to support a future decision for geologic, in-place stabilization or other disposal method. If it were determined that all or part of the single-shell tank waste is to be retrieved, alternative processes for retrieving, processing and immobilizing the waste would be evaluated. Current concepts would utilize existing facilities being planned for double-shell tank wastes (i.e., HWVP, TGF) for disposal of single-shell tank waste if required. The current HWVP plant design could accommodate all single-shell tank waste, depending on pre-processing constraints, final waste characteristics and final grout disposal criteria.

Single-shell tank waste will be characterized by a combination of sampling and model analyses to determine the hazardous waste constituents on a tank-by-tank basis, as well as to confirm the radionuclide inventories predicted from records. It is known that there are hazardous waste constituents in the tanks, such as nitrite and cadmium, so all disposal options will consider the hazardous waste constituents and regulatory requirements for hazardous chemicals.

For wastes in single-shell tanks, the final disposal decision would be postponed until further development and evaluation are completed. In the interim, DOE would continue the present storage and maintenance activities. Examples of development and evaluation that may be undertaken for existing tank waste in single-shell tanks include the following:

- Characterize radioactive and hazardous waste components by sampling, analysis and modeling.

- Perform additional environmental impact analysis using improved performance assessment models and data.
- Demonstrate barrier performance.
- Determine need and methods to improve the stability of the waste form.
- Establish criteria to identify tanks where removal of wastes is required and determine optimal retrieval methods for processing and preparing this fraction for geologic disposal.
- Evaluate destruction/stabilization alternatives for hazardous components of the wastes, considering the applicable requirements of RCRA and CERCLA regulations.
- Evaluate alternative methods for retrieving, processing, and immobilizing single-shell tank wastes.
- Conduct a full-scale test of the design basis disposal method (on one tank farm) once it is selected. Appropriate environmental analysis would precede this demonstration.
- Initiate a series of independent reviews of disposal alternatives. A National Academy of Sciences review of technology issues associated with disposal has already been started.
- Prepare NEPA documentation, such as a supplemental EIS, or other public review documentation as appropriate.

3.3.5.2 Preferred Alternative for Future Tank Waste

The preferred alternative for future tank waste, shown in Figure 3.6, involves geologic disposal, either on site or off site, for the high-level portion of future tank waste. Only cesium would be removed from the supernatant liquid derived from future tank waste before incorporation of the supernatant liquid along with cladding waste, organic wash waste, and other streams into 99,000 m^3 of grout. Removal of cesium would be required to reduce thermal degradation in the grout product; the supernatant liquid, after cesium removal, would be converted to a cementitious grout for near-surface disposal in vaults. Cesium and sludge (containing strontium, TRU elements, and other fission product elements, such as rare earths and zirconium) would be processed in the vitrification plant (Appendix C). The product would be 369 m^3 of glass in 595 canisters. (The glass volume from future tank waste would be much less than in the geologic disposal alternative since in the preferred alternative no cladding removal sludge would be vitrified and less extensive chemical processing would be used.)

Future double-shell tank waste would receive the same considerations for hazardous chemical constituents as accorded existing double-shell tank waste (Section 3.3.5.1).

3.3.5.3 Preferred Alternative for Strontium and Cesium Capsules

The preferred alternative would provide for storage of the strontium and cesium capsules in water basins until a repository becomes available. The strontium and cesium would be packaged in accordance with repository waste acceptance specifications and shipped to a

commercial repository. For the purpose of evaluation of impacts for this EIS, it was assumed that the strontium and cesium capsules would be placed in canisters and shipped to a repository. An estimated total of about 509 canisters would be shipped for disposal. Most of the cesium and some of the strontium is already committed to beneficial uses. It is planned, though, that this material will be eventually returned for disposal.

3.3.5.4 Preferred Alternative for Retrievably Stored and Newly Generated TRU Solid Waste

In the preferred alternative, retrievably stored and newly generated TRU solid waste would be sent to WIPP. The waste would first be processed and packaged in the same way as in the geologic disposal alternative (Section 3.3.1.4), except for remotely handled TRU waste. The waste processing facility proposed for the geologic disposal alternative would not be provided in the preferred alternative since this facility would be sized for treatment of TRU-contaminated soil sites and pre-1970 TRU solid waste burial grounds (total of 1.4×10^5 m^3) as well as remotely handled TRU waste (500 m^3). In the preferred alternative the remotely handled TRU material would be processed on a much smaller scale, which favors use of a smaller facility using different technology. The waste would be processed in a new facility (or in a temporary facility, since such a small volume is involved) of suitable size, possibly as an addition to the Waste Receiving and Processing facility (Appendix E). A new facility to provide remote handling is assumed, containing hot cells for size reduction, immobilization, and packaging.

It is anticipated that close to 45% of the retrievably stored waste will be returned to burial grounds as low-level waste after being exhumed and assayed. The remainder will be repackaged as necessary, certified to meet WIPP acceptance criteria and sent to the Waste Isolation Pilot Plant (WIPP). If the low-level waste fraction returned to the burial ground is determined to be hazardous waste, it will meet hazardous waste requirements for shallow land burial. It is anticipated that some of the low-level waste may be classified as radioactive mixed waste. These wastes will be segregated and will be disposed of in accordance with the provisions of RCRA.

DOE would perform the following work as part of the preferred alternative for disposal of retrievably stored and newly generated TRU solid waste:

- Design and construct the WRAP facility.
- Evaluate alternative methods for retrieval of remote-handled TRU solid waste.

3.3.5.5 Preferred Alternative for TRU-Contaminated Soil Sites

The preferred alternative for TRU-contaminated soil sites would postpone a decision between geologic disposal and in-place stabilization and disposal until after completion of ongoing and planned development and evaluation. In the interim, DOE would continue the present maintenance activities for these waste sites.

TRU-contaminated soil sites are also being evaluated under the CERCLA program to determine whether additional stabilization or exhumation is needed because of their hazardous components (including radioactivity). The first stage, now completed, was to identify, on

the basis of existing records, the hazardous waste content. The second phase will be actual site characterization, if this is deemed necessary. As a minimum, because of their radioactive contamination, a protective barrier and marker system will be placed over each of these sites, unless they are exhumed. Those sites active after November 1980 will be evaluated under RCRA if they are mixed waste sites.

Examples of development and evaluation that may be performed for TRU-contaminated soil sites include the following:

- Perform additional characterization of selected sites' radioactive and hazardous waste components by sampling and analysis.
- Perform analysis using improved performance assessment models and data.
- Establish criteria to identify wastes unacceptable for in-place disposal and determine methods for retrieving, processing and preparing this fraction for geologic disposal.
- Demonstrate void/subsidence control.
- Consider destruction/stabilization alternatives.
- Determine needs and methods to improve the stability of the waste form.
- Evaluate alternative methods for removing waste from specific waste sites.
- Evaluate sites against CERCLA and/or RCRA requirements, as appropriate.

3.3.5.6 Preferred Alternative for Pre-1970 Buried Suspect TRU-Contaminated Solid Waste

The preferred alternative for Pre-1970 buried TRU solid waste is the same as for TRU-contaminated soil sites, as described in Section 3.3.5.5, except that the 618-11 site near the 300 Area would be retrieved and processed for disposal in a geologic repository (assumed for calculation purposes to be WIPP). Pre-1970 buried solid TRU waste sites are also being evaluated under the CERCLA program to determine whether additional stabilization or exhumation is needed because of their hazardous components (including radioactivity). The first stage, now completed, was to identify, on the basis of existing records, the hazardous waste content. The second phase will be actual site characterization, if this is deemed necessary. As a minimum, because of their radioactive contamination, a protective barrier and marker system will be placed over each of these sites, unless they are exhumed. Those sites active after November 1980 will be evaluated under RCRA if they are mixed waste sites.

3.3.6 Disposal Alternatives Considered but Dismissed from Detailed Consideration

In addition to the alternatives for disposal of defense waste described in this EIS, disposal options such as geologic disposal, seabed disposal, space disposal, deep-hole disposal, ice sheet disposal, and island disposal have been previously investigated for disposal of commercial radioactive waste (DOE 1980a). For commercial waste, geologic disposal was determined to be the alternative of choice (Record of Decision 46 FR 26677, May 14, 1981), which was confirmed by the Nuclear Waste Policy Act of 1982 (PL 97-425). Although the primary emphasis was on commercial waste, the EIS (DOE 1980a) recognized that "in a generic

sense, systems that can adequately dispose of commercial radioactive wastes have the capability to adequately dispose of wastes resulting from defense programs." Geologic disposal of defense wastes is, therefore, also the choice from among those alternatives cited above, and those other alternatives were not reexamined here.

The 27 variations on four alternatives for disposal of high-level waste examined in ERDA-77-44 were considered and reduced to the three disposal alternatives. The 27 plans represented part of the matrix defined by two waste classes (waste in tanks and capsules of strontium and cesium), four waste forms (glass, concrete, powder and clay), three disposal sites (onsite near-surface, onsite geologic repository, and offsite geologic repository), and two processing scenarios (disposal of all material associated with waste in tanks, and dividing existing waste into high-activity and low-activity components). Three waste forms were dismissed (concrete, powder, and clay) since glass has been shown to be an acceptable waste form for similar wastes at Savannah River and West Valley (Appendix C). As explained below, disposal of all material associated with waste in tanks was rejected for geologic disposal. The remaining portions of the matrix are included in the alternatives selected for detailed evaluation.

Other alternatives considered but which were eliminated from detailed study included the following:

- geologic repository disposal of entire tank contents
- geologic repository disposal of entire tank contents, tanks, ancillary equipment (piping, sumps, etc.) and contaminated soil from tank leaks

A brief discussion of these alternatives and the reason for elimination from detailed study is as follows.

3.3.6.1 Geologic Repository Disposal of Entire Tank Contents

In this discussion single-shell tanks, double-shell tanks containing existing waste and double-shell tanks to contain future waste are considered as a single class. The total volume of waste from tanks to be retrieved and processed for repository disposal amounts to about 142,500 m^3, 45,000 m^3 and 52,000 m^3 for single-shell tank waste, existing double-shell tank waste, and future double-shell tank waste, respectively, for a total of about 240,000 m^3. (This is the same volume of waste that is retrieved and fractionated before processing into glass and grout in the geologic disposal alternative.) An analysis of geologic disposal of the entire tank contents as well as that of fractionated waste was presented by Rockwell Hanford Operations (Rockwell 1980). It was concluded that processing the entire tank contents for disposal in a geologic repository would result in a volume of powder to process to glass 26 times that for processing fractionated waste as in the geologic disposal alternative. After processing to glass, the impact on repository requirements would amount to about 6 times that necessary for fractionated waste as described in the geologic disposal alternative. From these ratios, an appreciation can be gained of the increases in labor for treatment and disposal and of the increase in radiological and nonradiological risk associated with transporting the relevant wastes.

In accordance with provisions in Section 8 of the Nuclear Waste Policy Act, the President made an evaluation of the need for a defense-only repository and found no basis to conclude a separate repository was necessary (Letter from the President to the Secretary of Department of Energy, April 30, 1985).

To develop an estimate of the cost of implementing an alternative of disposing of the entire tank contents in a geologic repository, a comparison was made between the analyses in Rockwell (1980) and in this EIS for the disposal of fractionated tank waste and scaling up from costs provided by Rockwell (1980) for disposal of the entire tank contents. That led to an estimate of about $32 billion to dispose of the entire tank contents versus about $14 billion to dispose of the fractionated tank waste.

Because analysis of the three principal alternatives discussed in the draft EIS suggested low public risk under all reasonable scenarios, it was concluded that the additional risk to dispose of the tank residuals from increased processing, transportation and repository placement plus an additional $18 billion was not warranted to place the approximately 5%, by activity, of the remaining tank waste in a geologic repository. Hence, this alternative was eliminated from detailed consideration.

3.3.6.2 Geologic Disposal of Entire Tank Contents, Tanks, Ancillary Equipment (piping, sumps, etc.) and Contaminated Soil from Tank Leaks

In this discussion single-shell tank waste and existing and future double-shell tank waste are again taken as a single class. The increase in effort, risk and cost to remove and dispose of the entire tank contents was developed above. Removal of all 177 tanks plus connecting piping and other equipment together with all of the contaminated soil from tank leaks could be seen as an alternative to achieve nearly original status of the tank sites. It is expected that because of the contaminated nature of the waste tanks and changes in work practices, all work removing the tanks would be considered radiation work and stringent procedures would apply. Without any experience on this scale of operation, it was assumed at the present time that it would cost 5 to 10 times the original cost of building the tanks to remove them and cut up the material so that it could be placed in a geologic repository. It was estimated that to construct all of the tanks in today's economy would require about $500 million. Thus, the expectation for removal would be $2.5 to $5 billion.

The volume of rubble from dismantled tanks to dispose of would be on the order of 60,000 m^3. In addition, the quantity of contaminated soil that resulted from tank leaks would be on the order of 100,000 m^3. Assuming that disposal of these wastes would be proportional in cost to geologic disposal of contaminated TRU soil sites, which cost $400 million to dispose of 32,000 m^3, an estimate for disposing of the contaminated soil would be about $2 billion. Hence, to dispose of the tank contents, tanks and contaminated soil would cost on the order of $37 billion. Here again the added effort, risk and cost of placing in a geologic repository materials that would not be foreseen as having any risk to public health and safety was concluded to be unwarranted, and the alternative was eliminated from detailed study. However, recent clarification of the applicability of RCRA to defense waste (see Section 6.6) may necessitate additional consideration to disposal of the tanks and ancillary equipment.

3.4 COMPARISON OF IMPACTS FROM ALTERNATIVES

In this section, the disposal alternatives and the no disposal action (continued storage) alternative are compared with respect to operational and postdisposal impacts. More detailed descriptions of impacts are given in Chapter 5 and in the appendices.

As a result of the comprehensive analysis of alternatives conducted for this document, upper-bound estimates of the short-term and long-term health and environmental impacts of the alternatives have been made. These impacts are lower than might have been expected intuitively. The estimates of the risks of waste disposal for the options outlined in this analysis provide a conservative basis for decisions among the alternatives.

The health and environmental impacts in this analysis are based upon deterministic models in nearly all cases. That is, consequences are estimated as though the postulated releases of nuclides have occurred. One exception is the scenario for well drilling, where the frequency of events leading to lethal exposures is shown over a 10,000-year period. In that case, probability is incorporated to establish the likely number of drilling events. A second exception occurs in Appendix S, where probability of release and consequence magnitudes are estimated in such a manner as to relate exposures from the alternatives with the risk assessment methodology used by EPA in their "Environmental Radiation Protection Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes," 40 CFR 191.

3.4.1 Environmental Impacts from Disposal and No Disposal Action Operations

Consideration of environmental impacts that might result from implementing the waste disposal alternatives included:

- radiological impacts to public and workers from routine operations and to the public from accidental releases
- nonradiological impacts from routine operations and accidents
- ecological impacts
- socioeconomic impacts
- commitment of resources.

In addition, a comparison of the estimated costs of implementing the several alternatives is provided below.

3.4.1.1 Radiological Impacts from Routine Operations

Radiological impacts associated with the implementation of the disposal and the no disposal action alternatives are compared in Table 3.3. Ranges of impacts are shown for the preferred alternative to indicate the minimum and maximum disposal actions that could be implemented for that alternative.

Radiation doses[a] to the public during routine operations are highest for the geologic disposal alternative where the repository is located off site. In that case the population in the Hanford area, along transportation routes to the repository(ies) and in the repository area would receive a total of up to 140 man-rem over the disposal period. The principal contribution to the dose is from the disposal activities associated with retrieval, processing and repository placement.

The highest annual total-body doses to the maximum individual in the general population during routine operations were as follows:

	rem/yr
Geologic Disposal	4×10^{-4}
In-Place Stabilization	4×10^{-7}
Reference	6×10^{-7}
Preferred	6×10^{-7} to 4×10^{-4}
No Disposal Action	5×10^{-8}

These doses may be compared with the EPA Standard 40 CFR 191.03 of 2.5×10^{-2} rem/yr to any member of the public permitted for disposal operations.

As a point of reference for the doses in Table 3.3, the anticipated 1990 population in the Hanford environs (420,000) would receive about 2,500,000 man-rem from naturally occurring radioactive sources during the operational period ending in the year 2050. Thus, in comparison with dose from naturally occurring sources, the doses to the public in Table 3.3 are small in terms of environmental impacts among alternatives even though they differ by several orders of magnitude.

Radiation doses to the work force during routine operations are also highest for the geologic disposal alternative. Workers involved in retrieval, transportation and emplacement activities would receive a total of 15,000 man-rem, or from four to eight times greater than that for the other alternatives. It is expected that during operational activities, doses to workers would be controlled and monitored at all times. Hanford operational practices have historically resulted in an average for radiation-zone workers of 0.5 rem per person per year. Geologic disposal, however, would require up to seven times as many man-years as for implementation of the other alternatives. Thus, although radiological doses to the work force would be controlled at all times, geologic disposal has greater possibility for occupational exposures than other alternatives. All other alternatives have much lower occupational exposure, with no disposal action (continued storage) the lowest.

(a) Doses calculated in this EIS are based on dosimetry methods recommended in ICRP 2. The DOE, in concert with other agencies, has recently called for dosimetry methods based on ICRP 26/30 to be used in computation of dose (DOE Order 5480.1B). Conversion of computer programs based on ICRP 2 to those based on ICRP 26/30 methods is in progress but was not available in time to be used in this EIS. See Appendix F for a discussion of dosimetry methods used in this EIS.

TABLE 3.3. Comparison of Estimated Radiological Impacts from Routine Operations (1990-2050) for Each Alternative[a]

Disposal Alternatives	Occupational Doses, man-rem			Integrated Population Dose, man-rem[b]		Presumed Health Effects[c]	
	Operations	Repository Emplacement	Total	Operations	Transportation	Workers	Public
Geologic Disposal							
HLW Offsite, TRU to WIPP	14,000	1,400	15,000	50	80	2-15	0
HLW Onsite, TRU to WIPP	14,000	1,400	15,000	50	40	2-15	0
In-Place Stabilization and Disposal	2,400	--[d]	2,400	0.8	--	0-2	0
Reference (combination)							
HLW Offsite, TRU to WIPP	3,600	230	3,800	1	40	0-4	0
HLW Onsite, TRU to WIPP	3,600	230	3,800	1	40	0-4	0
Preferred Alternative[e]	3600-14,000	230-1,400	3,800-15,000	1-50	40-80	0-15	0
No Disposal Action							
Continued Storage[f]	1,900	--	1,900	2	--	0-2	0

(a) For comparison, the annual dose to each person from naturally occurring sources is about 0.1 rem. On that basis, the population dose in the Hanford environs from naturally occurring sources over the operational period would be about 2,500,000 man-rem. If the same ratio of health effects to population dose is applied to this dose as many as 2,500 health effects might be expected due to radiation dose from natural background.

(b) Distinction is made between dose for 1) the population within 80-km radius of 200 Area that would be incurred during disposal operations and 2) the population along transportation routes plus train crew (see Appendix I for detailed explanation). Doses rounded to one significant figure.

(c) Health effects are fatal cancers and genetic effects presumed to have been caused by exposure to radiation. A rate of 100 to 1,000 health effects per million man-rem was used.

(d) A dash indicates that there is no associated dose.

(e) Impacts for preferred alternative are shown as ranges. Since disposal of single-shell tank waste, TRU-contaminated soil sites and pre-1970 buried suspect TRU-contaminated solid wastes in the preferred alternative has been deferred, the impacts for the preferred alternative could range from those of the reference alternative to those of the geologic alternative for these waste classes.

(f) Impacts shown are for the 60-year operational period. Similar impacts could be expected for each century of storage thereafter.

3.4.1.2 Potential Radiological Accidents

The potential for accidents during operations associated with the various disposal alternatives was also investigated. Accidents most likely to result in dose to the public are those in which radionuclides are released to the atmosphere. Accidents identified ranged from minor process upsets that occur about once a year, but result in no release, to accidents that occur less frequently, but which have a potential for significant release of radioactive material. Estimates of total-body dose commitments to the population from postulated accidents and releases were made and are compared in Table 3.4.

Generally the same operational accidents would be anticipated in each of the alternatives for the several classes of waste. It turns out that this is true for the accidents having the largest consequences. For waste classes where differences occur in the results of accidents, the consequences are all of low significance. Thus, operational accidents do not appear to be discriminating in terms of environmental impacts among the alternatives.

The total radiological risk from transportation accidents (see Appendix I) amounted to 2.7×10^{-4} to 1.2×10^{-2} for the geologic, reference and preferred alternatives, for HLW disposal of on site or off site, respectively. The risk was zero for the in-place stabilization and disposal alternative and the no disposal action alternative. Only one radiation-related fatality was calculated to result from shipment of all waste to an offsite repository in the geologic alternative, and none were calculated to result from transportation of waste in the other alternatives.

3.4.1.3 Nonradiological Impacts--Injuries, Illnesses and Fatalities

Table 3.5 summarizes nonradiological injuries, illnesses and fatalities associated with workers implementing the several alternatives. Most of these values were generated based on anticipated man-hours to accomplish certain tasks or, in the case of transportation, they were based on accident statistics related to distance traveled. Calculation methods are detailed in Appendix G.

The highest number of injuries, illnesses and fatalities would result for the geologic disposal alternative (accidents at the geologic disposal site excluded). Over 900 injuries and illnesses could result, or from about four to eight times as many as for the other alternatives. Although small, the number of nonradiological fatalities associated with the geologic disposal alternative is five times that for the reference alternative.

TABLE 3.4. Summary of Radiological Consequences to the Public Associated with Postulated Accidents During Implementation of Alternatives

Waste Class	Description of Upper-Bound Accident	70-yr--Population Dose Commitment, man-rem				
		Geologic[a] Disposal	In-Place[a] Stabilization and Disposal	Reference[a] Alternative	Preferred Alternative[b]	No Disposal[c] Action
Existing Tank Waste	Explosion of ferrocyanide or other organic precipitates during mechanical retrieval or stabilizing operations	7,000	7,000	7,000	7,000	NA[d]
	Pressurized release of liquid waste due to failure of a diversion box pipefitting during hydraulic retrieval operations	NA	NA	NA	2,000	2,000
Future Tank Waste	Pressurized release of liquid waste due to failure of a diversion box pipefitting during hydraulic retrieval operations	2,000	2,000	2,000	2,000	2,000
Sr/Cs Capsules	Rupture of a strontium capsule by improper handling during retrieval operations	1×10^{-2}	NA	1×10^{-2}	1×10^{-2}	NA
	Shearing of a strontium capsule by improper handling in DWSF operations	NA	10	NA	NA	10
Retrievably Stored and Newly Generated TRU	Pressurized release due to buildup of radiolytic gases from waste drum rupture if dropped	100	NA	100	100	NA
	Breach of waste container during package disposal operations	NA	80	NA	NA	NA
	Collapse of voids at waste site during subsidence-control operations	NA	NA	NA	NA	0.2
TRU-Contaminated Soil Sites	Deflagration of contaminated material due to process malfunction in slagging pyrolysis incinerator	4×10^{-2}	NA	NA	4×10^{-2}	NA
	Collapse of voids in soil site during subsidence-control operations	NA	2×10^{-3}	2×10^{-3}	2×10^{-3}	2×10^{-3}
Pre-1970 TRU Solid Waste	Deflagration of contaminated material due to process malfunction in slagging pyrolysis incinerator	0.3	NA	NA	0.3	NA
	Collapse of void space at waste site during subsidence-control operations	NA	2×10^{-2}	2×10^{-2}	2×10^{-2}	2×10^{-2}

(a) Additional protection in the case of TRU-contaminated soil and pre-1970 TRU buried waste already disposed of.
(b) Impacts for preferred alternative are shown as ranges. Since disposal of single-shell tank waste, TRU-contaminated soil sites and pre-1970 buried suspect TRU-contaminated solid wastes in the preferred alternative have been deferred, the impacts for the preferred alternative could range from those of the reference alternative to those of the geologic alternative for those waste classes.
(c) No additional protection in the case of TRU-contaminated soil and pre-1970 TRU buried waste already disposed of.
(d) NA--not applicable or bounded by the impact of another accident in that waste class.

TABLE 3.5. Summary of Estimated Nonradiological Injuries, Illnesses and Fatalities Associated with Implementing Alternatives

Disposal Alternatives	Injuries and Illnesses[a]	Fatalities (total)
Geologic Disposal		
HLW Onsite; TRU to WIPP	910	5
HLW Offsite; TRU to WIPP	880	6
In-Place Stabilization and Disposal	110	0
Reference (Combination)		
HLW Onsite; TRU to WIPP	230	1
HLW Offsite; TRU to WIPP	220	1
Preferred[b]		
HLW Onsite; TRU to WIPP	230-910	1-5
HLW Offsite; TRU to WIPP	220-880	1-6
No Disposal Action[c]		
Continued Storage	130	0

(a) Lost workday cases.
(b) Impacts for preferred alternative are shown as ranges. Since the final decisions on disposal of single-shell tank waste, TRU-contaminated soil sites and pre-1970 buried suspect TRU-contaminated solid wastes have not been made, the impacts for the preferred alternative could range from those of the reference alternative to those of the geologic alternative for those waste classes.
(c) For first 100 years. The same impacts could be expected for each additional century of continued storage.

Nonradiological impacts associated with transportation were estimated as follows (Appendix I):

	Injuries	Fatalities
Geologic Disposal		
HLW onsite; TRU to WIPP	13	1
HLW offsite; TRU to WIPP	21	2
In-place Stabilization and Disposal	0	0
Reference Alternative		
HLW onsite; TRU to WIPP	10	1
HLW offsite; TRU to WIPP	10	1
Preferred Alternative		
HLW onsite; TRU to WIPP		1
HLW offsite; TRU to WIPP		1-2
No (Disposal) Action	0	0

3.4.1.4 Resource Commitments

Estimates of commitments of resources associated with implementation of the several disposal alternatives are summarized in Table 3.6.

TABLE 3.6. Summary of Estimated Resource Commitments to Implement Alternatives

Resource	Disposal Alternatives: Geologic Disposal HLW Onsite	Geologic Disposal HLW Offsite	In-Place Stabilization and Disposal	Reference (Combination) HLW Onsite; TRU to WIPP	Reference (Combination) HLW Offsite; TRU to WIPP	Preferred Alternative[a] HLW Onsite; TRU to WIPP	Preferred Alternative[a] HLW Offsite; TRU to WIPP	No Disposal Action (Continued Storage)[b]
Energy								
Propane, m^3	97,000	97,000	3,100	14,000	14,000	14,000 - 97,000	14,000 - 97,000	17,000
Diesel Fuels, m^3	120,000	120,000	78,000	74,000	75,000	74,000 - 120,000	75,000 - 120,000	110
Gasoline, m^3	14,000	15,000	2,500	4,200	4,200	4,200 - 14,000	4,200 - 15,000	1,700
Electricity, GWh	5,000	5,100	1,500	3,800	3,800	3,800 - 5,000	3,800 - 5,100	300
Coal, t	520,000	530,000	73,000	46,000	47,000	46,000 - 520,000	47,000 - 530,000	110,000
Materials								
Concrete, m^3	300,000	300,000	18,000	65,000	65,000	65,000 - 300,000	65,000 - 300,000	46,000
Steel, t	80,000	80,000	11,000	14,000	14,000	14,000 - 80,000	14,000 - 80,000	26,000
Stainless steel, t	6,600	6,600	30	1,400	1,400	1,400 - 6,600	1,400 - 6,600	43
Lumber, m^3	47,000	47,000	4,500	10,000	10,000	10,000 - 47,000	10,000 - 47,000	8,000

(a) Impacts for preferred alternative are shown as ranges. Since disposal of single-shell tank waste, TRU-contaminated soil sites and pre-1970 buried suspect TRU-contaminated solid wastes in the preferred alternative has been deferred, the impacts for the preferred alternative could range from those of the reference alternative to those of the geologic alternative for those waste classes.
(b) For the first 100 years.

Implementation of the geologic disposal alternative would require the most resources, followed by the preferred alternative, reference disposal alternative, no disposal action (for the first 100 years) and in-place stabilization and disposal. These resources are required over a period of 15 to 30 years, and none are in short supply. Additional resources would be needed for the no disposal alternative because of the ongoing maintenance that would be required. Even the resources required by the geologic disposal alternative are not significant on a national scale, but appear significant when compared to the other alternatives.

3.4.1.5 Ecological Impacts

The greatest ecological impact is expected to result from implementation of the geologic disposal alternative. Although areas where the waste sites are located were already previously disturbed from production and waste management activities, the retrieval of wastes in tanks, trenches, etc., would result in renewed temporary disruptions of selected land areas on the 200 Areas plateau.

Temporary disruption of plant and animal communities would also result from implementation of each of the alternatives. Principal evidence of disposal activities remaining during the postdisposal period would consist of the protective barrier and marker system and the storage piles for repository mine spoils. There are no federally designated threatened or endangered species on which disposal actions would likely impinge, although the lack of human pressures on biota on the Hanford Site has resulted in the site being used as sanctuary for some species. Because only temporary further disruption of plant and animal communities at currently disrupted sites would be expected and would be similar regardless of alternative, ecological impacts are not helpful in differentiating among disposal alternatives.

3.4.1.6 Socioeconomics

The extensive nuclear-related development work that began at Hanford in 1943 has been a major factor in the socioeconomy of the surrounding area. The Tri-Cities (Richland, Kennewick, and Pasco) and the remainder of Benton and Franklin Counties are the areas that potentially would be most affected by future activities on the Hanford Site, based on a careful review of previous Hanford Site socioeconomic studies that have demonstrated that almost all growth-related socioeconomic effects occur within these two counties.

However, with recent termination of major non-defense-related construction efforts on the Hanford Site, as well as a general downturn in the economy, the local area has an excess of housing and schools. With new freeways recently completed, traffic increases would not be expected to be a problem. Thus housing, institution and transportation requirements for the workers and their families could be readily accommodated by the existing capacity in the Tri-Cities metropolitan area. Therefore, growth-related socioeconomic concerns would be of low significance in arriving at a decision on a disposal alternative. Potential social impacts associated with the hazardous, radioactive nature of the defense waste materials are also expected to be of low significance. As is explained in Appendix K, this is because the defense waste disposal alternatives are projected to reduce risks to the environment and health and safety from Hanford wastes to well below those from background levels and well within limits established by existing regulatory standards. There is a large body of

literature on risk perception; the nuances are beyond the scope of this EIS (see for example, the Journal of the Risk Analysis Society). In this study, risk to humans is defined as fatalities, genetic effects and mobidity. Risks to plants and animals are treated in this EIS, as are economic and societal consequences of the possible disposal actions. Perceptions, difficult to measure and even more difficult to quantify, are not treated in this EIS. However, public perceptions of economic risks, of defense waste management program credibility, and of the attractiveness of this region to future growth and development are expected to be enhanced by the implementation of a defense waste disposal program.

Concern has been expressed with respect to other activities on the Hanford Site in regard to future land use, and possible effects on tourism; similar concerns can be anticipated with respect to disposal of Hanford wastes. The Hanford Site, however, has been dedicated to nuclear-related work for over 40 years and is expected to remain so dedicated. Portions of the Site (~5%) have been affected by industrial-type construction and operation and are not pristine in nature. Past operations and waste disposal have made an irretrievable and irreversible commitment of major portions of the unconfined aquifer to waste management. On the other hand, except for access roads for fire control and security, the surface areas of the buffer zones on the Hanford Site surrounding the operational areas are in a nearly pristine state and are expected to remain so.

3.4.1.7 Costs

Estimated costs (Rockwell 1987) to implement disposal or continue storage of Hanford's high-level, transuranic and tank waste varied significantly among waste classes and alternatives. Costs associated with implementing the various alternatives are summarized in Table 3.7. Costs are higher than in the draft EIS primarily because of increased estimated cost of repository emplacement.

Costs are highest for the geologic disposal alternative, totaling about $17 billion, five to nine times those required for implementing the other alternatives.

These costs represent totals for the first 100 years of continued storage or for the periods of disposal, which may vary from 20 to 50 years, depending on the waste class of interest.

In the preferred and reference alternatives, the cost of retrieving and processing existing double-shell tank waste is higher per unit volume than that for future tank waste. The total cost for disposing of existing tank waste is about twice as much as for future tank waste. The transportation cost comprises only about 1% of the total disposal cost for tank waste. Therefore no significant difference exists between costs of onsite and offsite disposal of those wastes in repositories in similar media.

3.4.1.8 Decontamination and Decommissioning of Retired Waste Processing Facilities

Decontamination is the removal, by chemical or physical methods, of radioactive material from internal and external surfaces of components, systems and structures in a nuclear facility. It is usually the first step toward decommissioning. Decommissioning of a nuclear

TABLE 3.7. Summary of Costs to Implement Disposal Alternatives and the No Disposal Action Alternative, Millions of $1987 (rounded)[a]

Resource	Geologic Disposal: HLW Onsite; TRU to WIPP	Geologic Disposal: HLW Offsite; TRU to WIPP	In-Place Stabilization and Disposal	Reference (Combination): HLW Onsite; TRU to WIPP	Reference (Combination): HLW Offsite; TRU to WIPP	Preferred Alternative[b]: HLW Onsite; TRU to WIPP	Preferred Alternative[b]: HLW Offsite; TRU to WIPP	No Disposal Action Continued Storage[c]
Existing Double-Shell Tank Waste	1,400	1,900	700	1,300	1,300	1,300	1,300	400
Future Tank Waste	1,700	1,800	500	1,300	1,300	1,300	1,300	450
Sr and Cs Capsules	210	210	210	210	210	210	210	300
Retrievably Stored & Newly Generated TRU	180	180	68	190	190	190	190	9
Subtotal	3,500	4,100	1,500	3,000	3,000	3,000	3,000	1,200
Single-Shell Tank Waste	11,300	11,300	700	700	700	700 - 11,300	700 - 11,300	600
TRU Soil Sites	470	470	68	68	68	68 - 470	68 - 470	11
Pre-1970 TRU Solid Waste	1,600	1,600	140	170	170	170 - 1,600	170 - 1,600	5
Total (rounded)	16,900	17,500	2,400	3,900	3,900	3,900 - 16,400	3,900 - 16,400	1,800

(a) Costs were revised from the draft EIS to reflect increased Proposed repository fees. Since the above costs were calculated, further, increased repository fees have been proposed. If put into effect, these additional increases would raise the cost of the geologic alternative by 20%, the reference alternative by 5% and the preferred alternative by 5 to 20%. Although these changes do not affect the relative cost comparison of alternatives, they do widen the cost difference between the geologic and preferred alternatives and the other alternatives. However, the increase has not changed DOE's choice of a preferred alternative. Additional changes in estimated repository fees may be expected in the future.

(b) Costs for preferred alternative are shown as ranges. Because the final decisions on disposal of single-shell tank wastes, TRU-contaminated soil sites and pre-1970 buried suspect TRU-contaminated solid wastes have not been made, the costs of the preferred alternative could range from those of the reference alternative to those of the geologic alternative for those waste classes.

(c) For the first 100 years; costs are about $1.3 billion for each additional century.

facility can be defined as the measures taken at the end of a facility's lifetime to assure protection of public health and safety and the environment from the retired facility.

Decontamination and decommissioning (usually referred to as D&D) as discussed in this EIS are related to facilities built specifically for the treatment of Hanford high-level, tank and TRU waste prior to its disposal. Those facilities are the Hanford Waste Vitrification Plant (HWVP) and the Waste Receiving and Processing (WRAP) facility. Since the HWVP and WRAP are only in a conceptual-design stage, no definite plans are in place for D&D. If plans for construction and operation proceed, plans for D&D would also be made to facilitate these actions more readily at the end of the facilities' lifetimes. For purposes of analysis in this EIS, costs for D&D of these facilities have been estimated at 20% of construction costs.

The usual options for decommissioning are protective storage (also called mothballing), entombment, and removal of radioactive components and dismantling (or in some instances conversion to other nuclear-related uses). These options are briefly described as follows.

Protective Storage. In general the facility may be left intact except that radioactive liquids and wastes would be removed from the site. Appropriate security control, radiation monitoring and environmental surveillance would be established to assure public health and safety.

Entombment. Entombment consists of sealing all remaining highly radioactive or contaminated components. All radioactive fluids and waste would be removed from the site.

Removal of Radioactive Components and Dismantling. All radioactive sources are removed from the site, and the facility is fitted for other use or completely dismantled if no use is foreseen. Each of these options involves decontamination to some degree. A number of processes applicable to decontamination are given in DOE's Decommissioning Handbook (DOE 1980c). All of the basic decommissioning operations have been carried out in the past on at least a small scale. There would be nothing inherent about decontamination that would preclude its meeting standards for occupational exposure (DOE 1979). A study of decommissioning a fuel reprocessing plant containing a waste vitrification facility disclosed that radiological impacts would probably be a small fraction compared to natural background radiation (NRC 1977). Guidelines for radiological characterization of surplus DOE facilities to be decommissioned are given in A Guide for Radiological Characterization and Measurements for Decommissioning of U.S. Department of Energy Surplus Facilities (DOE 1983c).

Regardless of the decommissioning option for Hanford Waste disposal treatment facilities, offsite releases of radioactive material would probably be thousands of times lower than those reported in this EIS for the operational period of these facilities. Consequently, population doses would be correspondingly smaller. The largest population exposure from disposal operations reported in this EIS was for the geologic disposal alternative and amounted to 50 man-rem. Moreover, the impacts of waste treatment operations included the entire inventory of high-level, tank and TRU waste, and thus estimating dose from residuals would amount to double-accounting of a portion (albeit very small) of the inventory. The doses to individuals in the general population anticipated from

decontamination and decommissioning would also be expected to be far below limits established in standards for protection of the environment in EPA's 40 CFR 61 and 40 CFR 141.

Costs for decontamination and decommissioning of the three facilities, developed in Appendices C, D and E, amounted to about $140 million, $14 million and $9 million for the Hanford Waste Vitrification Plant, Transportable Grout Facility and the Waste Receiving and Processing facility, respectively.

3.4.2 Comparison of Long-Term Impacts Among the Disposal Alternatives and No Disposal Action (Continued Storage)

Long-term impacts that might be associated with each of the disposal alternatives and the no disposal action alternative (continued storage) are presented in Chapter 5, described in more detail in Appendices R and U, and are treated probabilistically in Appendix S. In the comparisons that follow, projected impacts on public health and safety in the long term are presented where a) waste sites remain undisturbed and the average annual recharge of meteoric water to groundwater for soils without protective barriers is 0.5 cm/yr (assumed to be representative of current climatic conditions) and b) where disposal systems are altered by natural events and the average annual recharge of meteoric water to groundwater for soils without protective barriers is 5 cm/yr. Impacts are also presented with respect to inadvertent intrusion into the waste sites and into potentially contaminated aquifers on the Hanford Site.

For purposes of analysis, long-term impacts are assessed under the assumption that for the disposal alternatives, active institutional control is absent from the Site after the year 2150 (relying only on passive institutional controls to deter inadvertent human intrusion into the waste sites) and for comparative analysis, that for no disposal action, neither active nor passive institutional controls are present on the Site after 2150. The first assumption is in accord with EPA standard 40 CFR 191 that dictates that active institutional controls cannot be relied upon to ensure public health and safety from disposed-of wastes for more than 100 years after disposal. (If DOE were to select the no disposal action alternative, and active institutional control were maintained, the intrusion accidents would not be realistic.) The same standard suggests that passive institutional controls can be expected to prevent systematic intrusion, but not to prevent occasional inadvertent intrusion. Appendix B of EPA Standard 40 CFR 191 also states that it should be assumed that passive institutional controls or the intruders' own exploratory procedures would be adequate for the intruders to soon detect, or be warned of, the incompatibility of the area with their activities. Thus inadvertent human intrusion into the marked waste sites would be expected to be limited (see also Appendices M and S).

The principal period of interest when estimating long-term impacts was taken to be 10,000 years in accord with EPA's standard 40 CFR 191. Estimates of releases to the accessible environment and their potential impacts were also made that extended the period of interest to 100,000 years.

3.4.2.1 Comparison of Long-Term Impacts of the Alternatives Where Conditions Remain Unchanged: Disposal Systems Operating as Designed

In this case, climatic conditions at Hanford are assumed to remain as at present, restricted access to the Hanford Site is maintained, and the waste sites are undisturbed by human intrusion. Climatic conditions have been characterized in terms of a range of average annual recharge rates for soils without protective barriers. The lower end of this range (0.5 cm/yr), as noted above, is used to represent current climatic conditions while a 5 cm/yr rate is used to represent a wetter climate.

In the case of radiological impacts, perspective is usually given in terms of dose and/or health effects, attributable to naturally occurring radiation sources, to the same downstream population over the same time period. Comparable perspective on impacts is not available for chemicals; hence, calculated concentrations of chemicals associated with the radioactive wastes are compared with EPA drinking-water standards (40 CFR 141.11) for water supplied by public water systems.

Radiological impacts in terms of health effects in the offsite population[(a)] for unchanged conditions are presented for comparison among the alternatives in Table 3.8.

Although differences among the disposal alternatives in terms of population dose can be seen, the total dose is so small that no presumed health effects are projected. Moreover, the largest impact, that of 3 to 30 health effects over 10,000 years associated with the no disposal action alternative, is comparable to the presumed health effects from just 5-years' exposure of this population to natural background radiation. Again, the impacts calculated for the no disposal action alternative are applicable only to the assumed scenario. They do not apply to present disposal operations in which active institutional control is maintained and are not suggestive of the risk of continued operations.

In Chapter 5, results are given under various conditions for potential concentrations of selected chemicals that are inextricably intertwined with radioactive wastes, particularly tank wastes, and that could be leached along with radionuclides from the wastes. For comparison of potential chemical impacts among the alternatives, projected concentrations of nitrate ion (NO_3^-), cadmium, chromium, mercury and fluoride in drinking water were selected as representative of impacts from chemicals in single-shell tanks. Projected concentrations of these chemicals, above ambient concentrations, in mixed Columbia River water are given in Table 3.9. As shown, concentrations of these chemicals are small compared to EPA's 40 CFR 141.11 drinking-water standards. These values apply to downstream users; see Section 3.4.2.3 for impacts on groundwater.

(a) In this instance, the offsite population is taken to be all persons who use the Columbia River as a source of drinking or irrigation water or recreation downstream from the Hanford Site. That population is postulated to grow from a present estimate of 200,000 to 5,000,000 by the year 12,000.

TABLE 3.8. Potential Radiological Impacts[a] in Terms of Presumed Health Effects[b] Over 10,000 Years in the Offsite Population for Current Climatic Conditions: Disposal Systems Operating as Designed

	Disposal Alternatives[c]				
	Geologic Disposal Near-Surface Disposal of Residuals	In-Place Stabilization and Disposal	Reference Alternative	Preferred Alternative[d]	No Disposal Action[e] Continued Storage
Existing Double-Shell Tank Waste	0 (1)[f]	0 (6)	0 (6)	0 (6)	0-1 (9×10^2)
Future Tank Waste	0 (0.4)	0 (1)	0 (1)	0 (1)	2-20 (2×10^4)
Sr/Cs Capsules	0[g]	0[h]	0[h]	0[h]	0[h]
Retrievably Stored and Newly Generated TRU Waste	0[g]	0[h]	0[h,i]	0[h,i]	0 (<0.1)
Subtotal	0 (2)[f]	0 (7)	0 (7)	0 (7)	2-20 (2×10^4)
Single-Shell Tank Waste	0 (1)[f]	0 (3)	0 (3)	0 (1-3)	0-4 (4×10^3)
Previously Disposed-of TRU-Contaminated Soil Sites	0[g]	0[h]	0[h]	0[h]	0[h]
Previously Disposed-of Pre-1970 Buried TRU Solid Waste Sites	0[g]	0[h]	0[h]	0[h]	0 (<0.1)
Total	0 (2)[f]	0 (10)	0 (10)	0 (8-10)	3-30 (3×10^4)

(a) Cumulative population total-body dose is given in parentheses in man-rem. Values may not add due to rounding.
(b) Using the same factors and assumptions, the total number of presumed health effects for the same population and time period from natural background would be from 300,000 to 3,000,000.
(c) Or additional protective action in the case of previously disposed-of TRU and suspect TRU-contaminated wastes.
(d) For waste classes whose disposal decision is deferred, impacts are given as a range: geologic to reference alternative.
(e) Or no additional protective action in the case of previously disposed-of TRU and suspected TRU wastes.
(f) Grouted portion of waste doubly accounted for. In the geologic disposal alternative, processed single-shell tank waste is blended with existing double-shell tank waste in preparation of grout.
(g) No residual wastes.
(h) No release to accessible environment (groundwater) in 10,000 years.
(i) Includes TRU waste removed from 618-11 site (pre-1970 buried suspect TRU-contaminated solid waste).

TABLE 3.9. Calculated Potential Concentrations of Selected Chemicals Associated with Hanford Defense Waste in Mixed Columbia River Water for Current Climatic Conditions,[a] mg/L

Chemical	Disposal Alternatives	No Disposal Action Continued Storage[b]	EPA Drinking-Water Limits
Nitrate Ion	6×10^{-7}	9×10^{-4}	4.5×10^{1}
Cadmiun	6×10^{-14}	3×10^{-11}	1×10^{-2}
Chromium	4×10^{-9}	1×10^{-5}	5×10^{-2}
Mercury	3×10^{-11}	3×10^{-7}	2×10^{-3}
Fluoride	2×10^{-11}	1×10^{-8}	1.4 - 2.4[c]

(a) Source is chemical inventory in tank waste. Contamination begins about 5,000 years after disposal.
(b) Chemicals are in unbarriered single-shell tanks; contaminants arrive at the river about 1,500 years after disposal.
(c) Depending on maximum daily air temperature.

As a point of reference, the ambient concentrations of NO_3^- in Columbia River water upstream of the Hanford Site (Vernita) and below the site at Richland averaged 0.36 mg/L and 0.37 mg/L, respectively, in about 50 samples taken in 1972. The maximum concentration in the set was 1.3 mg/L observed at Vernita.

In summary, where climatic conditions remain as at present, and even in the event of loss of active institutional control, projected environmental impacts are small and there is little to recommend one alternative over another with respect to long-term impacts on public health and safety. Even the no disposal action alternative exhibits only small impacts.

3.4.2.2 Comparison of Long-Term Impacts of the Alternatives Where Disposal Systems are Disrupted by Postulated Natural Events

An analysis was made of postulated natural events that might disrupt wastes in the future as they would be situated following implementation of the various alternatives. (Chapter 5 and Appendix R). Although numerous postulated events were reviewed, only three were identified as having a reasonable expectation of occurring and as being likely to have some consequences for the offsite population. These postulated events were a change to a wetter climate, return of glaciation and partial failure of the protective barrier.

As mentioned in Section 3.4.2.1, the principal potential pathway for exposure of the offsite population is via leaching of wastes by infiltrating precipitation and transport of the leachate through the underlying unsaturated sediments to groundwater and on to the Columbia River.

The wetter climate assumed for analysis in this EIS was one that resulted in an average annual recharge to groundwater of 5 cm/yr on the 200 Areas plateau. A recharge of 5 cm/yr

(conservatively assuming no marked change in vegetation over the disposal sites) is postulated to correspond to precipitation of about 30 cm/yr, which is double the present average annual precipitation levels at Hanford (Appendix Q).

Table 3.10 provides for comparison of radiological impacts over 10,000 years to the off-site population in the event of a wetter climate having an equivalent groundwater average annual recharge rate of 5 cm/yr.

Differences with respect to population dose in Table 3.10 are seen among the disposal alternatives, but again the doses are so small that no health effects are projected for the disposal alternatives. Even the range of presumed health effects for the no disposal action alternative is small compared to the 300,000 to 3,000,000 presumed health effects from natural background radiation for the same population and over the same time period.

A climate change scenario also was examined that included the return of an ice age. During previous ice ages, ice dams have formed on upper tributaries of the Columbia River. These dams, when broken through, have resulted in floods almost unimaginably large [about 2,000 km^3 of water in a period of a few weeks (USGS 1976) compared to the present average annual flow of the Columbia River of about 100 km^3/yr]. Such floods would no doubt impact any wastes disposed of near surface on the Hanford Site.

While radioactive decay will have reduced the hazard from these wastes markedly by the time of the postulated glacial flood in the next 40,000 to 50,000 years, a study was initiated to determine what the fate of the waste following such a flood might be. Results of this study (Craig and Hanson 1985) indicate that the first wave of such a flood could reasonably scour out the waste sites to a depth of several meters; then, as flood waters backed up at Wallula Gap and the water velocity decreased markedly, the sediments and wastes would probably be reworked, and then be redeposited within the Pasco Basin.

If all of ^{239}Pu (the radionuclide of principal interest at 40,000 years after disposal) in the scope of this EIS were entrained uniformly in just the upper 4 m of the sediments of the 6-km by 13-km waste disposal area, the resulting concentration of ^{239}Pu would be about 0.05 nCi/g. The lifetime total-body dose one might receive if residing on such sediments once the waters had receded would be about 0.3 rem. This may be compared to 7 rem that the individual would have received from natural background radiation. If larger areas of scour and reworking of sediments were involved, as they reasonably might be, this concentration would be further reduced. Because of the low concentrations of plutonium and other radionuclides at that time, the radiological consequences of a glacial flood would not be significant in contrast to the effects of the flood itself. Moreover, current technology, if it were available at that time, should be capable of controlling the buildup of water behind ice dams, thus precluding the catastrophic floods just described.

Scenarios were also postulated in which partial failure of the protective barrier occurs in conjunction with a wetter climate. These scenarios were assumed to take place beginning in the year 2500 (it was not believed reasonable to postulate a wetter climate as early as at the time of loss of institutional control, i.e., 2150). It was assumed for analysis of disruptive barrier failure that 10% of the waste comes in contact with infiltration of 50% of

TABLE 3.10. Potential Radiological Impacts[a] in Terms of Presumed Health Effects[b] in the Offsite Population over 10,000 Years for a Wetter Climate

	Disposal Alternatives[c]									
	Geologic Disposal								No Disposal Action[e]	
	Near-Surface Disposal of Residuals		In-Place Stabilization and Disposal		Reference Alternative		Preferred Alternative[d]		Continued Storage	
Existing Double-Shell Tank Waste	0	(20)[f]	0	(9)	0	(9)	0	(9)	80-800	(8×10^5)
Future Tank Waste	0	(8)	0	(9)	0	(9)	0	(9)	200-2,000	(2×10^6)
Sr/Cs Capsules	0[g]		0[h]		0[h]	0[h]		0[h]		
Retrievably Stored and Newly Generated TRU Waste	0[g]		0[h]		0[h,i]	0[h,i]			0	(0.2)
Subtotal	0	(28)[f]	0	(18)	0	(18)	0	(18)	300-3,000	(3×10^6)
Single-Shell Tank Waste	0	(22)[f]	0	(19)	0	(19)	0	(19-22)	100-1,000	(1×10^6)
Previously Disposed-of TRU-Contaminated Soil Sites	0[g]		0[h]		0[h]	0[h]		0	(<0.1)	
Previously Disposed-of Pre-1970 Buried TRU Solid Waste Sites	0[g]		0[h]		0[h]	0[h]		0	(4)	
Total	0	(30)[f]	0	(37)	0	(37)	0	(37-40)	400-4,000	(4×10^6)

(a) Cumulative population total-body dose is given in parentheses in man-rem. Values may not add due to rounding.
(b) Using the same factors and assumptions, the total number of presumed health effects for the same population and time period from natural background would be from 300,000 to 3,000,000.
(c) Or additional protective action in the case of previously disposed-of TRU and suspected TRU wastes.
(d) For waste classes whose disposal decision is deferred, impacts are given as a range: geologic to reference alternative.
(e) Or no additional protective action in the case of previously disposed-of TRU and suspected TRU wastes.
(f) Grouted portion of waste doubly accounted for. In the geologic disposal alternative, processed single-shell tank waste is blended with existing double-shell tank waste in preparation of grout.
(g) No residual wastes.
(h) No release to accessible environment (groundwater) in 10,000 years.
(i) Includes TRU waste removed from 618-11 site (previously disposed-of pre-1970 buried suspect TRU-contaminated solid waste).

the average annual precipitation. (For further discussion of this failure scenario see Appendix M.) Although the disruptive mechanism is not specified, it could result from a number of events. These include a range fire (started by lightning) that removes vegetation, after which prolonged and stronger-than-usual winds denude part of the exposed soil atop the barrier; animals excavate, over time, numerous burrows; or in the case of absence of active institutional controls (discussed later), human intrusion results in partial removal of soil covering. There is no factual relationship between a wetter climate and barrier failure; they were combined to obtain a conservative estimate of impacts.

The second barrier failure considered was a functional failure over a larger portion of the barrier. Various phenomena might cause the degraded performance used in this analysis (see Appendix M for details). One such cause might be the use of construction materials, particularly the topsoils, that are out of specifications. The functional failure is defined such that 50% of the barrier area allows 0.1 cm/yr of water to infiltrate the underlying waste when the average annual precipitation amounts to 30 cm/yr.

Consequences of such postulated barrier failures were combined and are given in Table 3.11 as the sum of consequences projected to occur with the barrier performing as designed and the additional consequences of failure. For the disposal alternatives, the consequences of the disruptive barrier failure scenario and coincident wetter climate are comparable to the presumed health effects (1 to 7) from a single year's exposure to natural background radiation of the present estimated 70,000 people drinking Columbia River water.

Analysis of chemical transport from the waste site where barriers remain intact under a wetter climate having an average annual recharge of 5 cm/yr was also made, and concentrations of nitrate ion (NO_3^-), cadmium, chromium, mercury and fluoride in mixed Columbia River water are presented in Table 3.12. Again, analysis indicates that the concentrations of these chemicals are small fractions of the limits established by EPA drinking-water standards.

3.4.2.3 Impacts in the Long Term from Postulated Human Intrusion into Waste Sites

This section presents an assessment of long-term radiological and hazardous-chemical consequences in the event that active institutional control is lost and disposal systems, or stored wastes in the case of the no disposal action alternative, are disrupted by human intrusion.

In presenting radiological impacts from intrusions into waste sites, the impacts are expressed as probability-weighted fatalities. Impacts are presented both where passive institutional controls such as land use records and markers are effective and where they are ignored or nonexistent. Where exposure is prolonged, the health effects relationship summarized in Appendix N is used. In some instances, consequences amount to large fatal doses (here taken as 300 rem total-body acute exposure), in which case latent cancers and genetic effects would be precluded. In addition, fatality is assumed if the sustained annual doses exceed the following: 30 rem to the total body; 140 rem to the lung; 3,000 rem to bone; or 1,000 rem to the thyroid. (These latter values were derived from the health effects relationship summarized in Appendix N. Health impacts based on the relationships presented in

TABLE 3.11. Potential Radiological Impacts[a] in Terms of Presumed Health Effects[b] in the Offsite Population over 10,000 Years from a Wetter Climate Coincident with Both Disruptive and Functional Barrier Failures Occurring in the Year 2500

	Disposal Alternatives[c]									
	Geologic Disposal								No Disposal Action[e]	
	Near-Surface Disposal of Residuals		In-Place Stabilization and Disposal		Reference Alternative		Preferred Alternative[d]		Continued Storage	
Existing Double-Shell Tank Waste	0	(120)[f]	0	(160)	0	(140)	0	(140)	80-800	(8×10^5)
Future Tank Waste	0	(40)	0	(69)	0	(49)	0	(49)	200-2,000	(2×10^6)
Sr/Cs Capsules	0[g]		0[h]		0[h]		0[h]		0[h]	
Retrievably Stored and Newly Generated TRU Waste	0[g]		0[h]		0[h,i]		0[i]		0	(0.2)
Subtotal	0	(160)	0	(230)	0	(190)	0	(190)	300-3,000	(3×10^6)
Single-Shell Tank Waste	0	(180)	0	(390)	0	(390)	0	(180-390)	100-1,000	(1×10^6)
Previously Disposed-of TRU-Contaminated Soil Sites	0[g]		0[h]		0[h]		0		0	(<0.1)
Previously Disposed-of Pre-1970 Buried TRU Solid Waste Sites	0[g]		0[h]		0[h]		0[h]		0	(4)
Total	0	(340)[f]	0-1	(620)	0-1	(580)	0	(370-580)	400-4,000	(4×10^6)

(a) Cumulative population total-body dose is given in parentheses in man-rem. Values may not add due to rounding.
(b) Using the same factors and assumptions, the total number of presumed health effects for the same population and time period from natural background would be from 300,000 to 3,000,000.
(c) Or additional protective action in the case of previously disposed-of TRU and suspected TRU wastes.
(d) For waste classes whose disposal decision is deferred, impacts are given as a range: geologic to reference alternative.
(e) Or no additional protective action in the case of previously disposed-of TRU and suspected TRU wastes.
(f) Grouted portion of waste doubly accounted for. In the geologic disposal alternative, processed single-shell tank waste is blended with existing double-shell tank waste in preparation of grout.
(g) No residual wastes.
(h) No release to accessible environment (groundwater) in 10,000 years.
(i) Includes TRU waste removed from 618-11 site (previously disposed-of pre-1970 buried suspect TRU-contaminated solid waste).

TABLE 3.12. Calculated Potential Concentrations of Chemicals Associated with Hanford Defense Waste in Mixed Columbia River Water for a Wetter Climate,[a] mg/L

Chemical	Disposal Alternatives	No Disposal Action (Continued Storage)[b]	EPA Drinking-Water Limits
Nitrate Ion	7×10^{-7}	9×10^{-3}	4.5×10^{1}
Cadmium	6×10^{-14}	3×10^{-10}	1×10^{-2}
Chromium	4×10^{-9}	2×10^{-4}	5×10^{-2}
Mercury	3×10^{-11}	2×10^{-6}	2×10^{-3}
Fluoride	2×10^{-11}	1×10^{-7}	1.4 to 2.4[c]

(a) Source is chemical inventory in single-shell tanks. Contamination begins about 5,000 years after disposal for barriered waste.
(b) Chemicals are in unbarriered single-shell tanks; contaminants arrive about 300 years after disposal.
(c) Depending on maximum daily air temperature.

Appendix N are probably overly pessimistic for individual exposures; however, they provide some means to make quantitative comparisons among the alternatives.)

Scenarios involving intrusion into a waste site for which a comparison among alternatives is made are the following:

- Exploratory drilling that penetrates a waste site (maximum-inventory sites for each waste class are used for source terms) and brings contaminated drilling mud to the surface, resulting in radiation exposure of the drilling crew.
- A drilling or small excavation scenario followed sometime thereafter by individuals residing on or near the contaminated soils and consuming garden produce raised in the contaminated soil.
- Drilling a well that intercepts an onsite aquifer; individuals reside near the well, drink well water, irrigate a garden with well water, and consume the produce.

In the exploratory drilling scenario it was found that intrusive drilling, for all waste classes except cesium capsules, did not yield fatal results to the drilling crew. Drilling into cesium within 300 years after disposal, or before the year 2350 in the case of no disposal action, could have fatal results.

In the geologic, preferred and reference alternatives, strontium and cesium capsules are disposed of in a deep geologic repository with an expected near-zero probability of penetration. No more than one fatal intrusion was estimated in the case of no disposal action, and no fatalities were estimated in the in-place stabilization and disposal alternative where passive controls were effective. Where passive controls were absent or ignored, no more than

one fatality was estimated for the in-place stabilization and disposal alternative. Thus the risk of fatality from inadvertent drilling into encapsulated strontium and cesium is low for each of the alternatives and essentially zero for the geologic, preferred and reference alternatives.

Impacts were analyzed also for the case where, after (perhaps long after) intrusion into a waste site by drilling or basement-sized excavation has taken place, someone moves on site, takes up residence on or near the contaminated waste site, and consumes produce from a garden grown in the contaminated soil. A summary of the consequences associated with this postdrilling scenario is presented in Table 3.13. For this scenario to occur, the individual would have to ignore the public records, the barriers, and the warning markers associated with the waste sites in each of the disposal alternatives. Such warnings would not be present if loss of active institutional control were to occur in the no disposal action alternative. In this hypothetical analysis it was assumed, for comparison, that active institutional control would be lost in the year 2150. If DOE were to choose the no disposal action alternative, and if active institutional control were maintained, the described intrusion accidents would not be realistic.

As shown in Table 3.13, no fatalities were projected for the geologic disposal alternative. (The values given in Table 3.13 are for a family of four.) When the probability of the intrusion and the reduced probability when taking credit for the protective barrier and marker system are considered, four fatalities were projected for the in-place stabilization and disposal alternative and the reference alternative, zero to four for the preferred alternative and 120 for the no disposal action. Thus the risk of fatality over 10,000 years is low where passive controls such as land use records and markers are effective. The impacts shown in Table 3.13 can be contrasted with those shown in Table 3.14, wherein passive controls were assumed to be absent or ignored.

An analysis was also made, where barriers remain effective, of the consequences that might arise from an individual drilling a well to water near (nominally 5 km) the waste disposal site (the 6- by 13-km site in the 200 Area) and using the well water for domestic purposes and for irrigating a garden. Concentrations of selected radionuclides in this well water down gradient of single-shell tanks in 200 West Area as a function of time are shown in Figure 3.7.(a) The long delay in arrival times is due to the presence of the protective barrier. Concentrations of these radionuclides in groundwater from the geologic disposal alternative result from the 5% single-shell tanks residuals plus the residuals that have been incorporated in grout over which the protective barrier has been placed.

Potential annual doses to individuals regularly consuming well water down gradient from single-shell tanks in 200 West Area are shown as a function of time in Figure 3.8. Doses shown in Figure 3.8 start about 5,000 years after disposal and continue for thousands of years thereafter. The doses are near zero for the first 1,000 years and are substantially

(a) Groundwater flowpaths beneath the 200 Areas are such that it is unlikely that other waste sites would add to that shown in the 200 West Area. Releases from other waste sites would have the effect of broadening the plume of contaminated water.

TABLE 3.13. Potential Radiological Impacts[a] over 10,000 Years Expressed as Probability-Weighted Fatalities Associated with the Postdrilling-Excavation/Habitation Scenario--Passive Institutional Controls Effective

	Disposal Alternatives[b]				
	Geologic Disposal				No Disposal Action[d]
	Near-Surface Disposal of Residuals	In-Place Stabilization and Disposal	Reference Alternative	Preferred Alternative[c]	Continued Storage
Existing Double-Shell Tank Waste	0	0	0	0	20
Future Tank Waste	0	0	0	0	20
Sr/Cs Capsules	0[e]	0	0[e]	0	12
Retrievably Stored and Newly Generated TRU Waste	0[e]	0	0[e,f]	0[e,f]	0
Subtotal	0	0	0	0	52
Single-Shell Tank Waste	0	4	4	0-4	64
Previously Disposed-of TRU-Contaminated Soil Sites	0[e]	0	0	0	0
Previously Disposed-of Pre-1970 Buried TRU Solid Waste Sites	0[e]	0	0	0	0
Total	0	4	4	0-4	120

(a) Estimated such that there is one chance in 10,000 that the number of events cited would be exceeded. It is assumed that a family of 4 is involved in each event.
(b) Or additional protective action in the case of previously disposed-of TRU and suspected TRU wastes.
(c) Or no additional protective action in the case of previously disposed-of TRU and suspected TRU wastes.
(d) For waste classes whose disposal decision is deferred. Impacts are given as a range: geologic to reference alternative.
(e) No residual wastes.
(f) Includes TRU waste removed from 618-11 site (previously disposed-of pre-1970 buried suspect TRU-contaminated solid waste).

TABLE 3.14. Potential Radiological Impacts[a] over 10,000 Years Expressed as Probability-Weighted Fatalities Associated with the Postdrilling-Excavation/Habitation Scenario--Passive Institutional Controls Absent or Ignored

	Disposal Alternatives[b]				
	Geologic Disposal				No Disposal Action[d]
	Near-Surface Disposal of Residuals	In-Place Stabilization and Disposal	Reference Alternative	Preferred Alternative[c]	Continued Storage
Existing Double-Shell Tank Waste	0	0	0	0	20
Future Tank Waste	0	48	0	0	20
Sr/Cs Capsules	0[e]	16	0[e]	0[e]	12
Retrievably Stored and Newly Generated TRU Waste	0[e]	0	0[e,f]	0[e,f]	0
Subtotal	0	64	0	0	52
Single-Shell Tank Waste	0	64	64	0-64	64
Previously Disposed-of TRU-Contaminated Soil Sites	0[e]	0	0	0	0
Previously Disposed-of Pre-1970 Buried TRU Solid Waste Sites	0[e]	0	0	0	0
Total	0	130	64	0-64	120

(a) Estimated such that there is one chance in 10,000 that the number of events cited would be exceeded. It is assumed that a family of 4 is involved in each event. All events are assumed to be clustered within the period of lethality, i.e., less than 300 years after disposal.
(b) Or additional protective action in the case of previously disposed-of TRU and suspected TRU wastes.
(c) For waste classes whose disposal decision is deferred, impacts are given as a range: geologic to reference alternative.
(d) Or no additional protective action in the case of previously disposed-of TRU and suspected TRU wastes.
(e) No residual wastes.
(f) Includes TRU waste removed from 618-11 site (previously disposed-of pre-1970 buried suspect TRU-contaminated solid waste).

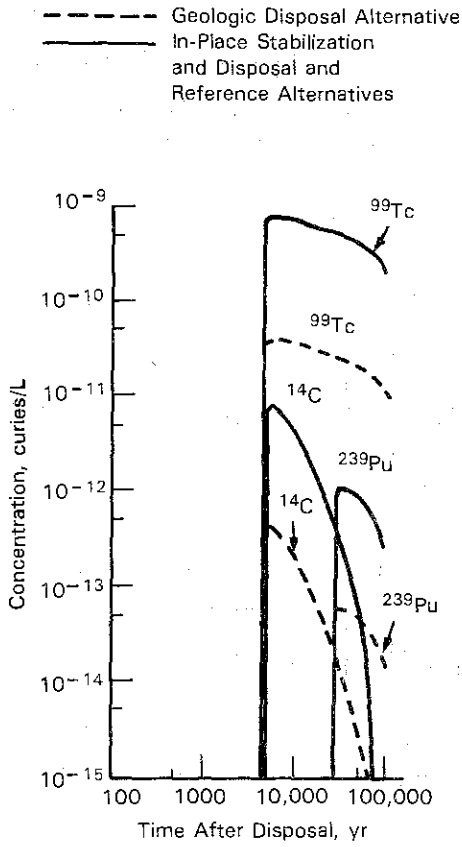

FIGURE 3.7. Concentration of Selected Radionuclides in Well Water from 200 West Area Single-Shell Tanks, 5-cm/yr Recharge (The preferred alternative is bounded by the geologic and reference alternatives.)

below limits established by EPA standards for protection of individuals from high-level and TRU wastes, 40 CFR 191.15. The largest doses, a few millirem/year, are essentially constant for many tens of thousands of years following first entry of radionuclides into the accessible environment, about 5,000 years after disposal.

Potential maximum annual doses to individuals regularly consuming well water from a hypothetical well located down gradient from the 200 Areas waste disposal area are contrasted among the alternatives for conditions under the current climate, a wetter climate and a wetter climate with postulated barrier failures in Tables 3.15, 3.16 and 3.17, respectively.

Doses to an individual regularly drinking water from a hypothetical well contaminated from disposal of wastes for both current and wetter climates are small where the barrier remains effective. The reported doses begin at about 5,000 years after disposal. Although the contrast is large between doses for the no disposal action and disposal alternatives, the impacts are not likely to be an important factor in choosing among the disposal alternatives.

The maximum projected annual critical-organ dose is contrasted among the alternatives in Table 3.18. Again there is little to distinguish among disposal alternatives; the impacts

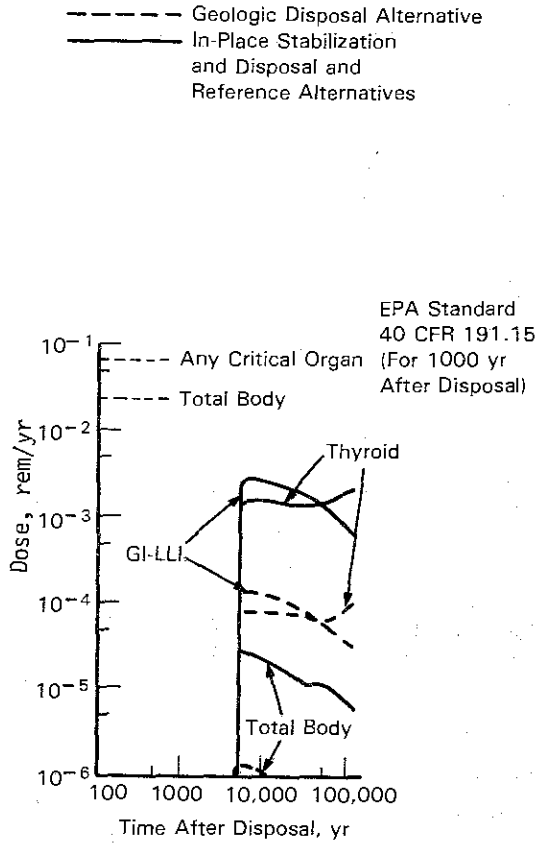

FIGURE 3.8. Annual Dose to Individuals Consuming Well Water Down Gradient of 200 West Area Single-Shell Tanks, 5-cm/yr Recharge (The preferred alternative is bounded by the geologic and reference alternatives.)

from the no disposal action alternative are substantially higher. In the case of a wetter climate, the impacts of the no disposal action alternative are much higher. The main reason for similarity among the disposal alternatives is that the radionuclide contributing the most to dose, ^{129}I, is disposed of near surface in each of the disposal alternatives. There are only 58 Ci of ^{129}I in the entire inventory in question, but if dissolved from the waste it moves at the rate of water and is not impeded. Regardless of impact on groundwater/drinking-water dose, using EPA factors, 58 Ci of ^{129}I would suggest the potential for only about five fatal cancers over 10,000 years if all were released to EPA generic surface waters (no more than one if the Columbia River were the receiving water).

If a well to groundwater near a disposal site produced water for irrigation of food crops as well as for drinking water, and if the water became contaminated, doses to exposed individuals would be higher than reported for consumption of drinking water alone. This scenario is referred to as the full-garden scenario. Potential lifetime total-body doses for individuals consuming contaminated groundwater and crops irrigated with that water under present climatic conditions are presented in Table 3.19. Doses associated with the disposal

TABLE 3.15. Potential Radiological Impacts in Terms of Individual Maximum 1-Year Total-Body Radiation Dose from Drinking Well Water for Current Climatic Conditions, rem

	Disposal Alternatives[a]				
	Geologic Disposal: Near-Surface Disposal of Residuals	In-Place Stabilization and Disposal	Reference Alternative	Preferred Alternative[b]	No Disposal Action[c]: Continued Storage
Existing Double-Shell Tank Waste	4×10^{-7} to 6×10^{-5}(g)	1×10^{-4}	1×10^{-4}	4×10^{-5} to 1×10^{-4}	8×10^{-1}
Future Tank Waste	1×10^{-5}	1×10^{-5}	2×10^{-5}	2×10^{-5}	3×10^{-1}
Sr/Cs Capsules	0(d)	0(e)	0(e)	0(e)	0(e)
Retrievably Stored and Newly Generated TRU Waste	0(d)	0(e)	0(e,f)	0(e,f)	4×10^{-4}
Single-Shell Tank Waste	1 to 4×10^{-5}(g)	4×10^{-5}	4×10^{-5}	1 to 4×10^{-5}	8×10^{-2}
Previously Disposed-of TRU-Contaminated Soil Sites	0(d)	0(e)	0(e)	0(e)	0(e)
Previously Disposed-of Pre-1970 Buried TRU Solid Waste Sites	0(d)	0(e)	0(e)	0(e)	3×10^{-4}

(a) Or additional protective action in the case of previously disposed-of TRU and suspected TRU wastes.
(b) For waste classes whose disposal decision is deferred, impacts are given as a range: geologic to reference alternative.
(c) Or no additional protective action in the case of previously disposed-of TRU and suspected TRU wastes.
(d) No residual wastes.
(e) No release to accessible environment (groundwater) in 10,000 years.
(f) Includes TRU waste removed from 618-11 site (previously disposed-of pre-1970 buried suspect TRU-contaminated solid waste).
(g) Grouted portion of waste doubly accounted for. In the geologic disposal alternative, processed single-shell tank waste is blended with existing double-shell tank waste in preparation of grout.

TABLE 3.16. Potential Radiological Impacts in Terms of Individual Maximum 1-Year Total-Body Radiation Dose from Drinking Well Water for a Wetter Climate, rem.

	Disposal Alternatives[a]				
	Geologic Disposal: Near-Surface Disposal of Residuals	In-Place Stabilization and Disposal	Reference Alternative	Preferred Alternative[b]	No Disposal Action[c]: Continued Storage
Existing Double-Shell Tank Waste	1×10^{-5}[d]	3×10^{-5}	3×10^{-5}	3×10^{-5}	1×10^{3}
Future Tank Waste	3×10^{-6}	6×10^{-6}	6×10^{-6}	6×10^{-6}	1×10^{2}
Sr/Cs Capsules	0[e]	0[f]	0[f]	0[f]	0[f]
Retrievably Stored and Newly Generated TRU Waste	0[e]	0[f]	0[f]	0[e,g]	1×10^{-5}
Single-Shell Tank Waste	1×10^{-5}[d]	3×10^{-5}	3×10^{-5}	1×10^{-5} to 3×10^{-5}	3×10^{2}
Previously Disposed-of TRU-Contaminated Soil Sites	0[e]	0[f]	0[f]	0[f]	9×10^{-8}
Previously Disposed-of Pre-1970 Buried TRU Solid Waste Sites	0[e]	0[f]	0[f]	0[f]	3×10^{-2}

(a) Or additional protective action in the case of previously disposed-of TRU and suspected TRU wastes.
(b) For waste classes whose disposal decision is deferred, impacts are given as a range: geologic to reference alternative.
(c) Or no additional protective action in the case of previously disposed-of TRU and suspected TRU wastes.
(d) Grouted portion of waste doubly accounted for. In the geologic disposal alternative, processed single-shell tank waste is blended with existing double-shell tank waste in preparation of grout.
(e) No residual wastes.
(f) No release to accessible environment (groundwater) in 10,000 years.
(g) Includes TRU waste removed from 618-11 site (previously disposed-of pre-1970 buried suspect TRU-contaminated solid waste).

TABLE 3.17 Potential Radiological Impacts in Terms of Individual Maximum 1-Year Total Body Dose from Drinking Well Water for a Wetter Climate Coincident with Both Disruptive and Functional Barrier Failures Occurring in the Year 2500, rem

	Disposal Alternatives[a]				
	Geologic Disposal: Near-Surface Disposal of Residuals	In-Place Stabilization and Disposal	Reference Alternative	Preferred Alternative[b]	No Disposal Action[c]: Continued Storage
Existing Double-Shell Tank Waste	1×10^{-3}[d]	1×10^{-3}	5×10^{-4}	1×10^{-3}	1×10^{3}
Future Tank Waste	2×10^{-5}	1×10^{-2}	8×10^{-5}	8×10^{-5}	1×10^{2}
Sr/Cs Capsules	0[e]	0[f]	0[f]	0[f]	0[f]
Retrievably Stored and Newly Generated TRU Waste	0[e]	0[f]	0[f,g]	0[f,g]	1×10^{-5}
Single-Shell Tank Waste	2×10^{-3}[d]	3×10^{-2}	3×10^{-2}	2×10^{-3} to 3×10^{-2}	3×10^{2}
Previously Disposed-of TRU-Contaminated Soil Sites	0[e]	0[f]	0[f]	0[f]	9×10^{-8}
Previously Disposed-of Pre-1970 Buried TRU Solid Waste Sites	0[e]	0[f]	0[f]	0[f]	3×10^{-2}

(a) Or additional protective action in the case of previously disposed-of TRU and suspected TRU wastes.
(b) For waste classes whose disposal decision is deferred, impacts are given as a range: geologic to reference alternative.
(c) Or no additional protective action in the case of previously disposed-of TRU and suspected TRU wastes.
(d) Grouted portion of waste doubly accounted for. In the geologic disposal alternative, processed single-shell tank waste is blended with existing double-shell tank waste in preparation of grout.
(e) No residual wastes.
(f) No release to accessible environment (groundwater) in 10,000 years.
(g) Includes TRU waste removed from 618-11 site (previously disposed-of pre-1970 buried suspect TRU-contaminated solid waste).

TABLE 3.18. Potential Radiological Impacts in Terms of Maximum Annual Organ Dose to an Individual Regularly Consuming Water from a Contaminated Well, rem[a]

	Geologic Disposal: Near-Surface Disposal Residuals	In-Place Stabilization and Disposal	Reference Alternative	Preferred Alternative	No Disposal Action
Current Climate	7×10^{-3} (Thyroid, ^{129}I, at 5,500 yr)	1×10^{-2} (Thyroid, ^{129}I, at 5,000 yr)	1×10^{-2} (Thyroid, ^{129}I, at 5,000 yr)	1×10^{-2} (Thyroid, ^{129}I, at 5,000 yr)	3×10^{1} (Thyroid, ^{129}I, at 400 yr)
Wetter Climate	1×10^{-3} (Thyroid, ^{129}I, at 5,200 yr)	3×10^{-3} (Thyroid, ^{129}I, at 5,000 yr)	3×10^{-3} (Thyroid, ^{129}I, at 5,100 yr)	3×10^{-3} (Thyroid, ^{129}I, at 5,000 yr)	4×10^{3} (bone, ^{90}Sr, at 400 yr)
Wetter Climate Plus Functional Barrier Failure	4×10^{-2} (Thyroid, ^{129}I, at 4,500 yr)	3×10^{-1} (GI, ^{99}Tc at 5,400 yr)	3×10^{-1} (GI, ^{99}Tc, at 5,400 yr)	4×10^{-2} (Thyroid, ^{129}I, at 4,500 yr) to 3×10^{-1} (GI, ^{99}Tc at 5,400 yr)	NA
Wetter Climate plus Disruptive Barrier Failure	1×10^{-1} (Thyroid, ^{129}I, at 1,000 yr)	1 (Thyroid, ^{129}I, at 200 yr)	1 (Thyroid, ^{129}I, at 200 yr)	1×10^{-1} (Thyroid, ^{129}I, at 500 yr) to 1 (Thyroid, ^{129}I at 200 yr)	NA

(a) Critical organ, principal contributing radionuclide and time of initial occurrence are given in parentheses. For perspective, EPA standard 40 CFR 191.15 provides for a limit of 25 mrem/yr to the total body and 75 mrem/yr to any critical organ during the first 1,000 years of undisturbed performance of the disposal system. EPA standard 40 CFR 141.16 limits dose to individuals consuming water from a community water system to 4 mrem/yr to the whole body or any critical organ.

TABLE 3.19. Potential Radiological Impacts Expressed as Individual Maximum Lifetime Total-Body Doses from the Full-Garden Scenario, 0.5 cm/yr Average Annual Recharge, rem

	Disposal Alternatives[a]				
	Geologic Disposal				
	Near-Surface Disposal of Residuals	In-Place Stabilization and Disposal	Reference Alternative	Preferred Alternative[b]	No Disposal Action[c] Continued Storage
Existing Double-Shell Tank Waste	2×10^{-1}[d]	1×10^{-1}	1×10^{-1}	1×10^{-1} to 2×10^{-1}	4×10^{2}
Future Tank Waste	6×10^{-3}	8×10^{-2}	2×10^{-2}	2×10^{-2}	1×10^{2}
Sr/Cs Capsules	0[e]	0[f]	0[e]	0[f]	0[f]
Retrievably Stored and Newly Generated TRU Waste	0[e]	0[f]	0[c,e]	0[e,g]	3×10^{-1}
Single-Shell Tank Waste	2×10^{-1}[d]	1×10^{-1}	1×10^{-1}	1×10^{-1} to 2×10^{-1}	1×10^{1}
Previously Disposed-of TRU-Contaminated Soil Sites	0[e]	0[f]	0[f]	0[f]	0[f]
Previously Disposed-of Pre-1970 Buried TRU Solid Waste Sites	0[e]	0[f]	0[f]	0[f]	1×10^{-1}

(a) Or additional protective action in the case of previously disposed-of TRU and suspected TRU wastes.
(b) For waste classes whose disposal decision is deferred, impacts are given as a range: geologic to reference alternative.
(c) Or no additional protective action in the case of previously disposed-of TRU and suspected TRU wastes.
(d) Grouted portion of waste doubly accounted for. In the geologic disposal alternative, processed single-shell tank waste is blended with existing double-shell tank waste in preparation of grout.
(e) No residual wastes.
(f) No release to accessible environment (groundwater) in 10,000 years.
(g) Includes TRU waste removed from 618-11 site (previously disposed-of pre-1970 buried suspect TRU-contaminated solid waste).

alternatives are all small in comparison to the dose of 7 rem that the individual would have received from natural background during the same period. The dose associated with the no disposal alternative, though larger, would not be expected to be fatal.

The full-garden scenario was also analyzed for conditions where the climate changed to the equivalent of 5-cm/yr annual average recharge to groundwater. The results are presented in Table 3.20. Again potential doses associated with the disposal alternatives are small compared to the 7 rem the individual would have received from natural background. In contrast to the results for the no disposal action alternative under the drier climatic conditions, the results for the no disposal action alternative and a 5-cm/yr average annual recharge to groundwater indicate very large doses that would likely be fatal in a few years. The principal contributor to these high doses is the future tank waste (liquid) with its high ^{90}Sr content. If DOE were to choose the no disposal action alternative, and if active institutional control were maintained, the described intrusion accidents would not be realistic. After a few hundred years of storage, the ^{90}Sr would have decayed and the very high doses projected above for the no disposal action alternative would not occur.

The full-garden scenario was also analyzed in the cases of the disruptive and functional barrier failure occurring during a wetter climate having an equivalent of a 5-cm/yr average annual recharge to groundwater. Results are presented in Table 3.21. Doses associated with either failure scenario and with the disposal alternatives range up to about the same dose that the individual would receive (7 rem) from natural background radiation. The doses associated with the no disposal action alternative would remain as reported in Table 3.20 since there are no barriers to protect or fail in that alternative.

The potential for contamination of groundwater with chemicals would also exist. Concentrations of selected chemicals in groundwater near the waste disposal site were estimated for continuation of current climate and are presented in Table 3.22. Although concentrations of chemicals in groundwater (Appendix U) were estimated for both 200 East Area and 200 West Area, only the larger of the two are reported here.

In the case of the disposal alternatives, the concentrations of chemicals are below the limits established by EPA drinking-water standards. In the no disposal action alternative in the absence of active institutional controls, the standards are exceeded.

The peak arrival times for these chemicals are about 5,000 years and 1,200 years after disposal for each of the barriered disposal alternatives and the no disposal action alternative, respectively.

As in the case of radionuclide release scenarios, if DOE chose the no disposal action alternative, and if active institutional control were maintained, then monitoring and maintenance would render this scenario unrealistic.

Concentrations of chemicals in groundwater near the waste disposal site were also estimated where the average annual recharge was 5 cm/yr. The results are presented in Table 3.23.

TABLE 3.20. Potential Radiological Impacts Expressed as Individual Maximum Lifetime Total-Body Doses from the Full-Garden Scenario, 5 cm/yr Average Annual Recharge, Barriers Remain Effective, rem

	Disposal Alternatives[a]				
	Geologic Disposal: Near-Surface Disposal of Residuals	In-Place Stabilization and Disposal	Reference Alternative	Preferred Alternative[b]	No Disposal Action[c] (Continued Storage)
Existing Double-Shell Tank Waste	6×10^{-2}[d]	4×10^{-2}	4×10^{-2}	4×10^{-2}	9×10^{6}
Future Tank Waste	3×10^{-2}	3×10^{-2}	3×10^{-2}	3×10^{-2}	1×10^{6}
Sr/Cs Capsules	0[e]	0[f]	0[e]	0[f]	0[f]
Retrievably Stored and Newly Generated TRU Waste	0[e]	0[f]	0[e,g]	0[e,g]	3×10^{-1}
Single-Shell Tank Waste	6×10^{-2}[d]	1×10^{-1}	1×10^{-1}	6×10^{-2} to 1×10^{-1}	2×10^{6}
Previously Disposed-of TRU-Contaminated Soil Sites	0[e]	0[f]	0[f]	0[f]	8×10^{-4}
Previously Disposed-of Pre-1970 Buried TRU Solid Waste Sites	0[e]	0[f]	0[f]	0[f]	1×10^{-1}

(a) Or additional protective action in the case of previously disposed-of TRU and suspected TRU wastes.
(b) For waste classes whose disposal decision is deferred, impacts are given as a range: geologic to reference alternative.
(c) Or no additional protective action in the case of previously disposed-of TRU and suspected TRU wastes.
(d) Grouted portion of waste doubly accounted for. In the geologic disposal alternative, processed single-shell tank waste is blended with existing double-shell tank waste in preparation of grout.
(e) No residual wastes.
(f) No release to accessible environment (groundwater) in 10,000 years.
(g) Includes TRU waste removed from 618-11 site (previously disposed-of pre-1970 buried suspect TRU-contaminated solid waste).

TABLE 3.21. Potential Radiological Impacts Expressed as Individual Lifetime Total-Body Doses from the Full-Garden Scenario for Both Disruptive and Functional Barrier Failures Coincident with a Wetter Climate, rem

	Disposal Alternatives[a]				
	Geologic Disposal				
	Near-Surface Disposal of Residuals	In-Place Stabilization and Disposal	Reference Alternative	Preferred Alternative[b]	No Disposal Action[c] Continued Storage
Existing Double-Shell Tank Waste	4[d]	2	6×10^{-1}	6×10^{-1}	9×10^{6}
Future Tank Waste	1×10^{-1}	1×10^{1}	2×10^{-1}	2×10^{-1}	1×10^{6}
Sr/Cs Capsules	0[e]	0[f]	0[e]	0[e]	0[f]
Retrievably Stored and Newly Generated TRU Waste	0[e]	0[f]	0[e,g]	0[e,g]	3×10^{-1}
Single-Shell Tank Waste	4[d]	2×10^{1}	2×10^{1}	4 to (2×10^{1})	2×10^{6}
Previously Disposed-of TRU-Contaminated Soil Sites	0[e]	0[f]	0[f]	0[f]	8×10^{-4}
Previously Disposed-of Pre-1970 Buried TRU Solid Waste Sites	0[e]	0[f]	0[f]	0[f]	1×10^{-1}

(a) Or additional protective action in the case of previously disposed-of TRU and suspected TRU wastes.
(b) For waste classes whose disposal decision is deferred, impacts are given as a range: geologic to reference alternative.
(c) Or no additional protective action in the case of previously disposed-of TRU and suspected TRU wastes.
(d) Grouted portion of waste doubly accounted for. In the geologic disposal alternative, processed single-shell tank waste is blended with existing double-shell tank waste in preparation of grout.
(e) No residual wastes.
(f) No release to accessible environment in 10,000 years.
(g) Includes TRU waste removed from 618-11 site (previously disposed-of pre-1970 buried suspect TRU-contaminated solid waste).

TABLE 3.22. Calculated Potential Concentrations of Selected Chemicals in Groundwater Near the Waste Disposal Site--0.5-cm/yr Recharge, mg/L

Chemical	Disposal Alternatives	No Disposal Action (Continued Storage)	EPA Drinking-Water Limits
Nitrate Ion	1.0	1.4×10^{3}	4.5×10^{1}
Cadmium	8.6×10^{-8}	5.3×10^{-5}	1×10^{-2}
Chromium	6.0×10^{-3}	2.5×10^{1}	5×10^{-2}
Mercury	5.6×10^{-5}	1.4×10^{-1}	2×10^{-3}
Fluoride	4.2×10^{-6}	9.2×10^{-3}	1.4 to 2.4[a]

(a) Depending on maximum daily air temperature.

TABLE 3.23. Concentrations of Selected Chemicals in Groundwater Near the Waste Disposal Site--5-cm/yr Recharge, mg/L

Chemical	Disposal Alternatives	No Disposal Action (Continued Storage)	EPA Drinking-Water Limits
Nitrate Ion	3.8×10^{-1}	6.0×10^{3}	4.5×10^{1}
Cadmium	4.4×10^{-7}	2.2×10^{-4}	1×10^{-2}
Chromium	2.4×10^{-3}	5.9×10^{1}	5×10^{-2}
Mercury	2.2×10^{-5}	7.4×10^{-1}	2×10^{-3}
Fluoride	2.5×10^{-6}	3.8×10^{-2}	1.4 to 2.4[a]

(a) Depending on maximum daily air temperature.

Again concentrations of chemicals associated with the disposal alternatives compare favorably with the drinking-water standards. In some cases the additional recharge provides dilution to decrease concentrations. On the other hand, in the no disposal action alternative the additional dilution is apparently offset by more rapid dissolution, and the concentrations are larger than for the same scenario for 0.5 cm/yr average annual recharge. Times of peak arrival are about 5,000 years for the barriered disposal alternatives and about 300 years for the no disposal action alternative in the absence of institutional control. In the disposal alternatives, concentrations of chemicals in groundwater in the event of barrier failure would be expected to be on the order of, but less than, the concentrations shown for

the no disposal action alternative. (Tank wastes are in liquid form in the no disposal action alternative and are in solid form in all disposal alternatives, which in the latter case would result in slower releases and smaller concentrations.) Additional waste characterization and transport modeling will be performed prior to implementation of a disposal alternative to assess regulatory compliance.

The arrival times of 300 and 1,200 years for chemicals in the no disposal action alternative were based on average annual recharges of 5 cm/yr and 0.5 cm/yr, respectively. The equivalent artificial recharge caused by current disposal of low-level liquid waste amounts to about 5,000 cm/yr over the area of waste disposal, and is thus a substantially higher driving force resulting in a much shorter travel time. This recharge is the cause of the presently observed distribution and transport of such pollutants as tritium and nitrate in groundwater (Price et al. 1985).

Another scenario was considered wherein at some time in the future the area adjacent to the west bank of the Columbia River in the northeastern part of the site is resettled and wells are dug that reach groundwater. The area in question was inhabited at the time the Hanford Site was established (towns of White Bluffs and Hanford). This scenario is restricted to the number of 2-ha small farms that could be supplied by the volume of contaminated water available. On this basis, the number of small farms was limited to 65. It was then assumed that 65 families composed of four individuals each resettled the land and drew drinking and food crop irrigation water from wells. (In earlier times irrigation water was supplied to this area from the Hanford ditch that took its water supply from the Columbia River upstream of the communities.)

An estimate of the integrated population dose to and health effects among occupants of these small farms was made for both an average annual recharge of 0.5 and 5 cm. The results are presented in Table 3.24.

In the case of the resettlement scenario, there would be none to four health effects associated with the waste disposal alternatives. Thus it could be concluded that resettlement of this area could take place in the future without harm from the wastes disposed of according to any of the waste disposal alternatives described. In the case of no disposal action and in the absence of active institutional control, this scenario would indicate fatal consequences for up to the entire exposed set (65 families of four individuals or about 300 total) for the wetter climate and 10-100 fatalities for the current climate. This scenario could be repeated several times over the 10,000-year period if knowledge of the problem were lost and as the intermittent arrival of high concentrations of radionuclides occurred. If DOE were to choose the no disposal action alternative, and if active institutional control were maintained, the described insrusion accidents would not be realistic.

TABLE 3.24. Potential Integrated Population Total-Body Doses and Presumed Health Effects from the Multiple Small Farm Scenario for the Waste Disposal Alternatives

Disposal Alternative	0.5-cm/yr Recharge		5-cm/yr Recharge	
	Dose, man-rem	Health Effects	Dose, man-rem	Health Effects
Geologic Disposal	4×10^3	0-4	1×10^3	0-1
In-Place Stabilization and Disposal	2×10^3	0-2	2×10^3	0-2
Reference Alternative	2×10^3	0-2	2×10^3	0-2
No Disposal Action	1×10^5	10-100(a)	2×10^9	300(a)
Preferred(b)	2×10^3 to 4×10^3	0-4	1×10^3 to 2×10^3	0-2

(a) May occur more than once.
(b) For waste classes whose disposal decision is deferred, the impacts would range from those for the geologic to the reference alternatives.

3.4.3 Comparison Among the Alternatives of Key Impacts from Future Tank Waste and Newly Generated TRU Waste

Impacts from future tank waste and newly generated TRU waste are presented here separately to provide a measure of impacts of disposal from additional PUREX campaigns processing N Reactor fuel. Units are waste equivalent of 12,000 t of irradiated uranium processed per campaign.

It could be assumed, for example, that an extension of special nuclear materials production activities would result in the reprocessing of an additional 20,000 t of irradiated uranium. Therefore, the impacts from this extended operation would approximate twice those that are calculated for the 1985-1995 campaign and that are compared among the alternatives in this section. The impacts from the 1983-1995 campaign have already been added to all tables in this EIS that present total impacts. For the 20,000 t extended production of special nuclear materials beyond 1995, the exposure and health impacts stated in this section should be multiplied by two and added to all tables that present total impacts.

Disposition of wastes and therefore the impacts of the preferred alternative are the same as for the reference alternative for these two waste classes.

Radiation doses to the work force and the offsite population as a result of waste disposal operations are shown in Table 3.25.

Operational impacts are essentially zero for the no disposal action alternative and would suggest up to one health effect for the in-place stabilization and disposal and the geologic disposal alternatives. The reference and preferred alternatives indicate up to two health effects.

TABLE 3.25. Calculated Total-Body Radiation Doses Resulting from Routine Operations for Future Tank Waste and Newly Generated TRU Waste

	Occupational Dose, man-rem	Maximum Individual Dose, rem	Population Dose man-rem[a]	Transportation	Total,	Health
	Operations	70-yr Exposure[a]	70-yr Exposure[a,b]	Dose, man-rem[c]	man-rem	Effects
Geologic Disposal Alternative	1,300	1×10^{-4}	9.7	28	1,300	0-1
In-Place Stabilization and Disposal Alternative	750	2×10^{-6}	0.1	negligible	750	0-1
Reference Alternative	1,700	2×10^{-7}	0.4	22	1,700	0-2
Preferred Alternative	1,700	2×10^{-7}	0.4	22	1,700	0-2
No Disposal Action[d]	180	9×10^{-6}	0.5	negligible	180	0

(a) 70-year exposure implies a lifetime accumulated dose from all operations.
(b) Based on estimated 1990 population of 420,000 within 80 km of Hanford.
(c) Transport of high-level waste to alternative high-level waste repository.
(d) For 60-year operating period. Doses would accumulate similarly for each century of continued storage thereafter.

Long-term impacts on the offsite population are contrasted for several scenarios in Table 3.26.

Only in the case of the no disposal action alternative with the assumed loss of institutional control is any meaningful impact suggested. The latter arises principally from the potential for release because of the high mobility of liquid wastes if they were to remain in tanks beyond their expected lifetime.

Long-term impacts to those who might intrude into the waste disposal site and reside on land contaminated by drilling mud or excavation debris are given in Table 3.27 in terms of probability-weighted fatalities (passive institutional controls absent or ignored). A family of four is assumed to be associated with each event.

Wastes in repositories (the destination of those wastes in the geologic, reference and preferred alternatives) approach zero risk in terms of drilling and near-surface excavation. There would likely be no fatalities over 10,000 years for the in-place stabilization and disposal alternative, where warnings were heeded, and 48 fatalities where monuments, records or markers were absent or ignored.

In addition, a full-garden scenario was postulated that had an individual (or individuals) come onto the Hanford Site (but not onto the waste disposal site), drill a well to groundwater and use the water for domestic purposes and to irrigate a garden. Impacts among the alternatives for several variations on the full-garden scenario are contrasted in Table 3.28. As shown in Table 3.28, lifetime doses from the full-garden scenarios are small except in the no disposal action alternative. In that alternative all doses would be fatal except in the case of the current climate.

The potential for impacts from chemicals inextricably intertwined with radionuclides is dominated by those in single-shell tanks. However, the future tank waste introduces about 1,200 t of fluoride, which is in addition to the 800 t in single-shell tanks. Examination of the potential for contamination of Columbia River water showed that the concentrations in mixed Columbia River water would be well below limits established by EPA drinking-water standards under assumption of either the current or a wetter climate.

3.4.4 Comparison of Alternatives with Respect to Potential Impacts on Indians and Indian Reservation Lands

The doses from routine disposal operations to the total population within 80 km of the Site, including the eastern one-third of the Yakima Reservation (about 1% of the exposed population) were shown in Sections 3.4.1.1 to be near zero for each of the disposal alternatives. In the reasonably postulated accident with the most severe consequences (the same in each of the alternatives) the calculated population dose was about 1% of the dose allowed by EPA standards during routine disposal operations (40 CFR 191).

For each of the alternatives, estimates were also made of the amounts of nuclides that might be transported to the Columbia River over the next 10,000 years and the doses that downstream populations might receive. The doses calculated included contributions from drinking water, crops irrigated with river water and consumption of fish that had lived in

TABLE 3.26. Potential Radiological Impacts[a] in Terms of Presumed Health Effects[b] Among the Offsite Population Over 10,000 Years from Future Tank and Newly Generated TRU Waste

	Disposal Alternatives				
	Geologic Disposal: Near-Surface Disposal of Residuals	In-Place Stabilization and Disposal	Reference Alternative	Preferred Alternative	No Disposal Action
Current Climatic Conditions	0 (0.4)	0 (1)	0 (1)	0 (1)	2-20 (2×10^4)
Wetter Climate	0 (8)	0 (9)	0 (9)	0 (9)	200-2,000 (2×10^6)
Wetter Climate plus Disruptive and Functional Barrier Failures	0 (40)	0 (69)	0 (49)	0 (49)	NA

(a) Population dose is given in parentheses in man-rem.
(b) Using the same factors and assumptions, the total number of presumed health effects for the same population and time period from natural background would be from 300,000 to 3,000,000.

TABLE 3.27. Potential Radiological Impacts Over 10,000 Years Expressed as Probability-Weighted Fatal Intrusions[a] Associated with the Postdrilling-Excavation/Habitation Scenario--Passive Institutional Controls Absent or Ignored

	Disposal Alternatives				
	Geologic Disposal Near-Surface Disposal of Residuals	In-Place Stabilization and Disposal	Reference Alternative	Preferred Alternative	No Disposal Action
Future Tank Waste	0	48	0	0	20
Newly Generated TRU Waste	0	0	0	0	0
Total	0	48	0	0	20

(a) For conditions given, less than 1 chance in 10,000 of the number of fatal intrusions exceeding the value shown. Intrusions over 10,000 years assumed to be clustered during period of lethality.

TABLE 3.28. Potential Total-Body Radiological Impacts[a] Expressed as Lifetime Total-Body Doses for Future Tank and TRU Waste, rem

	Disposal Alternative				
	Geologic Disposal: Near-Surface Disposal of Residuals	In-Place Stabilization and Disposal	Reference Alternative	Preferred Alternative	No Disposal Action
Full-Garden Scenario, Current Climate (0.5-cm/yr average annual recharge)	6×10^{-3}	8×10^{-2}	2×10^{-2}	2×10^{-2}	1×10^{2}
Full-Garden Scenario, Wetter Climate (5-cm/yr average annual recharge)	3×10^{-2}	3×10^{-2}	3×10^{-2}	3×10^{-2}	1×10^{6}
Full-Garden Scenario, Wetter Climate and Disruptive and Functional Barrier Failure	1×10^{-1}	1×10^{1}	2×10^{-1}	2×10^{-1}	NA

(a) In the same time period, the individual would have received 7 rem from natural background radiation.

the river. The doses were then converted to health effects using factors given in Appendix N. Where the barriers performed as planned, no health effects were forecast for any of the alternatives. In the extremely unlikely event of disruptive failure of all of the barriers, coupled with a wetter climate, the number of health effects in the exposed population, including Indians, over 10,000 years amounted to 4 for the geologic disposal alternative, 26 for the in-place stabilization and disposal alternative, 20 for the reference alternative, 4 to 20 for the preferred alternative and 3,800 for the no disposal action alternative (based on 10 times the results given in Tables R.35, R.39, and R.43 for 10% barrier failure, and in Table R.46). The number of health effects in the same population, assuming that natural background radiation dose is the cause of the health effects, would be over 2,000,000, using the same factors. Although the number of health effects for each of the alternatives was small relative to that allowable, that associated with the geologic disposal alternative was the smallest.

A basis for distinction among alternatives might exist with respect to transportation of waste in the geologic disposal alternative if an offsite repository is required. In that case, waste shipped by truck would be expected to pass through the Umatilla Reservation along Interstate Highway I-84. However, all waste is to be shipped in solid form (no liquids) in certified shipping casks via certified shippers and in accordance with all applicable state and federal regulations for such shipments.

While active institutional control exists, actual physical access to the Site will be limited. However, consultation in accordance with DOE's compliance guidelines regarding the American Indian Religious Freedom Act (AIRFA), PL 95-341, and the National Historic Preservation Act (NHPA), 16 USC 410 et. seq., is planned as part of implementation of the disposal options finally chosen.

Since traditional use of the land by Indians is almost exclusively surface or near surface, and since 3.6-m barriers of basalt riprap topped by 1.5 m of soil would cover the wastes, any of the disposal alternatives should preclude significant impact on Indians socioeconomically, or in terms of health and safety, even if they were to make prolonged visits to the Site in the future with the assumption that active institutional control had been lost. Compliance and consultation, as appropriate, with the requirements of AIRFA and NHPA would occur prior to any land disturbance.

3.4.5 Comparison Among the Alternatives of Impacts on Archaeological, Cultural and Historical Resources

As noted in Section 4.8.5, the principal archaeological, cultural, and historical resources on the Hanford Site relate to places or sites of previous occupancy and use by Indians. The sites are most often associated with the Columbia River; however, other sites have been identified such as in the Gable Mountain/Gable Butte area.

None of the sites identified are within the waste disposal area; as a consequence, none would be affected directly, regardless of alternative. In all except the no disposal action

alternative, large quantities of basalt riprap and soil are needed with which to build barriers over waste sites or over residuals sent to near-surface burial. As a consequence of riprap addition, any impacts on archaeological, cultural or historical sites are expected to be essentially the same regardless of disposal alternative. The DOE is committed to taking all reasonable steps to preserve such places and has initiated a site-wide survey for archaeological and cultural sites to aid in developing an overall plan for resources protection. This plan has been established to carry out the requirements of the federal historic preservation and cultural resource protection statute. It will provide for:

1. development of a research design to guide the survey and direct recovery efforts, in consultation with affected parties
2. initial inventory of cultural resources from both existing records of past archaeological work on the Hanford Site and consultation with knowledgable parties
3. field surveys and subsurface testing for previously unrecorded cultural resources in areas of planned excavation
4. application of National Register eligibility criteria to cultural resources discovered under step 3
5. assessment of site characterization impacts on significant historic and cultural resources
6. planning for avoiding or minimizing these impacts.

The quarry sites for obtaining the riprap will be selected in concert with the resources protection plan.

Because of the distances involved, activities on the 200 Area plateau, regardless of alternative, are not expected to have any impact on sites along the Columbia River or on the National Historic sites in Pasco and Kennewick.

3.4.6 Consideration of Chemicals Associated with Radioactive Wastes

In this section the disposition of chemicals associated with the radioactive waste is described for each disposal alternative.

3.4.6.1 Disposition of Chemicals According to the Disposal Alternatives

In the geologic disposal alternative, the double-shell and single-shell tank wastes will be processed and incorporated into a borosilicate glass for disposal in a commercial repository. Processing before conversion to a borosilicate glass creates a low-activity waste stream that contains the majority of the hazardous chemicals present in the tank wastes. These low-activity radioactive wastes and associated chemicals would be made into grout and disposed of in compliance with RCRA requirements, in near-surface vaults. Strontium and cesium capsules would be processed as required for disposal in a commercial repository. TRU wastes and associated chemicals would be retrieved and packaged for disposal in WIPP.

In the in-place stabilization and disposal alternative, single-shell tank wastes, including the chemical inventory, would be left in the tanks, stabilized and covered with the protective barrier and marker system. Existing double-shell tank wastes would be retrieved, treated with ozone or some alternate process to destroy organic complexants, and made into grout. Future double-shell tank wastes would be retrieved, the cesium would be removed, and the remaining waste would be made into grout. The cesium would be encapsulated and placed in near-surface drywells along with other encapsulated waste. TRU wastes would be disposed of in place. Thus, under the in-place stabilization and disposal alternative, hazardous chemicals associated with the waste would be disposed of in place, or, in the case of double-shell tank wastes, they would be made into grout and disposed of, in compliance with RCRA requirements, in near-surface vaults. In all cases the wastes would be covered with the protective barrier and marker system.

In the reference alternative, double-shell tank wastes would be treated in the same way they would be treated in the geologic disposal alternatives (except that technetium would remain in the low-activity waste stream). The majority of the hazardous chemicals would be associated with the low-activity waste stream created by processing the double-shell tank wastes to incorporate them into borosilicate glass. As in the geologic disposal alternative, this low-activity waste would be made into grout and disposed of, in compliance with RCRA requirements, in near-surface vaults. Single-shell tank wastes and associated chemicals would be stabilized and disposed of in place and covered with the protective barrier and marker system. Retrievably stored TRU wastes would be retrieved, processed and packaged as necessary for disposal in WIPP. Strontium and cesium capsules would be processed and packaged as necessary for disposal in a commercial repository. TRU-contaminated soil sites and buried suspect TRU wastes would be stabilized and disposed of in place with the protective barrier and marker system. Under the reference alternative, the majority of the hazardous chemicals associated with the radioactive wastes would be stabilized and disposed of in place or disposed of near surface in grout vaults.

In the preferred alternative, double-shell tank wastes would be processed and converted to borosilicate glass as in the reference alternative. The majority of the hazardous-chemical waste would be associated with the low-activity radioactive wastes created during the processing of the double-shell tank wastes. This low-activity waste and associated chemicals would be made into grout and disposed of, in compliance with RCRA requirements, in near-surface vaults. The strontium and cesium capsules would be processed and packaged as necessary for disposal in a commercial geologic repository. Retrievably stored TRU would be processed and packaged as necessary for disposal in WIPP.

Disposal decisions regarding single-shell tank wastes, buried suspect TRU waste and TRU-contaminated soil sites would be deferred until further development and evaluation is complete. Continued management of the single-shell tank wastes would be conducted according to applicable hazardous regulations, either CERCLA or RCRA. The buried suspect TRU and TRU-contaminated soil sites would be managed in compliance with CERCLA requirements.

3.4.6.2 Public Health Risk from Chemicals Associated with Radioactive Waste

Potential impacts from selected chemicals associated with the radioactive wastes are presented in Sections 3.4.2.1, 3.4.2.2, 3.4.2.3 and in Chapter 5. Additional information on waste characterization and chemical transport is needed before a comprehensive impact assessment can be performed for all of the chemicals known or suspected to occur with the radioactive wastes.

When the additional information is available, a further assessment of chemical impacts on human health will be performed. It will most likely take the form of a risk assessment (similar to that performed for radioactive materials) that will include the following elements:

- identifying the hazards posed by each chemical constituent
- assessing the degree of exposure to the chemical
- assessing the biological response to specific doses
- characterizing the potential risk to human health.

Hazardous-chemical constituents can be placed in two broad categories: carcinogens, or substances that may cause cancer, and noncarcinogens, which may adversely affect the health of organisms but do not cause cancer. It is assumed that there is some risk of cancer for all carcinogens, even at low doses. For noncarcinogens, however, adverse biological effects are not observed below a certain threshold dose.

Potential effects from known carcinogens have been studied extensively, and the EPA's Carcinogen Assessment group has published Cancer Potency Factors for use in evaluating the potential cancer risk from exposure to carcinogens. For evaluating the potential impact that can result from exposure to noncarcinogens, the EPA recommends the use of Reference Dose, that is, the highest average daily exposure over a lifetime that would not be expected to produce adverse effects.

To assess exposure, the environmental transport and fate of the chemicals will be monitored and/or modeled and predicted over time, the quantity reaching the individual or population will be estimated, and the duration of the exposure will be estimated. Assumptions will be made regarding when, where, and how often exposure to the chemical occurs. The likelihood and extent of adverse effects associated with chemicals will be estimated using the approaches, or equivalent approaches, described above. Carcinogens and noncarcinogens will be treated separately.

3.4.7 Summary Comparison Table

A summary comparison of impacts among the alternatives presented in Section 3.4 is given in Table 3.29. In that table impacts on the general public, workers and others who might one day come onto the Site for exploration or resettlement are provided. The table is organized by groups to whom the impacts occur, the scenarios on which the impacts are based, the measure of the impact (note that units of the measure of impact change from section to section) and the disposal alternatives and no disposal action alternative, both with and without active institutional control.

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TABLE 3.29. Summary Comparison of Impacts Among Alternatives

Issue	Measure	Geologic Disposal[a]: HLW Onsite; TRU to WIPP	Geologic Disposal[a]: HLW Offsite; TRU to WIPP	In-Place Stabilization and Disposal	Reference Alternative[a]: HLW Onsite; TRU to WIPP	Reference Alternative[a]: HLW Offsite; TRU to WIPP	Preferred Alternative[a,b]: HLW Onsite; TRU to WIPP	Preferred Alternative[a,b]: HLW Offsite; TRU to WIPP	No Di: Continued Storage
IMPACTS ON PUBLIC									
Operations									
Routine (yr 1990-2050)	Health effects[c]	0	0	0	0	0	0	0	0
Accidents (most serious)	Health effects	1-7	1-7	1-7	1-7	1-7	1-7	1-7	0-2
Transportation									
Radiological	Health effects	0	0	0	0	0	0	0	0
Nonradiological	Fatalities[d]	1	3	0	1	1	1	1-3	0
Postdisposal--Long Term (10,000 yr)									
Impacts on Offsite Population from Onsite Disposal[a]									
Current Climate									
Radiological	Health effects	0	0	0	0	0	0	0	NA[f]
Chemicals (NO_3^-, Hg, Cr, Cd, F)	Percentage drinking-water standard	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001	NA
Wetter Climate[g]									
Radiological	Health effects	0	0	0-1	0-1	0-1	0-1	0-1	NA
Chemicals (NO_3^-, Hg, Cr, Cd, F)	Percentage drinking-water standard	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	NA
Impacts on Intruders from Onsite Disposal[a]									
Drillers (into Cs capsule)	Chance of one fatal drilling event	0	0	<1/1,000,000[j]	0	0	0	0	NA
Postdrilling Habitation	Fatalities[e]								
Barrier and Marker System Effective		0	0	4	4	4	0-4	0-4	NA
Warnings Absent or ignored		0	0	130	64	64	0-64	0-64	NA
Impacts on Others from Onsite Disposal[a]									
Shoreline Resettlement									
Current Climate	Health effects	0-4	0-4	0-2	0-2	0-2	0-4	0-4	NA
Wetter Climate	Health effects	0-1	0-1	0-2	0-2	0-2	0-2	0-2	NA
Impacts on Groundwater Between Disposal Site and Columbia River From Onsite Disposal[a,m]									
Radiological	Maximum annual critical-organ dose[q] in rem to hypothetical individual consuming 2 L/day (yr after disposal)								
Current Climate[n]		7×10^{-3}/(+5,500 yr)	1×10^{-2}/(+5,000 yr)		1×10^{-2}/(+5,000 yr)		1×10^{-2}/(+5,000 yr)		(p)
Wetter Climate		1×10^{-3}/(+5,200 yr)	3×10^{-3}/(+5,000 yr)		3×10^{-3}/(+5,100 yr)		3×10^{-3}/(+5,000 yr)		(p)
Wetter Climate and Postulated Barrier Failure Scenarios		1×10^{-1}/(+1,000 yr)	1/(+200 yr)		1/(+200 yr)		1×10^{-1}/(+5,000 yr) to 1/(+200 yr)		(p)

Issue	ative[a,b] W Offsite; U to WIPP	No Disposal Action: Continued Storage	No Disposal Action: Loss of Institutional Control Scenario[k]
IMPACTS ON PUBLIC - contd.			
Chemicals (NO_3^-, Hg, Cr, Cd, F)			
Current Climate	(Cr)	(p)	50,000 (Cr)
Wetter Climate	(Cr)	(p)	120,000 (Cr)
IMPACTS ON OPERATIONS WORKFORCE (YR 1990-2050)	15	0-1[h]	NA
IMPACTS ON KEY RESOURCES			
Fossil Fuels			
Diesel Fuel, Propane, Gasoline	3-230	18	NA
Coal	-530	110	NA
Steel	-80	26	NA
Electricity	,800-5,100	300	NA
IMPACTS ON ECOSYSTEMS AND SOCIOECONOMICS			
COSTS	,700-17,200	1,800[i]	NA

(a) Residuals disposed of on site with EPA 40 CFR 191.
(b) For waste classes whose disposal de
(c) Presumed health effects based on 10 of 1,000,000 man-rem.
(d) Statistical fatalities based on veh
(e) Probability-weighted fatalities bas
(f) Not applicable; continuation of act
(g) Includes effect of barrier failure
(h) Similar impacts could be expected f
(i) Costs for first century; costs woul
(j) Likelihood of fatality from drillin
(k) Loss of active institutional contro which active institutional control
(l) Values given are for a single event
(m) There is no public use, nor is any
(n) Time shown, e.g., +5,100 years, is
(p) No use of groundwater as long as in
(q) Doses presented for the groundwater organ doses are higher tban total-b Standards, 40 CFR 141.

TABLE 3.29. (contd)

Issue	Measure	Geologic Disposal[a] HLW Onsite; TRU to WIPP	Geologic Disposal[a] HLW Offsite; TRU to WIPP	In-Place Stabilization and Disposal	Reference Alternative[a] HLW Onsite; TRU to WIPP	Reference Alternative[a] HLW Offsite; TRU to WIPP	Preferred Alternative[a,b] HLW Onsite; TRU to WIPP	Preferred Alternative[a,b] HLW Offsite; TRU to WIPP	Contin Stora
IMPACTS ON PUBLIC - contd.									
Chemicals (NO_3^-, Hg, Cr, Cd, F)	Percentage of drinking-water standard								
Current Climate		12 (Cr)	12 (Cr)	12 (Cr)	12 (Cr)	12 (Cr)	12 (Cr)	12 (Cr)	(p)
Wetter Climate		5 (Cr)	5 (Cr)	5 (Cr)	5 (Cr)	5 (Cr)	5 (Cr)	5 (Cr)	(p)
IMPACTS ON OPERATIONS WORKFORCE (YR 1990-2050)	Health effects	2-15	2-15	0-2	0-4	0-4	0-15	0-15	0-1[h]
IMPACTS ON KEY RESOURCES									
Fossil Fuels	Thousands of m^3 committed								
Diesel Fuel, Propane, Gasoline		230	230	84	92	93	93-230	93-230	18
Coal		520	530	73	46	47	46-520	47-530	110
Steel	Thousands of t committed	80	80	11	14	14	14-80	14-80	26
Electricity	GWh committed	5,000	5,100	1,500	3,700	3,700	3,800-5,000	3,800-5,100	300
IMPACTS ON ECOSYSTEMS AND SOCIOECONOMICS:	No Significant Impacts Were Found								
COSTS	Millions of dollars	16,500	17,200	2,400	3,700	3,700	3,700-16,500	3,700-17,200	1,800[i]

(a) Residuals disposed of on site with protective barrier; wastes disposed in geologic repository assumed to be in compliance with NRC 10 CFR 60, EPA 40 CFR 191.
(b) For waste classes whose disposal decision is deferred, impacts are given as the range of geologic to reference alternative.
(c) Presumed health effects based on 100 to 1,000 health effects (fatal cancers plus genetic effects) presumed to result from population exposure of 1,000,000 man-rem.
(d) Statistical fatalities based on vehicular accident statistics.
(e) Probability-weighted fatalities based on probabilities of events and estimates of fatal doses. Family of 4 for each event.
(f) Not applicable; continuation of active institutional control precludes scenario.
(g) Includes effect of barrier failure scenario.
(h) Similar impacts could be expected for each additional century of storage.
(i) Costs for first century; costs would continue at about 1.3 billion dollars for each additional century of storage.
(j) Likelihood of fatality from drilling into Cs capsule essentially zero after about 300 years.
(k) Loss of active institutional control in the no disposal action case is assumed solely to permit parallel analysis with the disposal alternatives for which active institutional control may not be relied upon for more than 100 years after disposal, according to EPA 40 CFR 191.
(l) Values given are for a single event; due to intermittent arrival of radionuclides the event could occur several times over 10,000 years.
(m) There is no public use, nor is any planned, of the groundwater between the waste disposal site and the Columbia River.
(n) Time shown, e.g., +5,100 years, is time after disposal.
(p) No use of groundwater as long as institutional control persists.
(q) Doses presented for the groundwater scenario were changed from total-body doses in the draft EIS to individual-organ doses in the final EIS. Individual-organ doses are higher than total-body doses and are the doses that would most likely be compared to limits such as provided in EPA Drinking Water Standards, 40 CFR 141.

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CHAPTER 4.0

AFFECTED ENVIRONMENT

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4.0 AFFECTED ENVIRONMENT

This chapter provides a general description of the Hanford Site and surrounding areas, emphasizing environmental attributes that potentially could be affected by defense waste disposal practices. More detailed environmental site descriptions for the Hanford Site are given in ERDA (1975), NRC (1975, 1982), Rogers and Rickard (1977), Jamison (1982), DOE (1982a, 1984), Watson et al. (1984), and Stone et al. (1983). This EIS also considers disposal of transuranic (TRU) waste at the Waste Isolation Pilot Plant (WIPP) Site in New Mexico if following a successful demonstration phase it were approved as a geologic repository. Thus the affected environment would also include the environs of that site, a detailed description of which is given in DOE (1980b). It is not the intent of this document to provide environmental input for the selection of a repository for high-level waste (HLW); however, to complete the analysis of disposal system impacts, transportation of waste and its disposal in a repository are considered. To provide bounding consequences for offsite transportation, this repository was assumed to be in the southeastern United States.

The Department of Energy's Hanford Site lies within the semiarid Pasco Basin, part of the Columbia Plateau in southeastern Washington State (Figure 1.2 in Chapter 1). The Site occupies an area of about 1,500 km^2 and is about 48 km north to south and 38 km east to west. This land area, with restricted public access, presently provides a buffer for the smaller areas presently used for operations, waste storage and waste disposal (Figure 4.1). The Columbia River flows through the northern part of the Site, and turning south it forms part of its eastern boundary. The Yakima River runs along part of the southern boundary and joins the Columbia River near the City of Richland. Adjoining lands to the west, north, and east are principally range and agricultural land. The cities of Richland, Kennewick, and Pasco (often called the Tri-Cities) comprise the nearest population center and are located southeast of the Site.

4.1 BACKGROUND RADIATION

Radionuclide concentrations in Hanford air, Columbia River water, and soil for the year 1984 are given in Tables 4.1, 4.2, and 4.3, respectively. The DOE has revised its radiation standards for protection of the public in the vicinity of DOE facilities. Interim standards, effective 1 July 1985, limit the continuous dose to any member of the public to 100 mrem/yr from all routine DOE operations. From the air pathway alone the limit for total-body dose is 25 mrem/yr (in accord with EPA's 40 CFR 61, Subpart H). The levels measured are much lower than those in the applicable DOE derived concentration guides. Specific airborne radionuclide concentrations were similar among the onsite sampling locations, except that the levels of ^{85}Kr, ^{129}I, ^{3}H, and $^{239,240}Pu$ were higher very near the PUREX facility, located in the 200 East Area (Price et al. 1985).

Groundwater is collected from a network of more than 300 sampling wells and analyzed for radionuclide concentration (Prater et al. 1984). The groundwater sampling system and how it is used to calibrate transport models is described in Appendix V. The movement of various nuclides through the unconfined aquifer is reported annually (Price et al. 1985).

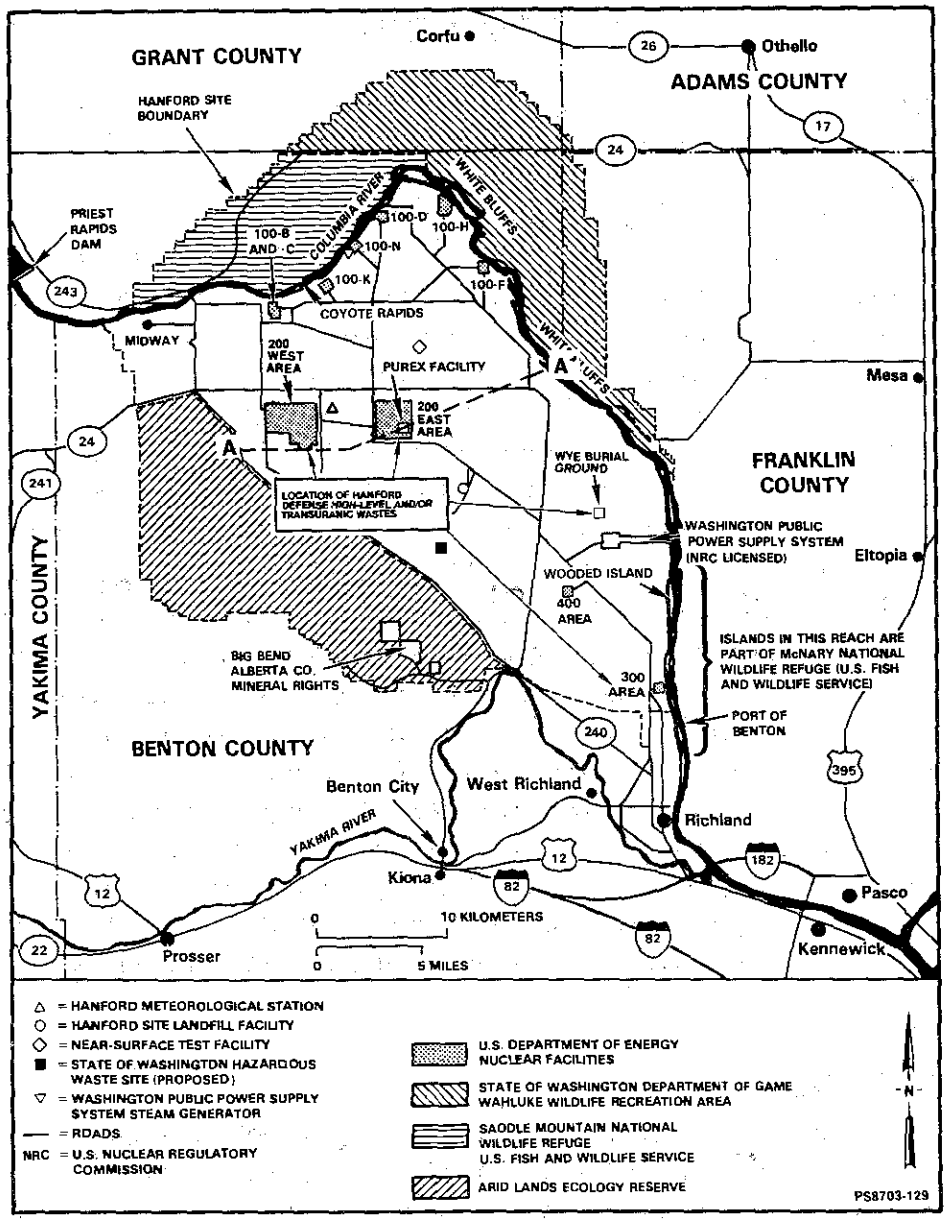

FIGURE 4.1. Features of the Hanford Site (DOE 1986). Cross section A-A' is given in Figure 4.3.

The levels of radionuclides in the biota of the site are shown in Table 4.4. Most concentrations are less than 1 pCi/g, with the exception of ^{137}Cs in the muscle of ducks from 200 Area waste water ponds, and the ^{90}Sr in rabbit bone collected in the 200 Areas.

The external environmental radiation dose measurements from all sources, including natural background radiation, at locations within the Hanford Site averaged from 70 to 96 mrem/yr; for locations near the Site perimeter, averages ranged from 66 to 80 mrem/yr; and for stations 30 km or more distant from the 200 Areas, the averages ranged from 58 to

TABLE 4.1. Selected Airborne Radionuclide Concentrations on the Hanford Site in 1984 (Price et al. 1985)

Radionuclide	pCi/m^3(a) Maximum	Minimum	Average	Concentration Guide(b)
^{3}H (HTO)	6.8 ± 2.2	<-1.2 ± 2.5	2.2 ± 0.3	200,000
$^{14}C(CO_2)$	1.7 ± 0.1	<0.8 ± 1.3	1.3 ± 0.1	1,000,000
^{85}Kr	4600 ± 590	21 ± 10	590 ± 280	300,000
^{90}Sr	$8 \times 10^{-4} \pm 2 \times 10^{-4}$	$<4 \times 10^{-6} \pm 5 \times 10^{-5}$	$2 \times 10^{-4} \pm 6 \times 10^{-5}$	30
^{129}I	$2 \times 10^{-3} \pm 3 \times 10^{-4}$	$1 \times 10^{-5} \pm 1 \times 10^{-6}$	$<5 \times 10^{-4} \pm 9 \times 10^{-4}$	20
^{131}I	$1.4 \times 10^{-2} \pm 5 \times 10^{-2}$	$<-2 \times 10^{-2} \pm 2 \times 10^{-2}$	$<1 \times 10^{-4} \pm 6 \times 10^{-4}$	100
^{137}Cs	$7 \times 10^{-3} \pm 3 \times 10^{-3}$	$<-2 \times 10^{-3} \pm 2 \times 10^{-3}$	$4 \times 10^{-4} \pm 2 \times 10^{-4}$	500
U (total)	$4 \times 10^{-4} \pm 1 \times 10^{-4}$	$2 \times 10^{-5} \pm 9 \times 10^{-6}$	$9 \times 10^{-5} \pm 3 \times 10^{-5}$	2
^{238}Pu	$<2 \times 10^{-5} \pm 3 \times 10^{-5}$	$<-4 \times 10^{-6} \pm 3 \times 10^{-6}$	$2 \times 10^{-6} \pm 2 \times 10^{-6}$	7×10^{-2}
$^{239,240}Pu$	$3 \times 10^{-5} \pm 7 \times 10^{-6}$	$<-4 \times 10^{-7} \pm 5 \times 10^{-6}$	$7 \times 10^{-6} \pm 2 \times 10^{-6}$	6×10^{-2}
Gross Beta	$9 \times 10^{-2} \pm 1 \times 10^{-2}$	$<2 \times 10^{-3} \pm 4 \times 10^{-3}$	$2 \times 10^{-2} \pm 1 \times 10^{-3}$	
Gross Alpha	$1 \times 10^{-3} \pm 5 \times 10^{-4}$	$<2 \times 10^{-4} \pm 2 \times 10^{-4}$	$1 \times 10^{-3} \pm 7 \times 10^{-5}$	

(a) Maximum and minimum values ± two sigma counting error. Averages ± two standard error of the calculated mean (95% confidence interval).
(b) DOE 1981.

73 mrem/yr (Price et al. 1985). The differences between the perimeter and more distant stations are not substantiated by radionuclide measurements in soil and vegetation at these locations, and may be due to natural geographic variations in terrestrial radiation. Environmental dose rates ranging from 70 to 150 mrem/yr were measured along the shorelines and islands of the Hanford Reach of the Columbia River. These doses come from residual radioactivity (primarily ^{60}Co and ^{154}Eu) from the cooling water discharged to the river between 1944 and 1972 by the older Hanford production reactors which were retired from use by 1972. All of the preceding external dose values include natural and fallout background radiation, which averages 88 mrem/yr for Washington State.

The calculated total-body dose from Hanford sources to the hypothetical maximally exposed individual for 1984 was 2 mrem, well below the present DOE radiation protection standard of 100 mrem/yr. The calculated total-body dose to the population within 80 km from the 200 Areas from exposure to Hanford sources in 1984 was 5 man-rem. The annual population dose from natural background radiation would be about 34,000 man-rem based on the 1980 census population of 340,000.

Reviews of natural radiation sources are given in DOE (1980a), Speer et al. (1976), Houston and Blumer (1978; 1979a,b; 1980a,b), the National Academy of Sciences (1978), and the National Council on Radiation Protection and Measurements (NCRP 1975).

TABLE 4.2. Radionuclide Concentrations in Columbia River Water Downstream from the Hanford Site, Measured in 1984 (Price et al. 1985)

Radionuclide		pCi/L[a] Maximum	Minimum	Average	Concentration Guide[b]
^{3}H		270 ± 14	130 ± 13	170 ± 23	3,000,000
^{60}Co	P[c]	$2.2 \times 10^{-2} \pm 4.7 \times 10^{-3}$	$<1.2 \times 10^{-3} \pm 3.6 \times 10^{-3}$	$7.6 \times 10^{-3} \pm 2.5 \times 10^{-3}$	30,000
	D[c]	$9.3 \times 10^{-2} \pm 1.2 \times 10^{-2}$	$<-1 \times 10^{-3} \pm 8.8 \times 10^{-3}$	$1.2 \times 10^{-2} \pm 7.7 \times 10^{-3}$	
^{89}Sr		$3.6 \times 10^{-1} \pm 1.1 \times 10^{-1}$	$<-1.90 \times 10^{-2} \pm 1.3 \times 10^{-1}$	$1.5 \times 10^{-1} \pm 8.2 \times 10^{-2}$	3,000
^{90}Sr		$2.6 \times 10^{-1} \pm 1.1 \times 10^{-1}$	$<2.3 \times 10^{-2} \pm 4.9 \times 10^{-2}$	$1.7 \times 10^{-1} \pm 4.1 \times 10^{-2}$	300
^{95}Zr	P	$6.7 \times 10^{-3} \pm 4.4 \times 10^{-3}$	$<-3.3 \times 10^{-3} \pm 5.7 \times 10^{-3}$	$1.5 \times 10^{-3} \pm 1.5 \times 10^{-3}$	6,000
	D	$1.1 \times 10^{-2} \pm 1.1 \times 10^{-2}$	$<-8 \times 10^{-3} \pm 1 \times 10^{-2}$	$<5.3 \times 10^{-4} \pm 2.9 \times 10^{-3}$	
^{95}Nb	P	$5.5 \times 10^{-3} \pm 3.1 \times 10^{-3}$	$<-4.2 \times 10^{-3} \pm 3.3 \times 10^{-3}$	$1.4 \times 10^{-3} \pm 1.1 \times 10^{-3}$	100,000
	D	$9.5 \times 10^{-3} \pm 8.2 \times 10^{-3}$	$<-5.2 \times 10^{-3} \pm 7.3 \times 10^{-3}$	$<4 \times 10^{-4} \pm 2.1 \times 10^{-3}$	
^{106}Ru	P	$3.4 \times 10^{-2} \pm 2.3 \times 10^{-2}$	$<-1.9 \times 10^{-2} \pm 2.8 \times 10^{-2}$	$<2.5 \times 10^{-3} \pm 7.6 \times 10^{-3}$	10,000
	D	$6.1 \times 10^{-2} \pm 4.7 \times 10^{-2}$	$<-5 \times 10^{-2} \pm 5.1 \times 10^{-2}$	$<4.2 \times 10^{-4} \pm 1.6 \times 10^{-2}$	
^{129}I	D	$1.2 \times 10^{-4} \pm 1.1 \times 10^{-5}$	$4.4 \times 10^{-5} \pm 4.9 \times 10^{-6}$	$7.4 \times 10^{-5} \pm 2.9 \times 10^{-5}$	60
^{131}I	P	$6 \times 10^{-3} \pm 3.9 \times 10^{-3}$	$<-4 \times 10^{-3} \pm 5.1 \times 10^{-3}$	$2 \times 10^{-3} \pm 1.6 \times 10^{-3}$	300
	D	$5.6 \times 10^{-2} \pm 1.1 \times 10^{-2}$	$<-1.8 \times 10^{-3} \pm 1.1 \times 10^{-2}$	$1.7 \times 10^{-2} \pm 7 \times 10^{-3}$	
^{137}Cs	P	$1.5 \times 10^{-2} \pm 2.7 \times 10^{-3}$	$7.7 \times 10^{-3} \pm 3.3 \times 10^{-3}$	$1.1 \times 10^{-2} \pm 1.1 \times 10^{-3}$	20,000
	D	$3.2 \times 10^{-2} \pm 7.6 \times 10^{-3}$	$1.3 \times 10^{-2} \pm 5.9 \times 10^{-3}$	$2.3 \times 10^{-2} \pm 2.3 \times 10^{-3}$	
^{144}Ce	P	$<7.7 \times 10^{-3} \pm 1 \times 10^{-2}$	$<-5.1 \times 10^{-3} \pm 8.1 \times 10^{-3}$	$<9.6 \times 10^{-4} \pm 2.2 \times 10^{-3}$	10,000
	D	$1.6 \times 10^{-2} \pm 1.5 \times 10^{-2}$	$<-1.9 \times 10^{-2} \pm 2 \times 10^{-2}$	$<-1.6 \times 10^{-3} \pm 4.8 \times 10^{-3}$	
U (natural)		$7.3 \times 10^{-1} \pm 0.00$	$2.7 \times 10^{-1} \pm 0.00$	$4.5 \times 10^{-1} \pm 8.5 \times 10^{-2}$	600
^{238}Pu	P	$<3.1 \times 10^{-6} \pm 3.2 \times 10^{-6}$	$<1 \times 10^{-6} \pm 0.00$	$2.2 \times 10^{-6} \pm 1.4 \times 10^{-6}$	5,000
	D	$8.5 \times 10^{-5} \pm 5.6 \times 10^{-5}$	$<2 \times 10^{-5} \pm 0.00$	$4.4 \times 10^{-5} \pm 3.0 \times 10^{-5}$	
$^{239,240}Pu$	P	$2.5 \times 10^{-5} \pm 6 \times 10^{-6}$	$4 \times 10^{-6} \pm 2.0 \times 10^{-6}$	$1.8 \times 10^{-5} \pm 8.3 \times 10^{-6}$	5,000
	D	$4.9 \times 10^{-4} \pm 1.2 \times 10^{-4}$	$<2.6 \times 10^{-5} \pm 4.1 \times 10^{-5}$	$<1.5 \times 10^{-4} \pm 1.8 \times 10^{-4}$	

(a) Maximum and minimum values ± two sigma counting error. Average ± two standard error of the calculated mean (95% confidence interval).
(b) DOE 1981.
(c) P - particulate; D - dissolved.

4.2 GEOLOGY AND PHYSIOGRAPHY

The Hanford Site is located in the Pasco Basin, a structural and topographic depression within the Columbia Plateau. The terrain of the central and eastern parts of the Site is relatively flat (DOE 1984) and the central part of the Site, including the 200 Areas plateau, has undergone minimal erosion since deposition of Hanford formation sediments by glacial floodwaters about 13,000 years ago. These floods resulted when ice dams were breached in western Montana and northern Idaho, allowing large volumes of water to spill across eastern and central Washington (DOE 1986).

The principal geologic units (Figure 4.2) beneath the Hanford Site are, in ascending order: the Columbia River Basalt Group with interbedded sediments of the Ellensburg Formation, the Ringold Formation, and the Hanford Formation. The thick sequence--as much as 5,000 m (Mitchell and Bergstrom 1983)--of tholeiitic flood basalts of the Columbia River Basalt Group is estimated to range in age from 17 to 6 million years (Watkins and Baksi 1974;

TABLE 4.3. Radionuclides in Hanford Soils, Measured in 1984 (Price et al. 1985)

Radionuclide	pCi/g dry weight[a]		
	Maximum	Minimum	Average
^{90}Sr	$5.8 \times 10^{-1} \pm 2.9 \times 10^{-2}$	$<3.2 \times 10^{-2} \pm 5.4 \times 10^{-2}$	$3.2 \times 10^{-1} \pm 1 \times 10^{-1}$
^{137}Cs	21.0 ± 0.23	$6.4 \times 10^{-2} \pm 2.2 \times 10^{-2}$	1.9 ± 2.8
$^{239,240}Pu$	$7.4 \times 10^{-2} \pm 4.1 \times 10^{-3}$	$3.4 \times 10^{-3} \pm 1.9 \times 10^{-3}$	$1.6 \times 10^{-2} \pm 9.3 \times 10^{-3}$
U (total)	$1.0 \pm 1.5 \times 10^{-1}$	$2.7 \times 10^{-1} \pm 7.3 \times 10^{-2}$	$4.6 \times 10^{-1} \pm 1.1 \times 10^{-1}$

(a) Results ± two sigma counting error.

TABLE 4.4. Radionuclide Concentrations in Hanford Plants and Animals, Measured in 1984 (Price et al. 1985)

Sample Type	Location	^{90}Sr	^{137}Cs	^{60}Co	$^{239,240}Pu$	U (total)
Vegetation, pCi/g dry wt	Hanford Site	0.19 ± 0.14[a]	0.034 ± 0.033		0.001 ± 0.00085	0.0093 ± 0.0026
Birds, pCi/g wet wt						
Pheasant--Muscle	100 Areas		0.02 ± 0.02	0.003 ± 0.008		
	300 Area		0.01 ± 0.02	0.01 ± 0.02		
Chukar--Muscle	200 Areas		0.07 ± 0.03	0.007 ± 0.01		
Mallard Duck--	200 Areas					
Muscle	B Pond		3.4 ± 1.9			
	U Pond		<36 ± 77			
	300 Area		<0.3 ± 0.4			
Mammals, pCi/g wet wt						
Cottontail Rabbit						
--Muscle	100 Areas		0.014 ± 0.013			
--Bone		<16 ± 17				
Jack Rabbit						
--Muscle	200 Areas		0.019 ± 0.01			
--Bone		6.9 ± 2.7				
Deer						
--Muscle	Onsite road kills		<0.0004 ± 0.006			
--Liver				0.0002 ± 0.0002		
Columbia River Fish, pCi/g wet wt						
Whitefish--Muscle	Upstream of Site	0.008 ± 0.008	0.01 ± 0.02	0.001 ± 0.01		
	1000 vicinity	0.006 ± 0.003	0.02 ± 0.01	0.02 ± 0.01		
Bass--Muscle	100F sloughs	0.002 ± 0.001	0.06 ± 0.02	0.004 ± 0.01		

(a) Averages ± two standard error of the calculated mean.

McKee et al. 1977, 1981). These basalt flows are interbedded with and overlain by Miocene-Pliocene epiclastic and volcaniclastic sediments of the Ellensburg Formation (Myers et al. 1979).

Directly overlying the Columbia River Basalt Group are the fluvial/flood plain sediments of the Ringold Formation, deposited some 3.7 to 8.5 million years ago (Myers et al. 1979).

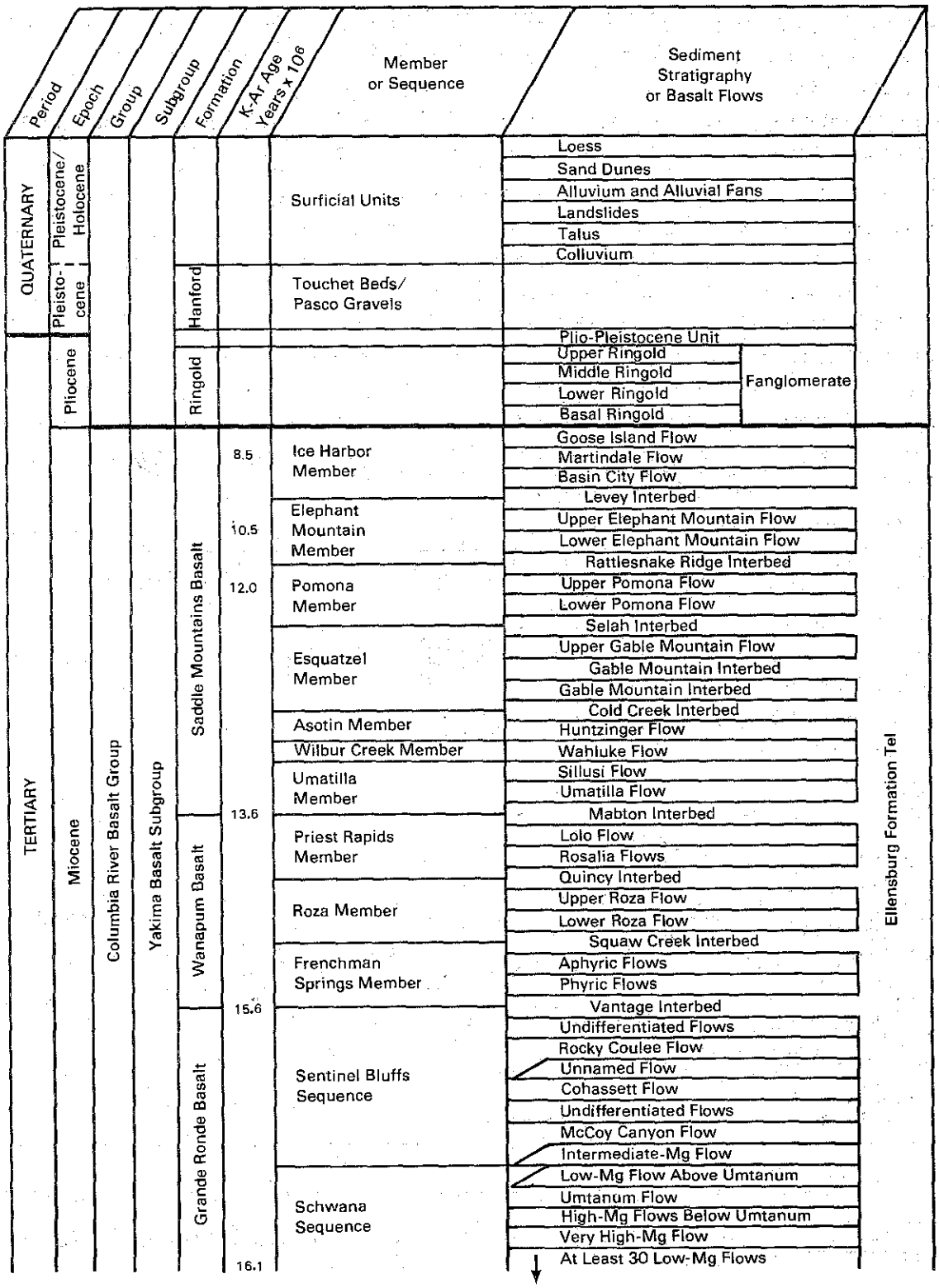

FIGURE 4.2. Stratigraphic Units Present in the Pasco Basin (DOE 1984)

These sediments have locally been divided into four textural units: 1) sand and gravel of the basal Ringold unit; 2) clay, silt, and fine sand with minor gravel lenses of the lower Ringold unit; 3) occasionally cemented sand and gravel of the middle Ringold unit; and 4) silt and fine sand of the upper Ringold unit (Brown 1959). A wind-deposited silt and fine sand with relatively high caliche content (the Plio-Pleistocene unit) overlies the Ringold Formation in the western part of the Hanford Site (Brown 1960).

The Hanford Formation lies on the eroded surface of the Ringold Formation, the Plio-Pleistocene unit, and the basalt and its interbedded sediments. These sediments were deposited by catastrophic floods when glacial dams in western Montana and northern Idaho were breached and massive volumes of glacial melt water spilled abruptly across eastern and central Washington. The last major depositional sequence from such flooding has been dated at about 13,000 years ago (Myers et al. 1979). These sediments have been divided into two main facies: 1) the Pasco Gravels facies, composed of poorly sorted clasts deposited in a high-energy environment, and 2) the Touchet Beds facies, comprising rhythmically bedded sequences of graded silt, sand, and minor gravel units of a slack-water environment (Myers et al. 1979).

The surface of the Hanford Site is locally veneered with alluvium, colluvium, and loess, including both active and inactive sand dunes. Figure 4.3 shows a representative cross section through the suprabasalt sediments beneath the plateau and the Hanford Site. The geologic units are discussed in detail by DOE (1984), Tallman et al. (1979), DOE (1982a), Myers et al. (1979), and Myers and Price (1981). Appendix O discusses the physical and chemical properties of these geologic materials as they relate to movement of groundwaters and contaminants. The potential for future magmatic, volcanic, or other geologic hazard is discussed in Appendix R.

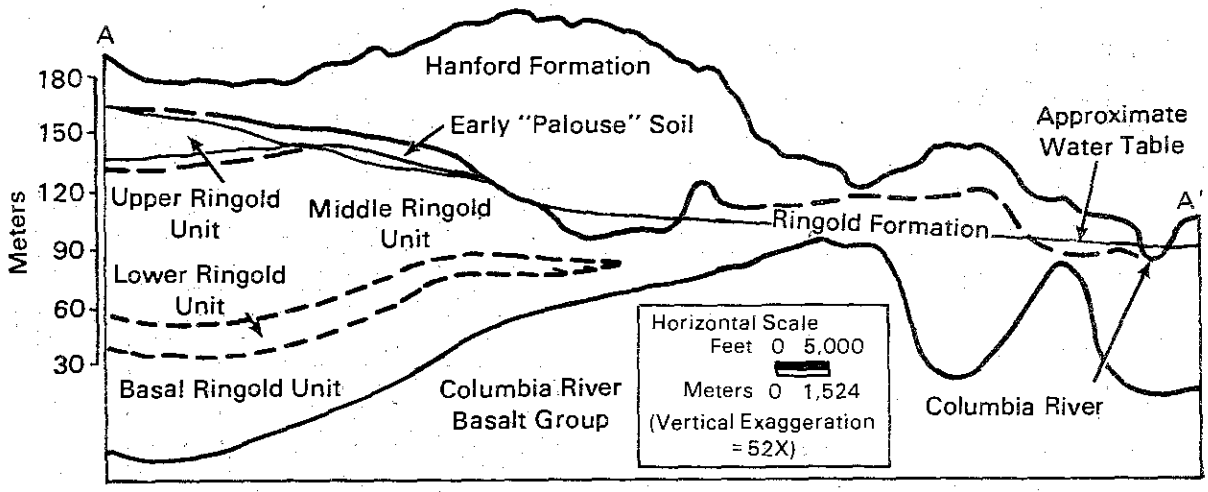

FIGURE 4.3. **Generalized East-West Cross Section of the Suprabasalt Sediments Beneath the Hanford Site** (after Tallman et al. 1979). **See Figure 4.1.**

The elevations of the alluvial plain that covers much of the Site range from 105 m above mean sea level in the southeast corner to 245 m in the northwest. The 200 Areas plateau, where most of the radioactive waste is stored, ranges in elevation from 190 to 245 m. The highest point is on Rattlesnake Mountain (1,093 m) on the southwestern border of the Site.

4.3 SEISMICITY

Earthquake records for the Pacific Northwest extend back to about 1850; however, these early records are very qualitative. Earthquakes occurring before 1969, when a network of seismographs was installed on the Columbia Plateau, were documented mainly from reports of tremors that were felt (Myers et al. 1979; Weston Geophysical Research 1977; WPPSS 1981a). Figure 4.4 shows the distribution and intensity of historical earthquakes and indicates that the Columbia Plateau is in an area of moderate seismicity (Berg and Baker 1963; Rasmussen 1967). Earthquakes within the central Columbia Plateau have been instrumentally located since 1969. While seismic activity above magnitude 3.0 has occurred in this region, activity above magnitude 3.5 is most commonly found around the northern and western portions of the Columbia Plateau, with a few events occurring along the border between Washington and Oregon (DOE 1984).

Swarms of small, shallow earthquakes are the predominant seismic events of the Columbia Plateau (Rohay and Davis 1983). Earthquake swarms (as detected by the regional seismograph network) may contain from four to more than 100 locatable earthquakes of magnitude 1.0 to 3.5 (DOE 1984). These swarms typically last a few days to several months and occur within areas typically 2 by 5 km and 3 to 5 km vertically (DOE 1984). Earthquake swarms characteristically do not follow a typical mainshock-aftershock sequence. The earthquakes within swarms gradually increase and decay in frequency, but not in magnitude.

Shallow earthquake swarm activity in the central Columbia Plateau is concentrated principally north and east of the Hanford Site. Here earthquakes of magnitude greater than 3.0 also occur. The swarm event of perhaps the largest magnitude was recorded instrumentally on December 20, 1973, as a magnitude 4.4 earthquake located in the Royal Slope area, north of the Hanford Site (DOE 1984). Other notable earthquake swarms have occurred at Coyote Rapids and Wooded Island (Figure 4.1). The swarms near Coyote Rapids have been relatively inactive compared to other areas. However, this was the site of the second largest instrumentally recorded earthquake in the central Columbia Plateau, with a magnitude of 3.8, on October 25, 1971 (Rohay and Davis 1983). The swarms near Wooded Island have been among the more intense in terms of number of events, but they all are of low magnitude (less than 3.0).

Earthquakes occur to a depth of 28 km in the central Columbia Plateau, although at much lower frequencies than the shallower swarm events (DOE 1984). This 28-km depth is the approximate thickness of the earth's crust beneath this portion of Washington State, as determined by seismic refraction studies (Caggiano and Duncan 1983). Deep seismic activity generally occurs randomly and is not associated with known geologic structures or with patterns of shallow seismicity (DOE 1984).

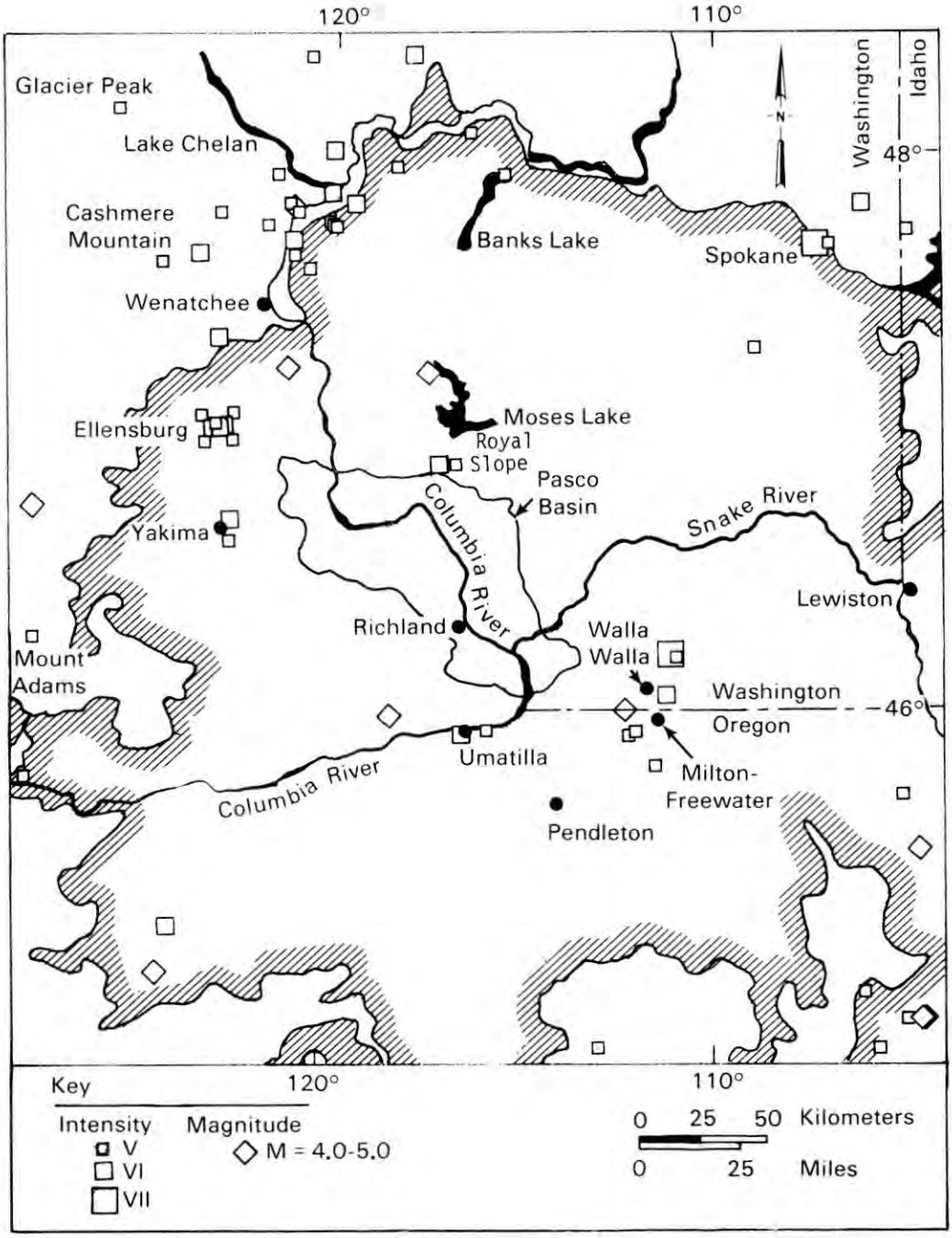

FIGURE 4.4. Historical Seismicity of the Columbia Plateau. All earthquakes between 1850 and 1969 with modified Mercalli intensity equal to or greater than V are shown.

Focal mechanism and fault plane solutions of earthquakes within eastern Washington and the central Columbia Plateau indicate that the principal compressional stresses are nearly horizontal and oriented north-south, while the principal tensional stresses are nearly vertical (DOE 1984). This suggests thrust or reverse faulting on east-west striking planes. These principal stress directions are in good agreement with mapped east-west oriented folds and associated thrust or reverse faults (DOE 1984).

Geologic structures of the Pasco Basin are typical of the Yakima Fold Belt subprovince, which is characterized by narrow, linear anticlines and broad synclines (Figure 4.5). These structures generally extend eastward from the western margin toward the center of the Columbia Plateau, where they generally die out (Myers et al. 1979). Tectonic models of the Pasco Basin are not in agreement over the degree of involvement of sub-basalt structures in the development of basalt structures. There is also considerable disagreement over the relationship between folding and faulting in basalts (Caggiano and Duncan 1983).

Geologic data have been interpreted to suggest that the Columbia Plateau, including the Pasco Basin, was deforming at a low to average rate in the middle to late Miocene (DOE 1984). Measurements of noneroded basalt flow thickness from synclinal valleys to anticlinal ridges in conjunction with ages of the basalt flows provide estimates of the rates of paleorelief development. The maximum variation in relief observed in the Pasco Basin occurs between Rattlesnake Hills and the Cold Creek Syncline. There, the combined rate of uplift and subsidence was estimated to be less than 150 $m/10^6$ yr (0.15 mm/yr) over the past 14.5 to 10.5 million years (Caggiano and Duncan 1983). Geodetic data suggest that deformation is continuing at similar rates today (DOE 1984).

Seismic activity and related phenomena such as liquefaction, fault rupture, and subsidence are not believed to be plausible events that might lead directly to release of waste, except for continued storage of liquid waste in tanks, and that only near the end of tank life. A related discussion of the seismicity is included in Appendix R.

4.4 HYDROLOGY

4.4.1 Surface Waters

The Columbia River, which flows through the northern part of the Site and along the eastern boundary, and the Yakima River, which flows along the southern boundary, are the dominant streams in the area. Both streams are important sources of industrial, agricultural and domestic water for the region. The average annual Columbia River flow in the Hanford Reach, based on 65 years of record, is about 3,400 m^3/sec (USGS 1985). Minimum flows of 117 m^3/sec have been recorded. For 57 years of record, the average annual flow of the Yakima River has been about 104 m^3/sec, with monthly maximum and minimum flows of 490 m^3/sec and 4.6 m^3/sec, respectively. Maximum Columbia River floods of historical record occurred in 1894 and 1948, with flows of 21,000 m^3/sec and 19,600 m^3/sec, respectively (DOE 1982a). Floods of this size would inundate part of the 100-F Area but would be of little consequence to the rest of the Site. The likelihood of floods of this magnitude recurring has been

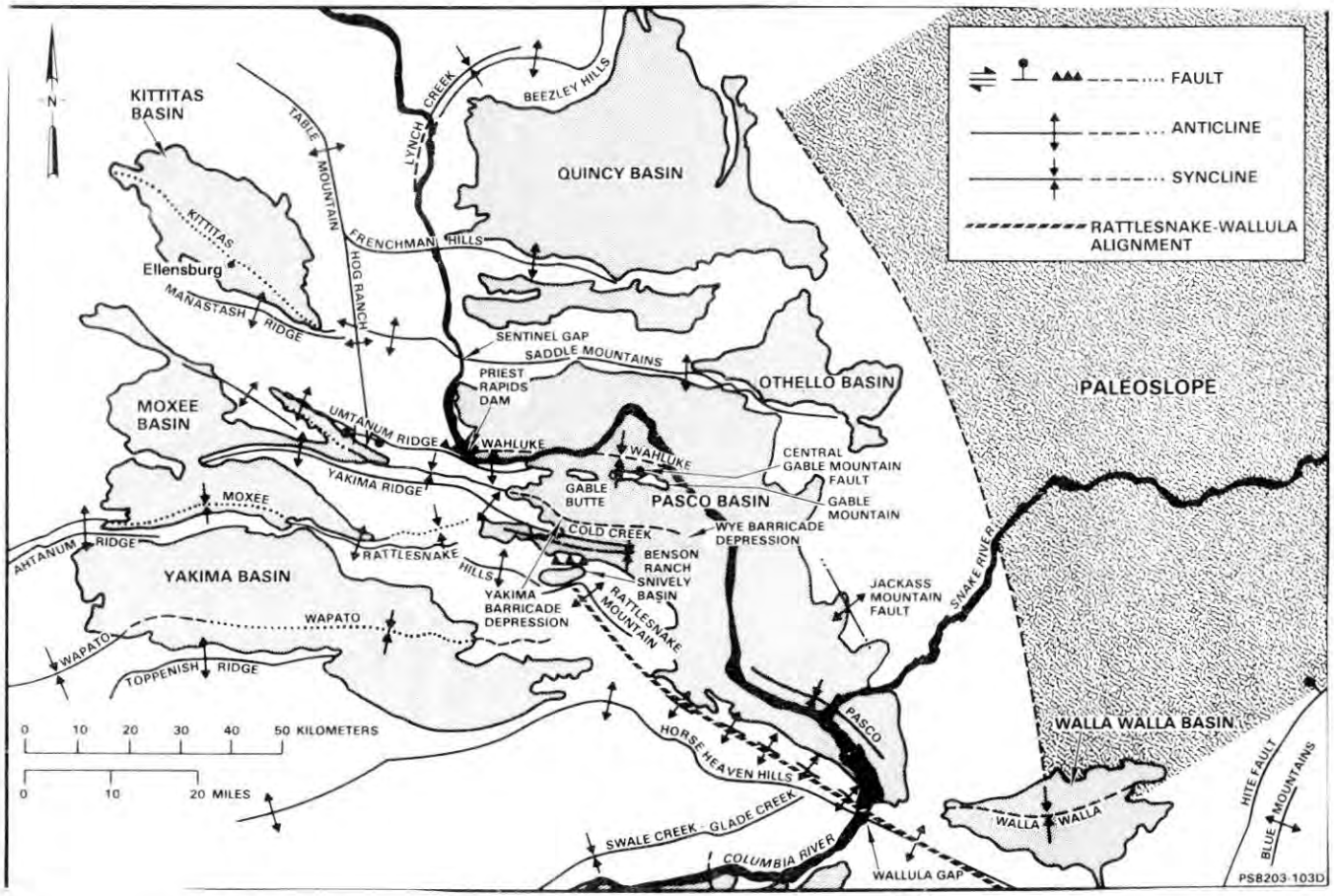

FIGURE 4.5. Generalized Geologic Structure Map of the Central Plateau (DOE 1984)

reduced by the construction of several flood control/water storage dams upstream of the Site. Normal river elevations within the Site range from 120 m where the river enters the Site near Vernita to 104 m where it leaves the Site near the 300 Area.

The probable maximum flood (the flood discharge that may be expected from the most severe combination of meteorologic and hydrologic conditions reasonably possible in the region) would produce a flow of 40,000 m^3/sec. Flood elevations would be about 129 m at 100-N Area and 117 m at the 300 Area (ERDA 1976). This flood would not affect the central part of the Site (the 200 Areas plateau), where most of the TRU wastes and HLW are now stored and which has an elevation greater than 152 m. Similarly, waters of a 100-year flood (13,000 m^3/s) would have no effect on the waste disposal sites.

The magnitudes of floods have been estimated that would result if 25% and 50% of the center section of Grand Coulee Dam were instantaneously destroyed (ERDA 1976). It has been determined that such breaches would result only from a direct hit by a large nuclear weapon; no natural event has been identified that would cause such breaches. A "50% flood" would create a maximum flow of brief duration of 227,000 m^3/sec and flood elevations of 143 to 148 m in the 100 Areas. The 100 Areas and the 300 Area would be flooded (Figure 4.6) and also most downstream cities adjacent to the river. The 200 Areas plateau would be above the "50% flood."

Since 1862, there have been fewer than 20 major floods on the Yakima River. The most severe of these occurred in November 1906, December 1933, and May 1948. Discharge magnitudes at Kiona, Washington, were 1,870, 1,900, and 1,050 m^3/sec, respectively (WPPSS 1981b). The recurrence intervals for the 1933 and 1948 floods are estimated at 170 and 33 years, respectively.

The development of irrigation reservoirs within the Yakima River Basin has considerably reduced flood potential of the river. For example, the December 1933 flood was reduced from 2,400 to 1,500 m^3/sec at Yakima, Washington, by management of upstream reservoir storage facilities. A December 1959 flood, which, if uncontrolled, could have reached a magnitude of 1,600 m^3/sec at Yakima, was held at 780 m^3/sec by the reservoir system.

Lands susceptible to a 100-year flood on the Yakima River are shown in Figure 4.7. Flooded areas near Horn Rapids could extend into the southern section of the Hanford Site; however, these waters would not reach the defense waste disposal locations. The Yakima River upstream from Horn Rapids is physically separated from the Hanford Site by Rattlesnake Mountain. This topographic barrier prevents potential flooding of the Yakima River from reaching the defense waste disposal location.

The potential for flash flooding from the Cold Creek drainage has been examined (Skaggs and Walters 1981), and a maximum flood depth of 2.3 m was estimated along the southwestern part of the 200 Areas plateau and extending to the 200 West Area (Figure 4.8); however, the maximum probable flood has not been well-defined for the Cold Creek drainage. A 100-year peak-stage flood, estimated to be about 1 m above the Cold Creek Valley floor, would not reach the 200 Areas.

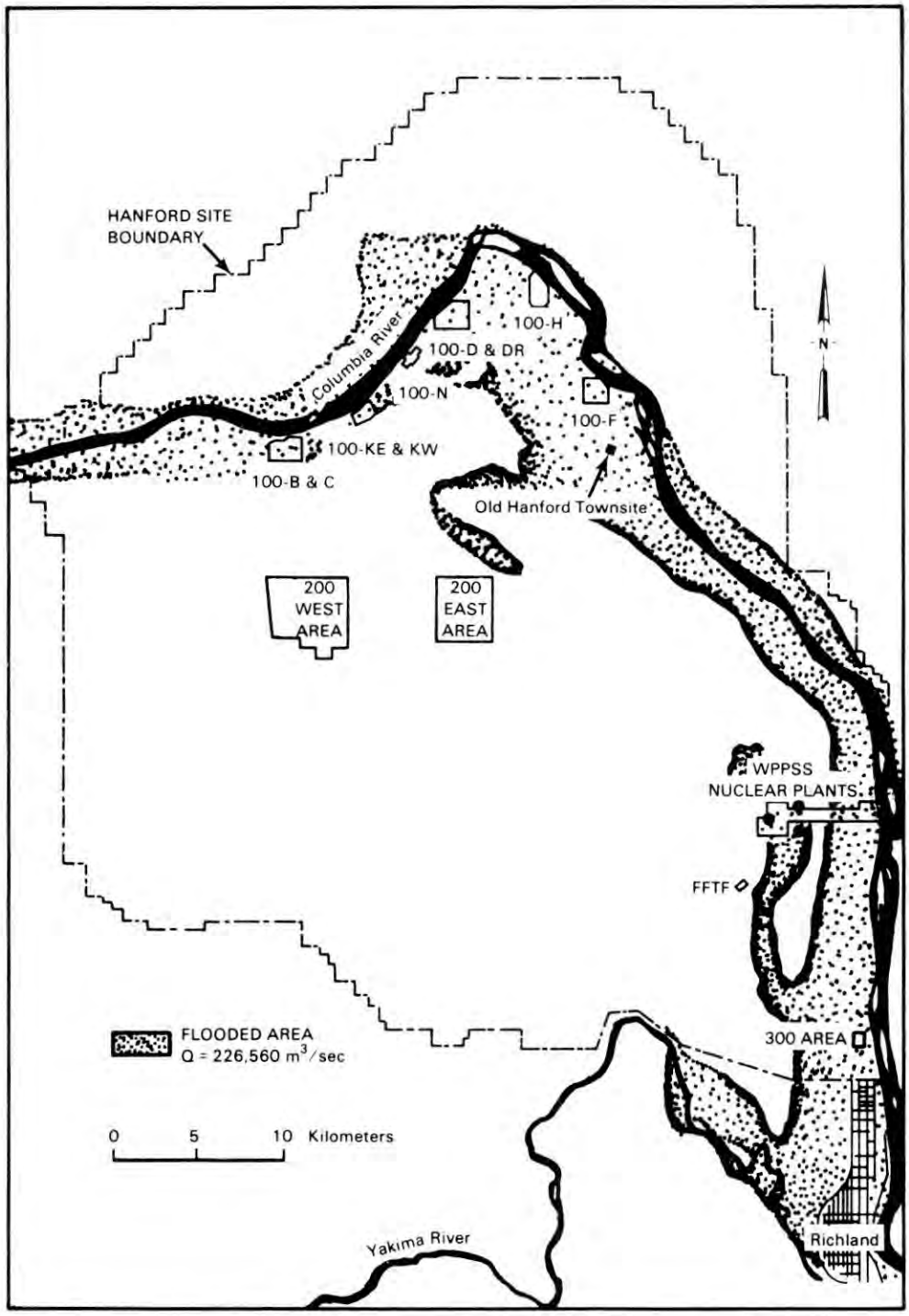

FIGURE 4.6. Flooded Areas Resulting from a Hypothetical 50% Breach of Grand Coulee Dam (ERDA 1976)

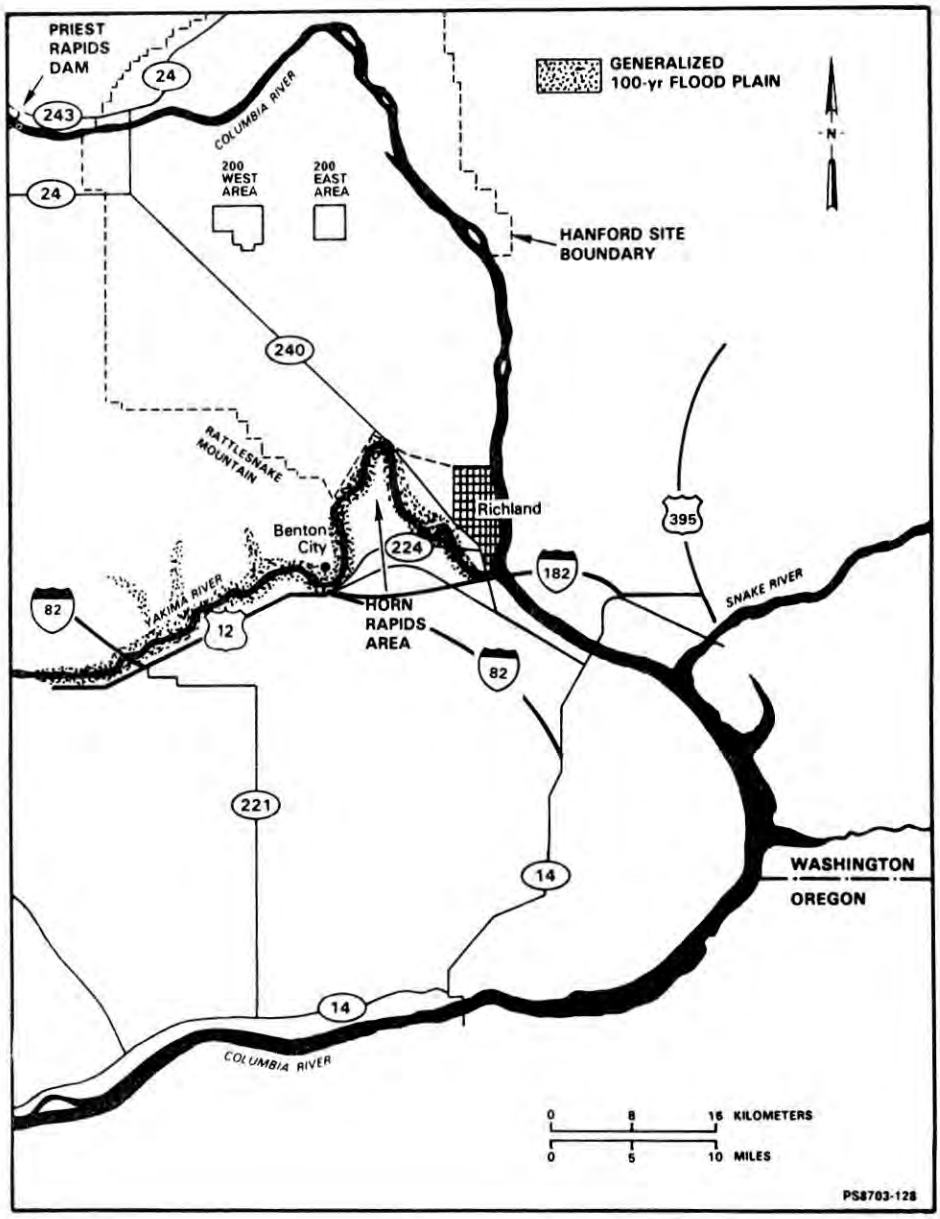

FIGURE 4.7. Flooded Areas Resulting from a 100-Year Flood of the Yakima River in the Vicinity of the Hanford Site (FEMA 1980)

The 200 Areas plateau has numerous ponds and ditches (Figure 4.9), mostly wasteways for process and cooling water. Effluents discharged to them sometimes contain small quantities of radionuclides, both fission products and TRU, and constitute an artificial source of groundwater recharge. Two ephemeral streams, Dry Creek and Cold Creek, cross the southwestern part of the Site and drain toward the Yakima River. Rattlesnake Springs, located on the

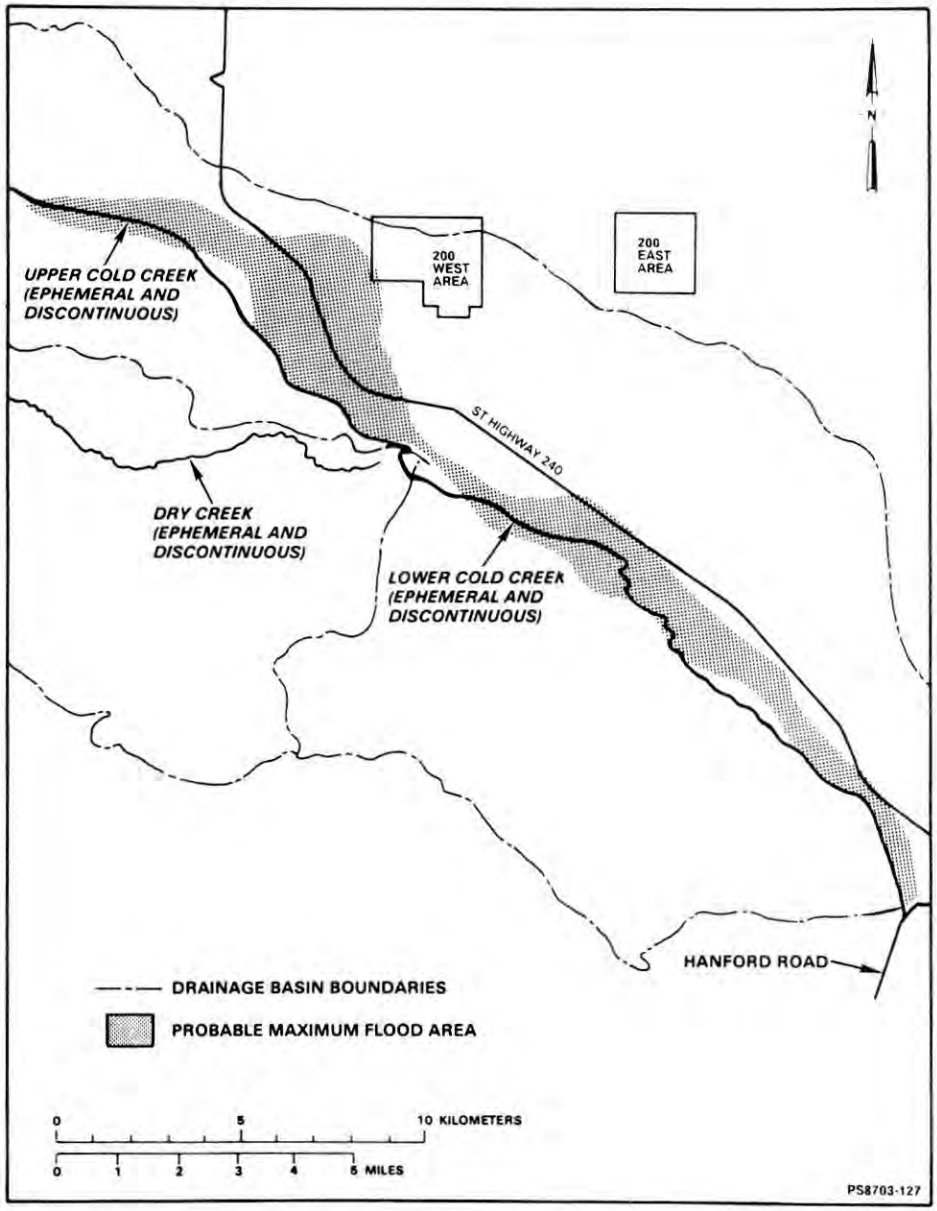

FIGURE 4.8. **Flooded Areas Resulting from a Probable Maximum Flood in Cold Creek Area** (Skaggs and Walters 1981)

western part of the Site, forms a small surface stream that flows for about 3 km before disappearing into the ground. The Yakima River recharges the unconfined aquifer in the southeastern part of the Site.

During the time that single-pass cooling reactors were in operation, radionuclides, chiefly from the neutron activation of constituents in cooling water and in reactor piping, were detected in marine organisms and sediments in the Pacific Ocean along the Oregon and Washington coasts (Watson et al. 1961; Seymour and Lewis 1964; and Joseph et al. 1971). With only N Reactor and WPPSS 2, with closed-cycle cooling systems, presently operating, the

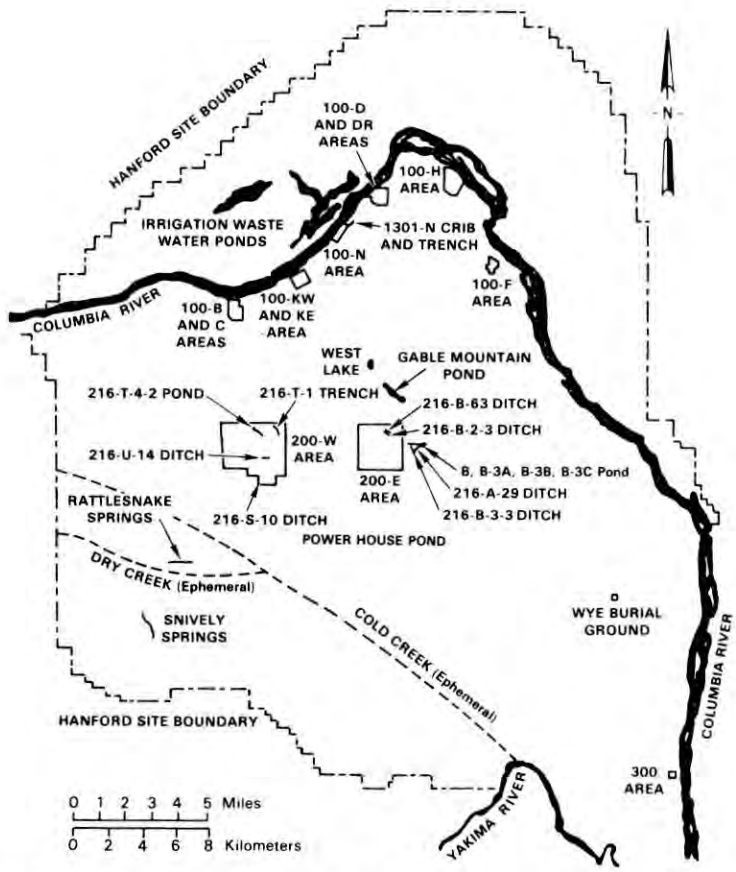

FIGURE 4.9. Surface Water Bodies, Including Ephemeral Streams, on the Hanford Site (DOE 1982a, 1984; Meinhardt and Frostenson 1979)

discharge of radionuclides to the Columbia River is very low (see Section 4.1 for concentrations in Columbia River water and fish). Measurements of radioactivity in river sediments downstream of the Hanford Site in 1977-1978 show that ^{60}Co, ^{137}Cs, $^{239,240}Pu$, and ^{241}Am were the most abundant. Total inventories of these from the Site to the river mouth were 270 Ci of ^{60}Co, 254 Ci of ^{137}Cs, 4.1 Ci of $^{239,240}Pu$, and 1.2 Ci of ^{241}Am (Beasley and Jennings 1984). The ^{60}Co activities are attributed to the discharges from the now inoperative plutonium reactors; most of the $^{239,240}Pu$ and ^{137}Cs activity and all the ^{241}Am activity are derived from worldwide weapons fallout. This can be compared to the release to the river of about 300,000 Ci/yr of radionuclides (of widely varying half-lives) from the Hanford reactors in the mid 1960s (Robertson et al. 1973).

Columbia River water quality is routinely monitored from locations upstream and downstream of the Hanford Site by Pacific Northwest Laboratory and the U.S. Geological Survey (Jaquish and Mitchell 1987). Results for 1986 are given in Table 4.5. The values for the two locations are similar and are generally within applicable standards.

TABLE 4.5. Columbia River Water Quality Data (Jaquish and Mitchell 1987)

Analysis	Units	Vernita Bridge (Upstream) No. of Samples	Maximum	Minimum	Annual Average[a]	Richland (Downstream) No. of Samples	Maximum	Minimum	Annual Average[a]	State Standard
PNL Environmental Monitoring										
pH	pH units	9	8.3	6.0	NA	9	8.1	6.1	NA	6.5 - 8.5
Fecal coliform	#/100 mL	12	240	<2	2[b]	12	240	<2	8[b]	100
Total coliform	#/100 mL	12	>2400	2	49[b]	12	1600	17	130[b]	
Biological oxygen demand	mg/L	12	8.2	<0.5	3.1 ± 1.1	12	5.9	0.5	2.8 ± 0.8	
Nitrate	mg/L	12	0.53	<0.05	0.17 ± 0.08	12	2.1	<0.05	0.3 ± 0.3	
USGS Sampling Program[c]										
Temperature[d]	°C	365	20.1	1.5	11.1 ± 3.6	365	21.1	1.1	11 ± 3.9	20 (maximum)
Dissolved oxygen	mg/L	6	13.8	8.4	11.5 ± 1.9	4	13.0	9.2	11.2 ± 1.8	8 (minimum)
Turbidity	NTU[e]	4	4.0	1.2	2.0 ± 1.3	4	3.2	1.4	2.6 ± 0.8	5 + background
pH	pH units	6	8.4	7.3	NA	4	8.4	7.2	NA	6.5 - 8.5
Fecal coliform	#/100 mL	4	4	0	1.5[b]	3	16	1	1[b]	100
Suspended solids, 105°C	mg/L	4	7	1	3.5 ± 2.6	4	8	3	4.8 ± 2.2	
Dissolved solids, 180°C	mg/L	4	93	73	82 ± 8	4	80	68	75 ± 5	
Specific conductance		6	150	130	140 ± 8	4	150	130	140 ± 11	
Hardness, as $CaCO_3$	mg/L	4	78	59	65 ± 9	4	68	59	65 ± 4	
Phosphorus, total	mg/L	6	0.06	0.02	0.03 ± 0.02	4	0.04	0.02	0.03 ± 0.01	
Chloride, dissolved	mg/L	4	1.2	0.9	1.1 ± 0.1	4	1.3	0.8	1.1 ± 0.2	
Chromium, dissolved	µg/L	2	<1	<1	<1	4	30	<10	<15	
Nitrogen, Kjeldahl	mg/L	6	0.3	<0.2	0.22 ± 0.03	4	0.4	<0.2	0.25 ± 0.10	
Total organic carbon	mg/L	3	6.8	2.2	5.0 ± 3.1	4	6.8	1.7	4.2 ± 2.2	
Iron, dissolved	µg/L	2	14	11	12.1 ± 4.1	4	18	6	10.0 ± 5.4	
Ammonia, dissolved (as N)	mg/L	6	0.05	<0.01	0.02 ± 0.02	4	0.04	<0.01	0.03 ± 0.01	

(a) Average values ± 2 standard error of the calculated mean.
(b) Annual median.
(c) Provisional data subject to revision.
(d) Maximum and minimum represent daily averages.
(e) Nephelometric Turbidity Units.
NA = Not Applicable.

The U.S. Army Corps of Engineers earlier considered the possible construction of Ben Franklin Dam to be located at River Mile 348, about 16 km upstream from Richland. No construction schedules or dates have been published, because the Corps of Engineers is not actively considering the dam site. If built, this dam would raise the river level about 18 m, to a normal pool elevation of about 122 m mean sea level (USCE 1981). Nuclear facilities along the shore would be affected by the higher water elevation, but the surface of the 200 Areas plateau would be much above this level. Near the 100 Areas the increase in the groundwater level would be about 5 to 10 m and 2 to 5 m beneath the 200 Areas. Groundwater plumes from the 200 Areas would be altered, increasing travel time in some areas, and reducing travel time and increasing dilution in others (USCE 1981). No problems of liquefaction in the 200 Areas or effects on 200 Areas structures would be expected.

Estimates of withdrawal of Columbia River water, for irrigation within 130 km downstream of Hanford, are given in Section 4.8.3. Irrigation water removed represents a major withdrawal of river water downstream of the Site. The mean Columbia River flow nearly doubles between the Site and the river mouth. The contributions of the major tributaries are given in Table 4.6.

4.4.2 Groundwater

Groundwater under the Site occurs under unconfined and confined conditions. The unconfined aquifer is contained within the glaciofluvial sands and gravels and the Ringold Formation. It is dominated by the middle member of the Ringold Formation, consisting of sorted sands and gravels of varying hardness. The bottom of the aquifer is the basalt surface or, in some areas, the clay zones of the lower member of the Ringold Formation. The confined aquifers consist of sedimentary interbeds and/or interflow zones that occur between dense basalt flows in the Columbia River basalt group. The main water-bearing portions of the interflow zones occur within a network of interconnecting vesicles and fractures of the flow tops or flow bottoms. Erosional "windows" through the confining beds (the dense basalt flows of the Saddle Mountain Basalt Formation) north of the 200 East Area provide potential direct interconnections between the unconfined and the uppermost confined aquifers. The most complete area of erosion is located in the vicinity of West Lake, where all but the last member (the Umatilla Member) of the Saddle Mountain Basalt was completely removed (see Figure 4.2). Graham et al. (1984) defined the hydrologic relationships between the uppermost confined aquifer (the Rattlesnake Ridge Aquifer) and the unconfined aquifer in an area surrounding Gable Mountain and B Ponds. Detailed descriptions of the geohydrology of the Hanford Site are given in Newcomb et al. (1972); Gephart et al. (1976); Gephart et al. (1979); Graham et al. (1981); DOE (1982a); Strait and Moore (1982); and Graham et al. (1984).

The water table, representing the upper limit of the unconfined aquifer, ranges from 56 to 100 m beneath the ground surface in the 200 Areas. The unconfined aquifer is over 70 m thick in some areas and thins to zero thickness along the flanks of the bordering rock formations. Some local basalt formations within the Site extend above the water table, the most notable being Gable Mountain and Gable Butte (Figure 4.10). A hindcast of pre-1944 groundwater elevations is shown in Figure 4.11.

TABLE 4.6. Flows of the Columbia River and Major Tributaries Downstream of Hanford

Stream	Miles from Tributary Mouth to Columbia River Mouth	Mean Flow, m^3/sec
Columbia River (below Priest Rapids Dam)[a]	391	3,401
Washington Tributaries		
Yakima River[b]	335	104
Snake River[a]	324	1,574
Walla Walla River[a]	314	16.9
Alder Creek[a]	258	0.243
Klickitat River[a]	180	45.7
White Salmon River[a]	168	31.9
Little White Salmon River[c]	163	12.1
Wind River[c]	155	35.6
Washougal River[c]	123	24.9
Lewis River[a]	87	159
Kalama River[c]	75	34.3
Cowlitz River[a]	68	262
Elochoman River[c]		10.9
Oregon Tributaries		
Umatilla River[d]	289	12.8
John Day River[d]	218	57.7
Deschutes River[d]	204	165
Hood River[d]	169	30.8
Sandy River[c]	121	71.6
Willamette River[d,e]	102	928
Youngs River[c]	12	5.38
Columbia River at the Mouth[c,f]	0	7,290

(a) USGS 1985.
(b) Personal communication L. E. Hubbard, U.S. Geological Survey, Portland, Oregon.
(c) Personal communication R. Williams, U.S. Geological Survey, Tacoma, Washington.
(d) Orem 1968.
(e) Estimated from summation of tributary flows.
(f) Hubbard et al. 1983.

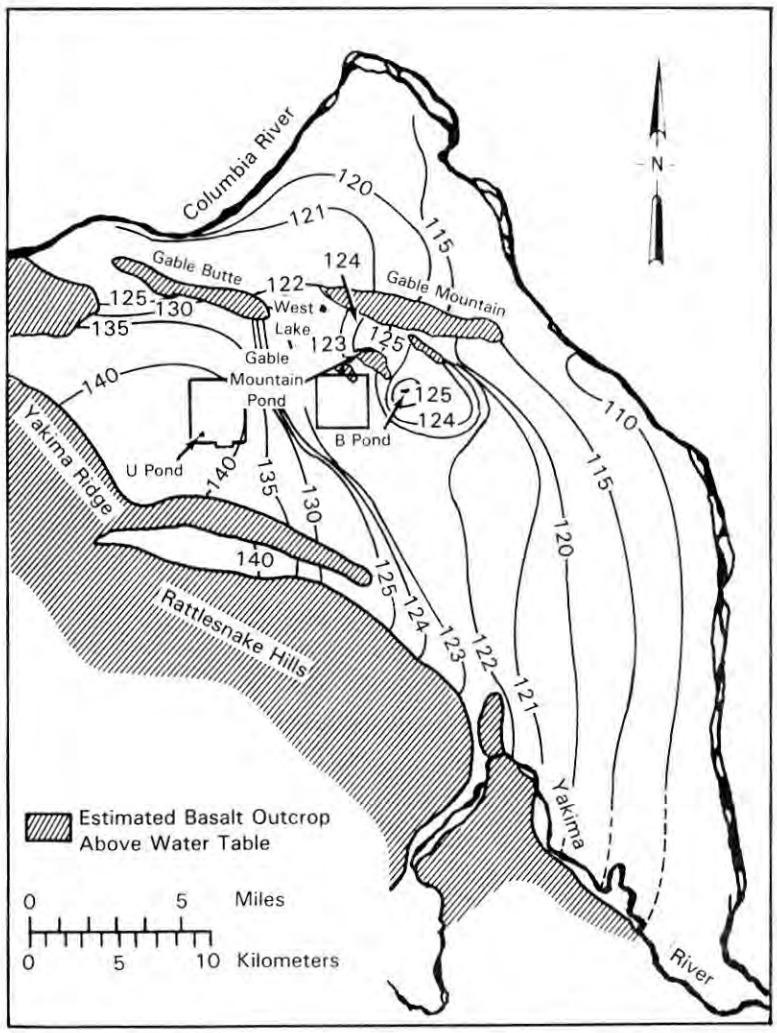

FIGURE 4.10. December 1982 Water Table Map for the Hanford Site, in Meters Above Mean Sea Level (Graham 1983)

Sources of natural recharge to the unconfined aquifer are rainfall and runoff from the higher bordering elevations, water infiltrating from small ephemeral streams, and river water along influent reaches of the Yakima and Columbia Rivers.

Artificial recharge to the unconfined aquifer results from the disposal of waste water to the ground in the 200 Areas. This recharge to the aquifer has been estimated to be about 5.5×10^7 L/day, or about ten times the natural recharge of 5×10^6 L/day entering the unconfined aquifer below the 200 Areas from the surrounding highlands. U Pond, B Pond, and Gable Mountain Pond (Figure 4.9) have been the major sources of the artificial recharge (Jamison 1982; Meinhardt and Frostenson 1979). The estimated levels of the water table under the Hanford Site are given in Figure 4.10. Beneath these disposal ponds, groundwater mounds have developed in response to the artificial recharge. Under U Pond, the water table has risen about 26 m since the start of disposal operations in 1944. The mound under B Pond has risen

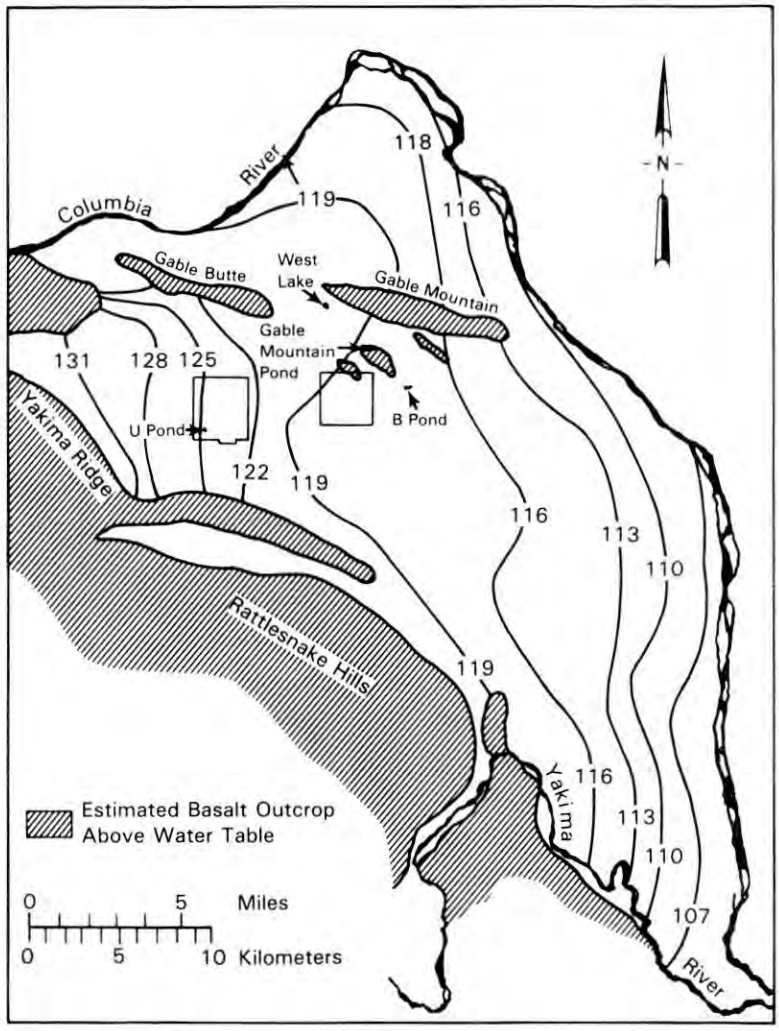

FIGURE 4.11. Hanford Site Water Table Map January 1944 Hindcast in Meters Above Mean Sea Level (ERDA 1975)

about 9 m. U Pond was decommissioned in March 1985, and Gable Mountain Pond is currently being reduced in size and is scheduled for decommissioning and stabilization by the end of 1987. These changes will affect the configuration of the artificial recharge to groundwater. West Lake, a natural depression located about 1.7 km north of Gable Mountain Pond (Figure 4.9), contained water intermittently before liquid-waste disposal operations began. West Lake now contains water perennially as a result of the higher water table induced by the artificial recharge.

From the recharge areas to the west, the groundwater flows downgradient to the discharge areas along the Columbia River. This general west-to-east flow pattern is interrupted locally by the groundwater mounds in the 200 Areas. The vertical and horizontal extent of these mounds appears to be directly related to the surface discharge of waste water from facilities in the 200 West and 200 East Areas (Zimmerman et al. 1986). From the 200 Areas,

there is also the component of groundwater flow to the north, between Gable Mountain and Gable Butte. These flow directions represent present conditions; the aquifer is dynamic, responding to changes in natural and artificial recharge.

4.4.2.1 Discharges of Radioactive Constituents

Waste waters discharged on the Hanford Site have reached the unconfined aquifer. The primary constituents that have reached the aquifer are ^{3}H, ^{129}I, ^{106}Ru, ^{99}Tc, uranium, and some nonradioactive chemicals. These constituents are non-attenuated, or only slightly attenuated, and have moved from the waste disposal sites, through the unsaturated (vadose) sediments, to the unconfined aquifer. Some radionuclides such as ^{90}Sr and ^{137}Cs have reached the groundwater, primarily through cribs. Moreover, the artificial recharge amounts to about 5000 cm/yr, which accounts for the relatively fast movement of some nuclides through the unsaturated zone to groundwater. Liquid wastes were discharged into underground cribs that were monitored by analyzing water samples taken from the groundwater directly below the crib. When the samples indicated that any long-lived nuclide concentration reached 10% of the control limits for radiation workers (ERDA 1977 and DOE 1986a), the crib was taken out of service. Minor quantities of longer-lived radionuclides have reached the water table via a failed groundwater monitoring well casing (Van Luik and Smith 1982), and through reverse (injection) well injection, a disposal practice discontinued at Hanford in 1947 (Smith 1980). Waste disposal practices and the resultant impacts were described in an environmental impact statement assessing Hanford operations in 1975 (ERDA 1975; see also Appendix V). Although waste disposal practices in the past have resulted in local contamination of the site and the unconfined aquifer, this contamination has not resulted in, and is not expected to result in, any significant radiation exposure to the public (ERDA 1975; NAS 1978, Jaquish and Mitchell 1987). However, the presence of this contamination dictates the need for controlled access and land use for at least the near term.

As discussed elsewhere (4.4.2) there is some evidence of vertical interconnections between the unconfined and upper confined aquifers. This is not thought to be a contributor to the impacts of defense waste disposal considered in this EIS (such interconnections would predictably have a longer path and slower travel time to the Columbia River through the confined aquifers). However, the migration of such radionuclides as ^{129}I can be important to the understanding of the Hanford hydrology.

An intercontractor working group was formed in 1986 to gather, summarize, and evaluate information on ^{129}I in groundwater (Westinghouse 1987). Findings and conclusions of this group include the following:

1) Above-background levels of ^{129}I have been measured on site in the confined aquifer system to a depth of 1,500 ft.
2) The amount of quantifiable ^{129}I information is insufficient to draw definite conclusions about its origin or its movement in the confined aquifer. Current programs should further develop the ^{129}I data base with new information that will meet necessary quality standards to allow definitive conclusions.

3) All recent onsite ^{129}I measurements are below the DOE Derived Concentration Guide (DCG) of 500 pCi/L, and all recent offsite measurements are well below the EPA Drinking Water Standard of 1 pCi/L.

The groundwater is routinely and extensively monitored to trace the movement of contaminants and to determine any impact from the Site to the public (Graham 1981). Groundwater monitoring reports are produced annually (Eddy et al. 1983; Wilbur et al. 1983; Prater et al. 1984; Law et al. 1986; Jaquish and Mitchell 1987). Concentrations of tritium and the nonradioactive nitrate ion in the groundwater, as determined by a well-monitoring program, are useful in defining the movement of groundwater and contaminants from the 200 Areas. However, these concentrations are the result of present and recent past operations that will not continue over the long term. They are expected to dissipate through dispersion, radioactive decay or discharge to the Columbia River prior to the earliest arrival to the river of wastes considered in this EIS. The use of groundwater-monitoring data to calibrate transport models is reviewed in Appendix V.

Studies were conducted to determine whether any contaminants have migrated downward from the unconfined aquifer to the upper, confined aquifer (Strait and Moore 1982; Graham et al. 1984). These studies indicated that there was some contamination in the upper confined aquifer south and east of Gable Mountain Pond, but that contamination levels were well below limits established in drinking water standards. Also, under present groundwater flow conditions, contaminants in the upper, confined aquifer in the vicinity of Gable Mountain Pond and B Pond are likely to eventually discharge back to the unconfined aquifer in the vicinity of West Lake (Graham 1983).

Although groundwater beneath the Hanford Site is considered a "significant" source of groundwater according to 40 CFR 191.12(n), there is no withdrawal of that groundwater for purposes of supplying any community water systems. There are no "special" sources of groundwater as defined in 40 CFR 191.12(o) in the vicinity of the Hanford Site.

4.4.2.2 Discharges of Nonradioactive Chemicals

Chemicals in the Hanford environment result from natural sources as well as Site operations. Sediments in the aquifer beneath the Hanford Site are the dominant sources of naturally occurring chemicals in the groundwater. Natural background levels of selected constituents are given in Table 4.7 (Jaquish and Mitchell 1987). These background levels are estimated from chemical monitoring of 38 wells in areas unlikely to be affected by past or present Site operations. Nitrate is not included in Table 4.7 because of its widespread distribution. Background concentrations of nitrate range from 500 to 2000 µg/L (ppb). Nitrate in the unconfined aquifer may result from natural sources and from pre-Hanford activities such as agriculture, as well as from Site operations.

Chemicals are used in a wide variety of processes at Hanford. Nitrate and chromium are major chemicals attributable to Site operations. These two substances are used as indicators for defining the extent of contamination from Site operations. The distribution of nitrate in the unconfined aquifer is illustrated in Figure 4.12. Nitrate is associated with process condensate liquid waste discharges in the 200 Areas. Elevated nitrate concentrations also

TABLE 4.7. Estimated Background Levels for Selected Constituents in Hanford Groundwater (Jaquish and Mitchell 1987)

Constituent	Detection Limit (μg/L)	Background Concentration[a] (μg/L)
Ag	10	<10
Al	150	<150
As	5	<5
Ba	6	38 ± 15
Be	5	<5
Ca	50	38,000 ± 12,000
Cd	2	<5
Cl	500	9,400 ± 5,100
Cr	10	10 - 20
Cu	10	<10
F	500	<500 - 1,500
Hg	0.1	<0.1
K	100	5,000 ± 1,400
Mn	5	<5 - 700
Na	100	18,000 ± 5,900
NH_4	50	110 ± 50
Ni	10	<10
Pb	5	<10
PO_4	1,000	<1,000
SO_4	500	33,000 ± 18,000
V	5	15 ± 8

(a) Stated as an average, an average ± the standard deviation, or a range.

exist beneath other operational areas as a result of nitric acid use in radioactive decontamination processes. Chromium-containing compounds were also used in decontamination processes. Sodium dichromate and chromic acid were used for reactor, equipment and facility decontamination.

Nitrate and chromium levels do exceed primary drinking water standards (EPA 1976) beneath several of the operational areas. Maximum concentrations of nitrate and chromium in the unconfined aquifer associated with each operational area are given in Table 4.8. Although nitrate and chromium do exist in concentrations above the maximum contaminant levels (as set forth in the National Primary Drinking Water Regulations 40 CFR 141 Subpart B) in Hanford monitoring wells, the groundwater in question is not currently a source of public drinking water. Discharge of nitrate and chromium to the Columbia River from the unconfined

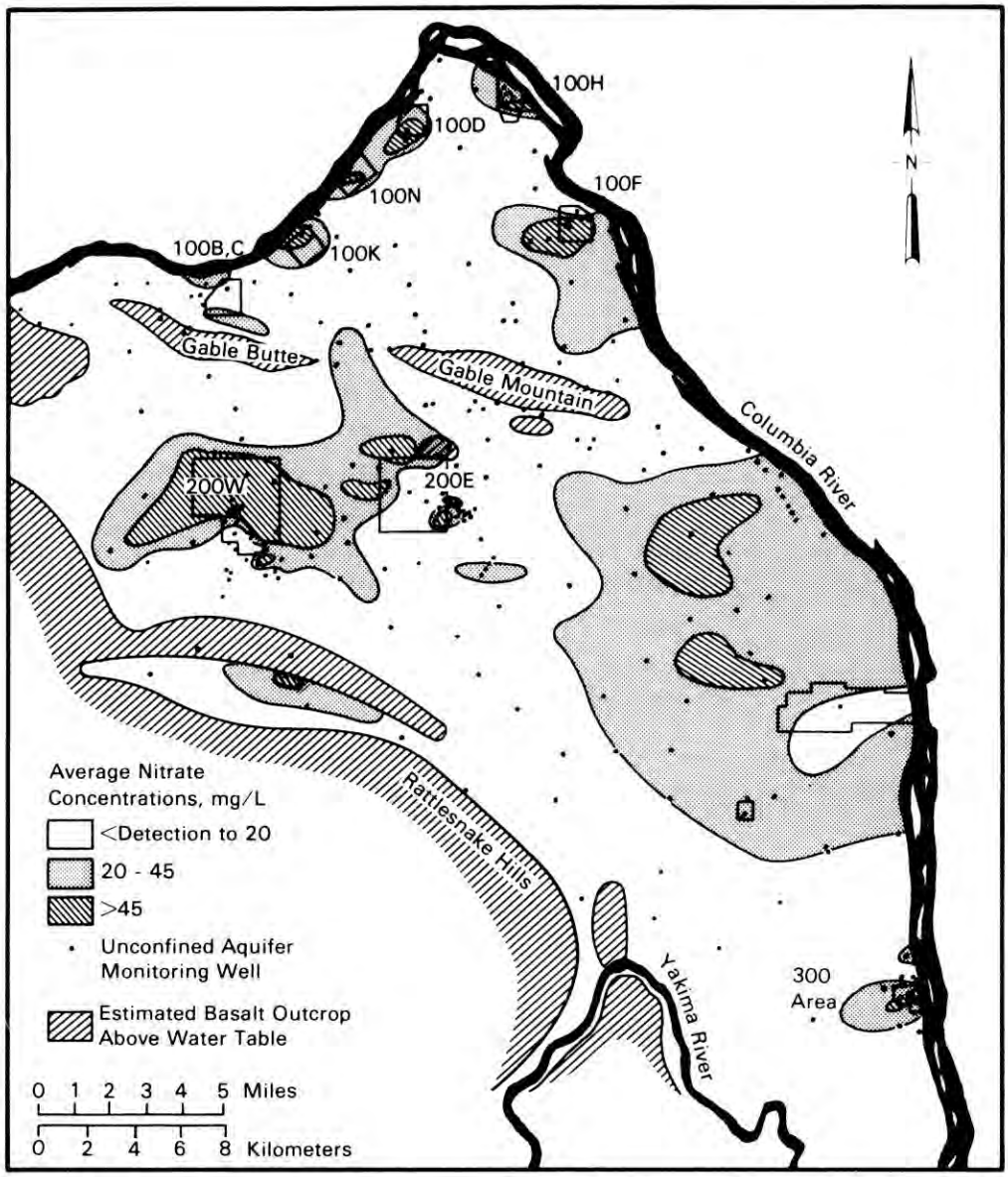

FIGURE 4.12. Distribution of Nitrate in the Unconfined Aquifer on the Hanford Site (Jaquish and Mitchell 1987)

aquifer appears to be the primary pathway for public exposure to these substances. As illustrated in Table 4.5, these substances have had little influence on Columbia River water quality.

Isolated instances of chemical contamination also exist in the unconfined aquifer at Hanford. Carbon tetrachloride exceeds drinking water standards (EPA 1976) in certain wells beneath the 200 West Area. Cyanide has been detected in two wells north of the 200 East Area, but no drinking water standard (EPA 1976) has been proposed for cyanide. Trichloroethylene has also been detected at concentrations exceeding the drinking water standard (EPA

TABLE 4.8. Maximum Measured Concentrations of Nitrate and Chromium in Hanford Groundwater by Area During 1987 (Evans, Mitchell and Dennison 1987)

Constituent	Location[a]	Maximum Concentration (μg/L)	Maximum Contaminant Level[b]
Nitrate	100 D	99,800	45,000
	100 F	191,000	45,000
	100 H	1,020,000	45,000
	100 K	68,100	45,000
	200 East	398,000	45,000
	200 West	977,000	45,000
	300	59,000	45,000
Chromium	100 B	62	50
	100 D	1,690	50
	100 H	437	50
	100 K	193	50
	200 West	143	50

(a) See Figure 4.1 for locations.
(b) EPA 1976.

1976) near the Hanford Site landfill facility. The maximum measured concentrations for carbon tetrachloride, cyanide, and trichloroethylene are 3,210, 460, and 56 μg/L, respectively (Evans, Mitchell and Dennison 1987). The DOE has established an ongoing monitoring program directed toward characterizing the presence, extent and transport of hazardous chemicals in the Hanford groundwater.

4.5 METEOROLOGICAL CONDITIONS AND AIR QUALITY

Climatological data are available from the Hanford Meteorology Station, which is located between the 200 Areas. Data have been collected at the Hanford Meteorology Station since 1945, and temperature and precipitation data from nearby locations are available for the period 1912 through 1943. A summary of these data, through 1980, has been published by Stone et al. (1983). Data from the Hanford Meteorology Station are assumed to be representative of the general climatic conditions for the region.

4.5.1 Wind

Wind data are collected routinely at the Hanford Meteorology Station. In addition to surface wind data (2.1-m level), wind data are collected at the 15.2, 30.5, 61.0, 91.4, and 121.9-m levels of a 125-m tower at the station. More than 20 telemetry stations distributed on and around the Hanford Site provide supplementary surface (9.1-m level) wind data for defining wind patterns.

Prevailing wind directions are from the northwest in all months (Figure 4.13). Secondary maxima are indicated for southwesterly winds. The wind direction summaries indicate that winds from the northwest quadrant occur most often during the winter (i.e., December, January, February) and summer (i.e., June, July, August). During the spring and fall, the frequency of southwesterly winds increases with a corresponding decrease in northwest flow. Winds blowing from other directions (e.g., northeast) display minimal variation from month to month.

Monthly and annual joint frequency distributions of wind direction versus wind speed are given in Stone et al. (1983). Monthly average wind speeds are lowest during the winter months, averaging 10 to 11 km/hr, and highest during the summer, averaging 14 to 16 km/hr on a monthly basis. Wind speeds that are well above average are usually associated with southwesterly winds. In the summer, high-speed winds from the southwest are responsible for most of the dust storms experienced in the region.

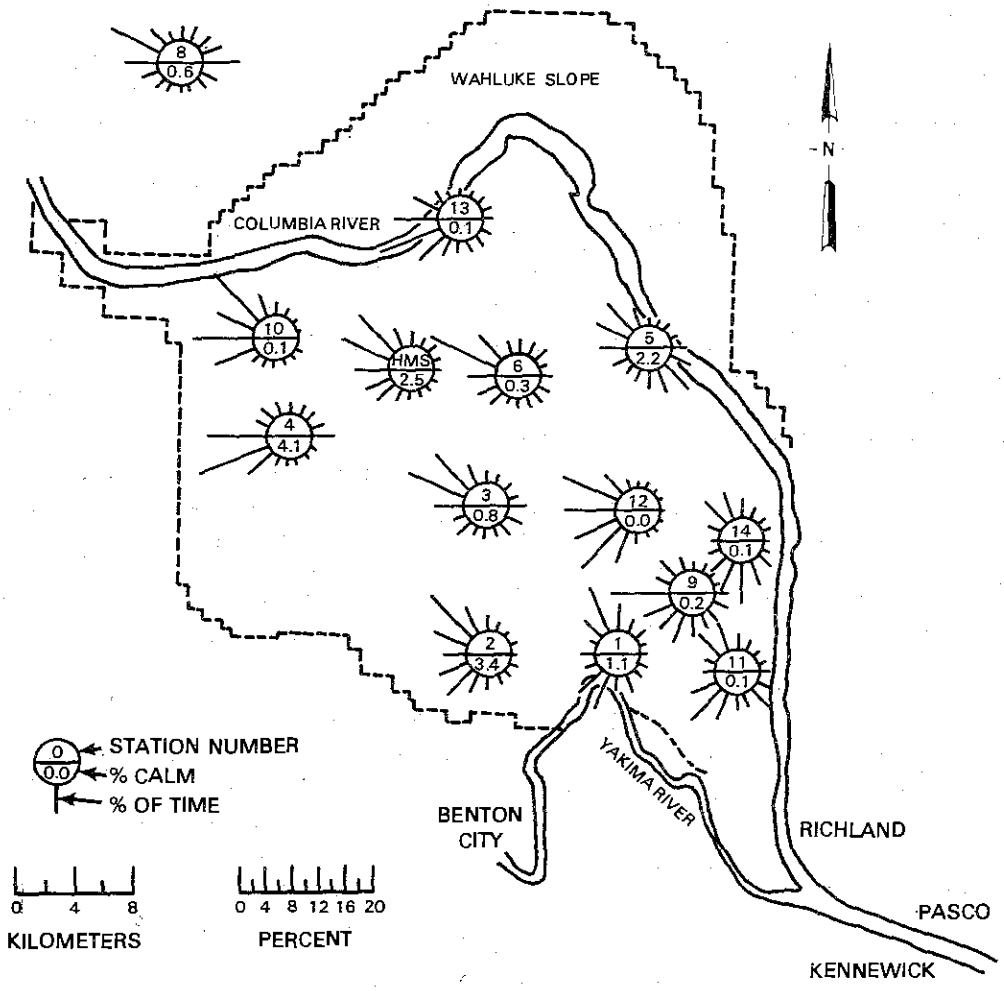

FIGURE 4.13. Wind Roses for the Hanford Telemetry Network, 1979-1982. The points of each rose represent the directions from which the winds come (Stone et al. 1983).

High winds are also associated with afternoon drainage winds and thunderstorms. The summertime drainage winds are generally northwesterly and frequently reach 50 km/hr. An average of ten thunderstorms occur each year. They are most frequent during the summer, but they have occurred in each month. The winds during thunderstorms do not have a directional preference.

Based on peak gusts observed from 1945 through 1980, Stone et al. (1983) estimate the extreme winds as shown in Table 4.9.

TABLE 4.9. Estimates of Extreme Winds at the Hanford Site

	Peak Gusts, km/hr	
Return Period, yr	15.2 m Above Ground	61 m Above Ground
2	97	109
10	114	129
100	137	151
1,000	159	175

Tornadoes are infrequent and generally small in the northwest portion of the United States. Grazulis (1984) lists no violent tornadoes for the region surrounding Hanford. The Hanford Meteorology Station climatological summary (Stone et al. 1983) and the National Severe Storms Forecast Center (NSSFC) data base list 22 separate tornado occurrences within 161 km of the Hanford Site from 1916 through August 1982, and two additional tornadoes have been reported since August 1982.

The expected area for a tornado in the Hanford area is about one square kilometer. Using the information in the preceding paragraph and the estimation technique described by Markee, Beckerley, and Sanders (1974), the estimated probability of a tornado's striking a point at Hanford is 4×10^{-6} per year. The probabilities of extreme winds associated with tornadoes striking a point can be estimated using the distribution of tornado intensities for the region. These probability estimates are given in Table 4.10.

TABLE 4.10. Estimate of the Probability of Extreme Winds Associated with Tornadoes Striking a Point at Hanford (Based on work in progress by J. V. Ramsdell, Pacific Northwest Laboratory)

Wind Speed, km/hr	Probability Per Year
100	2.6×10^{-6}
200	6.5×10^{-7}
300	1.6×10^{-7}
400	3.9×10^{-8}

4.5.2 Temperature and Humidity

Diurnal and monthly averages and extremes of temperature, dewpoint, and humidity are contained in Stone et al. (1983). For the period 1912 through 1980, the average monthly temperatures range from a low of -1.5°C in January to a high of 24.7°C in July. During the winter the highest monthly average temperature at the Hanford Meteorology Station was 6.9°C, and the record lowest was -5.9°C; both occurred during February. During the summer the record maximum monthly average temperature was 27.7°C--in July--and the record lowest was 17.2°C--in June. The annual average relative humidity at the Hanford Meteorology Station is 54%, with maxima during the winter months (averaging about 75%) and minimum average relative humidity during the summer (about 35%).

4.5.3 Precipitation

Average annual precipitation at the Hanford Meteorology Station is 16 cm. Most of the precipitation takes place during the winter with nearly half of the annual amount occurring in the months of November through February. Days with greater than 1.3 cm precipitation occur less than 1% of the year. Rainfall intensities of 1.3 cm/hr persisting for 1 hr are expected once every 10 years. Rainfall intensities of 2.5 cm/hr for 1 hr are expected only once every 500 years. Winter monthly average snowfall ranges from 0.8 cm in March to 13.5 cm in January. The record snowfall of 62 cm occurred in February 1916, but the second highest snowfall is less than half this amount.

4.5.4 Atmospheric Dispersion

Atmospheric dispersion is a function of wind speed, atmospheric stability, and mixing depth. Dispersion conditions are generally good when winds are moderate to strong, when the atmosphere is neutral or unstable stratified, and when there is a deep mixing layer. Good dispersion conditions associated with neutral and unstable stratification exist about 57% of the time during the summer. Less favorable dispersion conditions occur when the wind speed is light and the mixing layer is shallow. These conditions are most common during the winter when moderately to extremely stable stratification exists about 66% of the time. Less favorable conditions would also occur periodically for surface and low-level releases in all seasons from about sunset to about an hour after sunrise as a result of ground-based temperature inversions and shallow mixing layers.

Mixing-layer thicknesses have been estimated at the Hanford Meteorology Station using remote sensors. The variations in mixing-layer thickness described above are summarized in Table 4.11.

Occasionally there are extended periods of poor dispersion conditions that are associated with stagnant air in stationary high-pressure systems. Stone et al. (1972) estimated the probability of extended periods of poor dispersion conditions. The probability of an inversion period extending more than 12 hr varies from a low of about 10% in May and June to a high of about 64% in September and October. These probabilities decrease rapidly for durations greater than 12 hr. Table 4.12 summarizes the probabilities associated with

TABLE 4.11. Percent Frequency of Occurrence of Mixing Layer Thickness by Season and Time of Day

Mixing Layer, m	Winter		Summer	
	Night	Day	Night	Day
Less than 250	65.7	35.0	48.5	1.2
250-500	24.7	39.8	37.1	9.0
More than 500	9.6	25.2	14.4	89.9

TABLE 4.12. Percent Probabilities for Extended Periods of Surface-Based Inversions

Months	Inversion Duration		
	12 hr	24 hr	48 hr
January-February	54	2.5	0.28
March-April	50	<0.1	<0.1
May-June	10	<0.1	<0.1
July-August	18	<0.1	<0.1
September-October	64	0.11	<0.1
November-Oecember	50	1.2	0.13

extended surface-based inversions. Probabilities associated with extended periods of shallow-mixing-layer thicknesses have not been estimated.

To protect air quality, national Ambient Air-Quality Standards (AAQS) have been set by the U.S. Environmental Protection Agency (EPA). The standards define levels of air quality that are necessary, with an adequate margin of safety, to protect the public health (primary standards) and the public welfare (secondary standards). Standards exist for sulfur oxides (measured as sulfur dioxide), nitrogen dioxide, carbon monoxide, and total suspended particulates (Table 4.13). The standards apply to "that portion of the atmosphere, external to buildings, to which the general public has access" (40 U.S.C. Part 50).

State and local governments have the authority to impose AAQS that are stricter than the national standards. Washington State standards for sulfur dioxide and total suspended particulates are more stringent than the national standards (Table 4.13). At the local level, the Tri-County (Benton-Franklin-Walla Walla) Air Pollution Control Authority has established regional emission criteria, but has not established more stringent AAQS.

Sulfur dioxide, nitrogen dioxide, carbon monoxide, and total suspended particulates have been periodically monitored in the communities and commercial areas southeast of Hanford and/or sites within Hanford during the past two decades (NRC 1982). The maximum ambient concentrations measured in the region are presented in Table 4.13. Because these measurements

TABLE 4.13. Ambient Air Quality Standards and Maximum Measured Background Concentrations for the Hanford Site and the Surrounding Area, $\mu g/m^3$

	National Primary Standard	National Secondary Standard	Supplemental State Standard	Maximum Ambient Concentration
Nitrogen Dioxide (NO_2)				
Annual arithmetic mean	100	100	--	36
Sulfur Dioxide (SO_2)				
Annual arithmetic mean	80	80	52	0.5
24-hr maximum[a]	365	365	260	6
3-hr maximum[a]	--	1,300	--	20
1-hr maximum[a]	--	--	1,018	49
1-hr maximum[b]	--	--	655	49
Carbon Monoxide (CO)				
8-hr maximum[a]	10,000	10,000	--	6,500
1-hr maximum[a]	40,000	40,000	--	11,800
Total Suspended Particulates (TSP)				
Annual geometric mean	75	60	40 + back.[c]	56/20[d]
24-hr maximum[a]	260	150	120 + back.[c]	353/30[d]

(a) Not to be exceeded more than once per year.
(b) Not to be exceeded more than two times in any consecutive 7 days.
(c) back. = background concentration due to natural sources.
(d) The higher values represent concentrations due to the occurrence of exceptional natural events (i.e., duststorms, brushfires). In the absence of duststorms and other natural events, the maximum annual background concentration would generally not exceed 20 $\mu g/m^3$ and the maximum 24-hr background concentration would generally not exceed 30 $\mu g/m^3$. For siting and enforcement purposes, the EPA uses these lower values for eastern Washington State.

were taken near local sources of pollution and during periods when pollutant emission rates were higher than current levels, these values are estimated to be higher than current maximum background concentrations.

Currently, air concentrations of nitrogen dioxide and total suspended particulates are routinely monitored on the Hanford Site. The local monitoring program for nitrogen dioxide is being conducted by the Hanford Environmental Health Foundation (Ramsdell 1981; DOE 1982b; Sula et al. 1983). This monitoring indicates that the maximum annual average concentrations of nitrogen dioxide are less than 15 $\mu g/m^3$. Local monitoring of total suspended particulates for the Tri-County Air Pollution Control Board is conducted at the Hanford Meteorology Station. State-wide monitoring indicates that the concentrations of total suspended particulates periodically reach relatively high levels in eastern Washington State due to natural events (i.e., duststorms, sandstorms, volcanic eruptions, and large brushfires). Accordingly, high levels of total suspended particulates have been measured at the Hanford Meteorology Station during such events. Washington State ambient air-quality standards do not consider "rural fugitive dust" from such natural events when estimating the concentrations of

particulates in the area east of the Cascade mountain crest for regulatory purposes. Similarly, the EPA also exempts the rural fugitive dust component of background concentrations when considering permit applications and the enforcement of air-quality standards.

4.6 ECOLOGY

The ecology of the Hanford Site, along with species lists, has been reported in detail (ERDA 1975; Rogers and Rickard 1977; Jamison 1982; Watson et al. 1984). The following is a brief summary. The area in which waste disposal is considered has been in use for various purposes related to the Hanford mission since 1943 and is not now in a pristine state. The original vegetation pattern has been changed through various landscape manipulations associated with construction of buildings, roads, power lines, buried pipes and cables and plant operational activities.

4.6.1 Terrestrial Ecology

Plants

The land of the Hanford Site is mostly undeveloped, with scattered clusters of widely spaced industrial buildings. The buildings are interconnected by a network of roads, electrical transmission lines and railroads. In the years before 1943, portions of the land had been used for cultivated agriculture, and most of the land had been subjected to grazing by domestic livestock. Since 1944, most of the land has not been grazed by livestock, and land cultivation and irrigation have ceased. There has been no resident human population on the site since 1944 (Rickard and Watson 1985).

More than 240 species of plants have been identified on the Hanford Site. The natural vegetation of the gently sloping land between the Rattlesnake Hills and the western shore of the Columbia River is dominated by desert shrubs, especially big sagebrush, bitterbrush, rabbitbrush, and to a lesser degree spiny hopsage. The herbaceous understory to the shrubs is mostly dominated by grasses, especially cheatgrass (an alien annual species introduced to eastern Washington from Eurasia in the late 1800s) and the small native bunchgrass, Sandberg bluegrass. The invasion of cheatgrass has been attributed to the effects of livestock grazing for many decades before 1943 (Mack 1981). The predominant vegetation type on land areas that may be affected by waste management activities is the sagebrush-cheatgrass (*Artemisia tridentata* - *Bromus tectorum*). This vegetation type covers a large area and extends over much of the 200 Areas plateau.

During the 40 years of industrial operations in the 200 Areas, water used in the industrial processes was discharged more or less continuously into ditches and ponds. Over the years the ponds became colonized by the aquatic plants and animals characteristic of aquatic habitats in the surrounding region (Rickard, Fitzner and Cushing 1981).

The abandoned agricultural fields have been dominated by alien annual plants, such as cheatgrass and Russian thistle, for four decades, with little evidence of invasion by the native perennial plants. Wildfires have destroyed the sagebrush on large portions of the

200 Areas plateau, leaving cheatgrass and several species of native grasses as stand dominants. Re-establishment of sagebrush in the burned areas is expected to be slow because of ineffective reseeding from living sagebrush stands and the competition to sagebrush seedlings from cheatgrass.

Revegetation of land that has been severely disturbed by digging and backfilling is underway in the low-level radioactive waste disposal sites of the 200 Areas. Drought-resistent grasses, especially wheatgrasses (e.g. Agropyron desertorum), have been planted in some of the disturbed areas to stabilize the soil against wind and water erosion. Vegetation is being studied to measure its capacity to extract water from the soil and return it to the air through the transpiration process. Rooting depth is also being studied in relation to the depth of burial required to prevent root contact with buried wastes, as well as to the placement of loose rock layers in reconstructed soil profiles to help prevent deep root penetration.

Terrestrial Animals

The most extensive terrestrial animal habitat on the Hanford Site is the sagebrush-grass habitat type. The game mammals on the Hanford Site are the mule deer, elk, cottontail, and jackrabbit. The fur-bearers are the coyote, badger, and bobcat. All of these animals except elk reside in the vicinity of the 200 Areas. Elk are a recent introduction to Hanford Site; they became self-established on the Arid Lands Ecology Reserve (Figure 4.1) in 1972 and have been residents ever since (McCorquodale, Raedeke and Taber 1986). The 200 Areas plateau is used for foraging by a few mule deer on a year-round basis. It also supports scattered, small, isolated populations of Nuttall's cottontail rabbits and black-tailed jackrabbits. Mule deer have the capability to move from the Site to surrounding areas, where they may be harvested by hunters.

Resident small mammals include the Great Basin pocket mouse, deer mouse, Townsend ground squirrel, pocket gopher, harvest mouse, house mouse, Norway rat, sagebrush vole, grasshopper mouse, vagrant shrew, least chipmunk, and Merriam shrew. Muskrat, porcupine and raccoon have been observed near the waste ponds in the 200 Areas.

The game birds that nest in the sagebrush-grass habitat type are the sage grouse, mourning dove, chukar partridge, and gray partridge. There is a very small population of sage grouse on the Arid Lands Ecology Reserve, but these birds are not evident in the vicinity of the 200 Areas. California quail and Chinese ring-necked pheasants are found in more mesic, riparian habitats on the Hanford Site. Hunting has not been permitted on the Site south or west of the Columbia River since 1943. Hawks and owls use the Hanford Site as a refuge, especially during nesting (Fitzner et al. 1980). Raptors that nest in or near the 200 Areas plateau include Swainson's hawk, red-tailed hawk, northern harrier, kestrel, prairie falcon, burrowing owl and great horned owl. The endangered peregrine falcon apparently does not nest on the Site, but may reside in small numbers in neighboring regions (Rogers and Rickard 1977). With the exception of a few burrowing owls that may be displaced by construction activities, none of the raptor nesting areas are expected to be affected by the construction of waste management facilities.

Historically, the sagebrush-grass habitat has provided breeding sites for small birds and animals such as the horned lark, western meadowlark, and the Great Basin pocket mouse. Over 125 species of birds have been counted on the 200 Areas plateau (Rogers and Rickard 1977). However, an ever expanding use of land for irrigated agriculture, dryland wheat crops, and urbanization has resulted in substantial loss of sagebrush-grass habitat in eastern Washington. Although the land of the Hanford Site has not experienced the dramatic loss of sagebrush-grass habitat that has steadily occurred on the surrounding lands over the past four decades, some species of animals and plants that were abundant in sagebrush-grass habitats in the past have diminished in abundance to the point where they may in the near future become extirpated or extinct. Some species may require special kinds of management. Endangered and threatened plants and animals (as designated by both federal and State of Washington agencies) that occur or are thought to occur on the Hanford Site are briefly reviewed in Tables 4.14 and 4.15, as are their known relationships to the Site (and specifically the 200 Areas).

The Fish and Wildlife Service of the Department of the Interior was contacted for a current listing of endangered, threatened or candidate species for the Hanford Site. This information is consistent with Table 4.14. Review of the information provided by this agency indicates that threatened and endangered species would not be at risk from waste management on the 200 Areas plateau, which contains no known habitats critical to their existance.

Insects

More than 300 insect species, both terrestrial and aquatic, have been found on the Site (ERDA 1975). The grasshoppers and the darkling beetles are among the more conspicuous groups on the 200 Areas plateau (Rogers and Rickard 1977) and, along with other species, are important in the food web of the local birds and mammals. Most species of darkling beetles occur from spring through fall, although some species are present only during two or three months in the fall (Rogers and Rickard 1977). Grasshoppers are evident from late spring until fall. Both groups are subject to wide annual variations in abundance.

Reptiles and Amphibians

Three species of lizards, five species of snakes, and three species of toads and frogs have been observed on the Site. The most abundant reptiles are the side-blotched lizard and the gopher snake. The venomous rattlesnake is not abundant around the 200 Areas, but tends to be associated more with rocky areas. Amphibians are found around ponds in the 200 Areas and ponds and sloughs of the Columbia River.

Migrating Waterfowl

The Hanford Reach of the Columbia River[(a)] is an important resting place for Pacific flyway waterfowl and shore birds. Thousands of ducks and geese rest along the Reach during

(a) The Hanford Reach is the only unimpounded portion of the Columbia River in interior Washington. It extends upstream from Richland, Washington, to Priest Rapids Dam. Daily fluctuations in river flow are produced by manipulation of flows at upstream dams in response to the needs for electric power.

TABLE 4.14. Endangered, Threatened and Sensitive Animals on the Hanford Site (Washington State 1983)

Taxa	Status[a]	Relationship to the 200 Areas
WASHINGTON STATE STATUS OF SPECIAL BIRD SPECIES		
Birds Associated with the Hanford Reach of the Columbia River but not Known to Nest on the Hanford Site		
Bald Eagle *Haliaeetus leucocephalus*	FT ST	A possible occasional forager of sagebrush-grass habitats and waste ponds in the 200 Areas; a regular winter visitor to the Columbia River on the Hanford Site
American White Pelican *Pelecanus erythrorhyncus*	SE	Unlikely foragers at waste ponds in the 200 Areas; mostly fall and winter use of the Columbia River
Birds Associated with the Hanford Reach of the Columbia River that Also Nest on the Hanford Site		
Great Blue Heron *Ardea herodias*	PM	Nests in trees along the Columbia River; an occasional forager at waste ponds in the 200 Areas; a year-round resident
Black-Crowned Night Heron *Nycticorax nycticorax*	PM	Nests in trees along the Columbia River; an occasional forager at waste ponds in the 200 Areas; a year-round resident.
Birds Associated with Dryland Habitats of the Hanford Site but not Known to Nest on the Hanford Site		
Golden Eagle *Aquila chrysoaetes*	PS	Forages in sagebrush-grass habitats and at waste ponds in the 200 Areas; mostly a winter visitor
Birds that are Infrequent Visitors to the Hanford Site		
Peregrine Falcon *Falco peregrinus*	FE SE	An erratic visitor
Birds Associated with Sagebrush-Grass Habitats		
Ferruginous Hawk *Buteo regalis*	ST	An occasional forager in sagebrush-grass habitats; an occasional nester on the Arid Lands Ecology Reserve
Swainson's Hawk *Buteo swainsonii*	PS	Nests in planted trees near the 200 Areas; forages in sagebrush-grass habitats in spring and summer
Prairie Falcon *Falco mexicanus*	PS	Nests on basalt cliffs on Gable Butte; forages in sagebrush-grass habitats; a year-round resident
Burrowing Owl *Athene cunicularia*	PS	Nests in the vicinity of the 200 Areas; forages in sagebrush-grass habitats
Sage Thrasher *Oreoscoptes montanus*	PS	Not known to nest in the vicinity of the 200 Areas; a possible forager in sagebrush-grass habitats
Long-Billed Curlew *Numenius americanus*	PM	Nests in dryland habitats in the vicinity of the 200 Areas, mostly in spring and summer; forages in sagebrush-grass habitats

TABLE 4.14. (contd)

Taxa	Status[a]	Relationship to the 200 Areas
Sage Sparrow Amphispiza belli	PM	Nests in desert shrubs in the vicinity of the 200 Areas; forages in sagebrush-grass habitats in spring and summer
Sage Grouse Centrocercus urophasianus	Undetermined	Not known to nest or forage in the vicinity of the 200 Areas; a small population inhabits the Arid Lands Ecology Reserve
WASHINGTON STATE STATUS OF SPECIAL MAMMAL SPECIES		
Pygmy Rabbit Sylvilagus idahoensis	ST	An unlikely inhabitant of sagebrush-grass habitats in the 200 Areas; may be extirpated from the Hanford Site
Merriam's Shrew Sorex merriami	PS	An unlikely inhabitant of sagebrush-grass habitats in the 200 Areas; known to inhabit the Arid Land Ecology Reserve
White-Tailed Jackrabbit Lepus townsendii	PS	An unlikely inhabitant of sagebrush-grass habitats in the 200 Areas; may be extirpated from the Hanford Site
Sagebrush Vole Lagurus curtatus	PM	An unlikely inhabitant of the sagebrush-grass habitats in the vicinity of the 200 Areas; more abundant on the Arid Lands Ecology Reserve
Northern Grasshopper Mouse Onychomys leucogaster	PM	Present in sagebrush-grass habitats in the vicinity of the 200 Areas
Ord Kangaroo Rat Dipodomys ordii	PM	Not known to inhabit the Hanford Site
Townsend Ground Squirrel Spermophilus townsendii	PM	Locally abundant in sagebrush-grass habitats in the vicinity of the 200 Areas
Several species of bats may inhabit caves or abandoned buildings in the 200 Areas. The Long-Eared Myotis (Myotis evotis and Pallid Bat (Antrozous pallidus) are listed as Proposed Sensitive (PS). The Yuma Myotis (Myotis yumanensis) Fringed Myotis (M. thysanoides) Long-Legged Myotis (M. volans) Small-Footed Myotis (M. leibi) and Western Pipistrelle (Pipistrellus hesperus) are listed as Proposed Monitor (PM). The Townsend's Big-eared Bat (Plecotus townsendii) is listed as Proposed Threatened (PT).		
WASHINGTON STATE STATUS OF SPECIAL REPTILE AND AMPHIBIAN SPECIES		
Sagebrush Lizard Sceloporus graciosus	PM	Known to inhabit sagebrush-grass habitants in the vicinity of the 200 Areas
Northern Oesert Horned Lizard Phrynosoma platyrhinos	PM	Known to inhabit sagebrush-grass habitats in the vicinity of the 200 Areas
Striped Whipsnake Masticophis taeniatus	PM	May be present in sagebrush-grass habitats in the vicinity of the 200 Areas

TABLE 4.14. (contd)

Taxa	Status[a]	Relationship to the 200 Areas
WASHINGTON STATE STATUS OF SPECIAL REPTILE AND AMPHIBIAN SPECIES (contd)		
Night Snake *Hypsiglena torquata*	PM	May be present in sagebrush-grass habitats in the vicinity of the 200 Areas
Woodhouse's Toad *Bufo woodhousei*	PM	May be present in the vicinity of the 200 Areas near waste ditches and ponds
WASHINGTON STATE STATUS OF SPECIAL INVERTEBRATE SPECIES		
Columbia River Tiger Beetle *Cincindela columbica*	PE	Believed to inhabit the sandy shore of the Columbia River
Columbia River Limpet *Lanx nuttalli*	PM	Believed to inhabit the Hanford Reach of the Columbia River
Columbia River Spire Snail *Lithoglyphus colombiana*	PM	Believed to inhabit the Hanford Reach of the Columbia River
Oregon Swallowtail Butterfly *Papilio oregonius*	PM	Inhabits sagebrush-grass habitats; ecological status in the vicinity of the 200 Areas is unknown

(a) FE = Federally designated endangered species.
FT = Federally designated threatened species.

Definitions of special classifications of animal species:

State Endangered (SE). A species which is seriously threatened with extirpation within the state of Washington. These are classified by the State Game Commission as endangered wildlife (WAC 232-12-014). Protected from taking due to damage (RCW 77.12.265), trafficing (RCW 77.16.040) and possession, control, or destruction of nests or eggs (RCW 77.16.120).

Proposed Endangered (PE). A species proposed for consideration for State Endangered classification.

State Threatened (ST). A species that could become endangered without management or removal of threats. These species are classified by the State Game Commission as protected wildlife (WAL 232-12-011). Protected from possession, control, or destruction of nests or eggs (RCW 77.16.120).

Proposed Threatened (PT). A species proposed for consideration for State Threatened classification.

State Sensitive (SS). A species that could become Threatened if current water, land, and environmental practices continue. Classified by the State Game Commission as Protected Wildlife and protected from possession, control, or destruction of nests or eggs.

Proposed Sensitive (PS). A species proposed for consideration for State Sensitive classification.

Monitor Species (SM). A species of special interest because of public appeal, need for special habitats during a portion of their life cycle, status as indicators of environmental quality, population status that is mostly unknown, taxonomic status in need of further study, or justifiably removed from Endangered, Threatened or Sensitive classifications.

Proposed Monitor (PM). A species proposed for State Monitor classification.

TABLE 4.15. Endangered, Threatened and Sensitive Plants on the Hanford Site (Washington Natural Heritage Program 1984)

Taxa	Status[a]	Relationship to the 200 Areas
Columbia Milk-Vetch *Astragalus columbianus* Barneby	Threatened C	A local endemic with its major populations located on the Yakima Firing Center; not expected to occur in the vicinity of the 200 Areas
Persistentsepal Yellowcress *Rorippa columbiae* Suksd. ex Howell	Endangered C	Known to occur on the wetted shoreline of the Columbia River on the Hanford Site; not likely to occur in the vicinity of the 200 Areas
Thompson's Sandwort *Arenaria franklinii* Dougl. var. *Thompsonii* Peck	Threatened	Exists as *A. franklinii* on stabilized sand dunes in the vicinity of the 200 Areas; taxonomic status is currently under consideration
Hoover's Desert Parsley *Lomativum tuberosum* Hoover	Threatened C	A local endemic in Yakima, Benton, Grant and Kittitas Counties, not known from the vicinity of the 200 Areas
Gray Cryptantha *Cryptantha leucophea* Dougl. Pays	Sensitive	Occurs on stabilized sand dunes of the Hanford Site near the Wye Barricade; occurrence in the vicinity of the 200 Areas has not been established
Piper's Daisy *Erigeron piperianus* Cronq.	Sensitive	A local endemic, occurs on the Arid Lands Ecology Reserve; occurrence in the vicinity of the 200 Areas has not been established
Tooth-Sepal Dodder *Cuscuta denticulata* Engelm.	Monitor	Recently found in Benton County; parasitic on sagebrush; may occur in the vicinity of the 200 Areas

(a) Plants that are listed as "C" are candidates on the 1980 Federal Register Notice of Review and 1983 Supplement.

Definitions of special classifications of vascular plants in Washington and special terminology:

Endangered. A vascular plant taxon in danger of becoming extinct or extirpated in Washington within the near future if factors contributing to its decline continue. These are taxa whose populations are at critically low levels or whose habitats have been degraded or depleted to a significant degree.

Threatened. A vascular plant taxon likely to become endangered within the near future in Washington if factors contributing to its population decline or habitat degradation or loss continue.

Sensitive. A vascular plant taxon, with small populations or localized distribution within the state, that is not presently endangered or threatened, but whose populations and habitats will be jeopardized if current land use practices continue.

Monitor. A vascular plant taxon of potential concern because of uncertain taxonomic status or paucity of information concerning distribution; or a taxon that is actually more abundant or less threatened than previously thought.

Local endemic. A taxon restricted to a limited geographical area, usually within a single county or several adjacent counties.

the annual autumnal migration. A section of the Reach upstream from the old Hanford townsite is closed to waterfowl hunting, providing a refuge for many ducks and geese not resting on federal refuges located elsewhere in the Columbia Basin. The Hanford Reach is also an important nesting and resting area for the western Canada goose. For four decades, the nesting goose population has persisted there in relatively stable numbers (Ball, Bowhay and Yocom 1981).

The waste water ponds in the 200 Areas have attracted waterfowl in considerable numbers (Rickard, Fitzner and Cushing 1981). The most abundant nesting waterfowl on the ponds has been the American coot. The reproductive performance of coots nesting on the industrial ponds at Hanford has been compared with coots nesting on ponds located in the Columbia National Wildlife Refuge, located northeast of the Hanford Site (Fitzner, Sipco and Schreckhise 1980). Population performance of coots on Hanford ponds is comparable to that of other ponds.

The only natural wetland areas on the Site are West Lake, just north of 200 East Area, and Rattlesnake Springs, which is located to the west of the 200 West Area.

4.6.2 Aquatic Ecology

Aquatic habitats on the Site include the ponds and ditches in or near the 200 Areas, the Columbia River, and two very small streams formed by Rattlesnake Springs and Snively Springs west of the 200 Areas plateau (Figure 4.7). Ponds found in or near the 200 Areas are Gable Mountain Pond, which is undergoing decommissioning, and B Pond, which receives cooling water from the 200 E Area (Emery and McShane 1980; Meinhardt and Frostenson 1979). The waste-water disposal sites have similar water quality characteristics, and support similar kinds of algae, rooted plants, and invertebrates; all contain introduced populations of goldfish. West Pond (created by the rise in the water table in the 200 Areas) is very alkaline, has a much lower density and diversity of plants and animals, and has no fish. The ponds and ditches are the only sources of water in the arid environment of the 200 Areas plateau and therefore provide habitat for many birds and mammals. The ditches are generally less productive than the ponds in terms of biomass per unit area of bottom or unit volume of water. Streams formed by Rattlesnake and Snively Springs are quite productive but are remote from the waste sites.

The Columbia River is by far the most important aquatic habitat associated with the Hanford Site. Since 1943, the river has received heated water and radionuclides in aqueous discharges from nuclear reactors located on the Hanford Site (Rickard and Watson 1985). Since January 1971, the radionuclide burdens to the Columbia River and its associated biota have been dramatically diminished following the closure of eight once-through coolant reactors (Cushing et al. 1981).

Forty-five species of fish have been identified from the Hanford Reach (Gray and Dauble 1977). The anadromous fishes are chinook salmon, steelhead trout, coho salmon, sockeye salmon, and American shad. Resident game fishes are smallmouth bass, largemouth bass,

mountain whitefish, sturgeon, walleye, yellow perch, black crappie, bluegill, channel catfish, and bullhead. The anadromous and resident fishes provide a sports fishery of local importance.

The Hanford Reach has sustained a spawning population of fall chinook salmon. In the late 1940s and the 1950s, there were estimated to be less than 1,000 salmon redds in the Hanford Reach (Rickard and Watson 1985). During the 1980s, the estimated numbers of salmon redds has exceeded 5,000. The increase in redds in recent years is attributed to fisheries management practices designed to restore and sustain a mainstem Columbia River chinook salmon population. The Hanford Site serves as the spawning area for more than one-third of the fall chinook in the mid-Columbia River.

Columbia River fish provide a food base for nesting populations of great blue herons, black-crowned night herons, and Forster's terns. Chemical analysis of excrement cast from heron nests containing young birds has been a useful way of monitoring the foods eaten by Hanford Site herons to determine the kinds and quantities of toxic materials available to birds in their foraging environments (Fitzner, Rickard and Hinds 1982). The carcasses of spawned salmon provide autumn and winter foods for bald eagles (Rickard, Hansen and Fitzner 1982), which, although not commonly found on the 200 Areas plateau, have been reported to forage in this area (Landeen and Mitchell 1981). The white pelican is also found mainly along the river during the fall and winter. The pygmy rabbit has been found near springs in the Snively Basin, to the west of the 200 Areas plateau (Washington State 1984). Both the federal and state authorities consider the peregrine falcon to be an endangered species and the bald eagle a threatened species. The state also classifies the white pelican as endangered and the ferruginous hawk and the pygmy rabbit as threatened (Table 4.14).

4.7 LAND USE

The entire 1,500 km^2 of the Hanford Site is a controlled area, for security and public health and safety reasons, and is expected to remain so for the foreseeable future. Within this controlled area are several DOE operational areas where access may be restricted further (Figure 4.1). These major areas are described below.

- The 100 Areas, bordering on the right bank[(a)] (south shore) of the Columbia River, are the sites of the eight retired plutonium production reactors and the operating dual-purpose (steam for electrical power generation and plutonium production) N Reactor. The 100 Areas occupy about 11 km^2.
- The 200-W and 200-E Areas are located on a plateau about 8 and 11 km, respectively, from the Columbia River. These areas have been dedicated for over 40 years to fuel reprocessing and waste processing management and disposal activities. The 200 Areas cover about 16 km^2.
- The 300 Area, located just north of the City of Richland, is the site of nuclear research and development and nuclear fuel fabrication. This area covers 1.5 km^2.

(a) Sides of a stream (right or left) are determined when facing downstream.

- The 400 Area is about 8 km north of the 300 Area and is the site of the Fast Flux Test Facility used in the testing of breeder reactor systems. Also included in this area is the Fuels and Materials Examination Facility.
- The 600 Area includes all of the Hanford Site not occupied by the 100, 200, 300 or 400 Areas. Land uses within the 600 Area include:
  1. the Arid Lands Ecology Reserve, a 310-km^2 tract set aside for ecological studies
  2. 4 km^2 leased to the State of Washington, part of which is used for LLW disposal
  3. 4.4 km^2 for Washington Public Power Supply System nuclear power plants
  4. 2.6 km^2 transferred to the State of Washington as a potential site for the disposal of nonradioactive hazardous wastes
  5. about 130 km^2 under revocable use permit to U.S. Fish and Wildlife Refuge
  6. 225 km^2 under revocable use permit to Washington State Department of Game for recreational game management
  7. support facilities for the controlled access areas
  8. the Near-Surface Test Facility in Gable Mountain. This facility is part of the Basalt Waste Isolation Program (BWIP) to assess the feasibility of radioactive waste disposal in basalt formations
  9. 46.7 km^2 for the reference repository site for the BWIP. This site includes all of the 200 West Area (DOE 1982a, 1984). The site of the principal borehole and exploratory shaft for the BWIP covers about 1 km^2 and is located just west of the 200 West Area within the reference repository site
  10. Retired dry waste disposal sites and low-level liquid waste disposal sites.

The areas designated for the Arid Lands Ecology Reserve, U.S. Fish and Wildlife Refuge, and Washington State Department of Game total about 660 km^2, which provide for a buffer zone around the areas of nuclear activity.

Land use in the surrounding area includes urban and industrial development, irrigated and dry-land farming, and grazing. Principal agricultural crops include hay, wheat, potatoes, corn, apples, soft fruit, hops, grapes and vegetables. In recent years wine grapes have gained importance. Industries in the nearby Tri-Cities are mainly those related to agriculture and energy production.

4.8 SOCIOECONOMICS

The extensive nuclear-related development work begun at Hanford in 1943 has been a major factor in the socioeconomy of the surrounding area. The Tri-Cities (Richland, Kennewick, and Pasco) and the remainder of Benton and Franklin Counties are the areas that potentially would be most affected by future waste management and disposal activities on the Site. This area

has been designated a Metropolitan Statistical Area (MSA)[a] by the Bureau of the Census. A detailed review of area socioeconomics is given in Cluett et al. (1984), DOE (1984), NRC (1982), Piott and Schau (1983) and Watson et al. (1984). See also Appendix K of this EIS for additional discussion of the range of socioeconomic impacts investigated.

4.8.1 Economy and Work Force

The primary economic bases of the Tri-Cities MSA are the activities at Hanford, services, wholesale and retail trade and manufacturing (NRC 1982; Piott and Schau 1984). Dominant sectors of the economy in 1983 include services (27% of nonagricultural employment), wholesale and retail trade (20%), manufacturing (18%) and government (17%). The contract construction work force declined from 13,550 in 1981 (21% of the nonagricultural total) to 5,620 (10% of the nonagricultural total) in December 1983 (Piott and Schau 1983, 1984). Much of this decline was due to the completion, deferral, or cancellation of nuclear power plant construction. According to current (1987) figures, the Washington Public Power Supply System (WPPSS), the major non-DOE-related employer at Hanford, has about 1,500 employees. About 14,450 persons are employed on DOE-related projects at Hanford (July 1987). Agricultural employment in Benton and Franklin Counties varies seasonally from a low of about 2,000 to a high of about 6,000 (Piott and Schau 1983).

The average annual per capita income, including agricultural payrolls, was about $8,300 in 1982. As of September 1985, the unemployment within the Tri-Cities was 7.8% compared with 7.2% for the state and 6.9% for the nation (personal communication, Schau 1985).

Certain projects possibly could compete for workers employed in disposal of Hanford high-level and transuranic wastes. These include the construction of a basalt waste isolation facility for disposing of commercially generated radioactive waste (and perhaps defense waste), with a projected peak force of 1,100, and the expansion of Priest Rapids and Wanapum Dams, with a projected peak work force of 1,100. In order to account for the potential cumulative socioeconomic effects of a major development activity overlapping the Hanford defense waste disposal program, a bounding scenario analysis was conducted with renewed construction and operation of the Supply System's WNP-1 included in one baseline scenario and excluded in another. See Appendix K for additional discussion of these scenarios.

From 1970 to 1982, housing units increased 94.3%, following increased population and employment that accompanied WPPSS projects in the mid-1970s (Watson et al. 1984). The number of housing units grew at an annual average rate of 7.8% from 1973 through 1981. Richland, Pasco, and Kennewick all have experienced sharp declines in housing growth since 1981 (Watson et al. 1984). Housing units in 1982 in the Tri-Cities totaled about 58,000 with 69% being single-family units, 20% multifamily units, and 11% mobile homes (Tri-Cities Real Estate 1983). The total vacancy rate in the Tri-Cities MSA in 1983 was about 8.6%, or 5,000 vacant housing units (Watson et al. 1984).

(a) An MSA is a designated population nucleus and includes surrounding areas that are part of the same economic and social structure. It is composed of a single city of 50,000 population or more plus the surrounding associated areas or is a generally urbanized area of more than 100,000 population. The MSA usually follows county boundaries.

4.8.2 Population

There were about 340,000 people residing within an 80-km radius of the 200 Areas according to estimates based on the 1980 census (Figure 4.14). The projected population within an 80-km radius of the 200 Areas for 1990 is about 420,000 (Sommer et al. 1981).

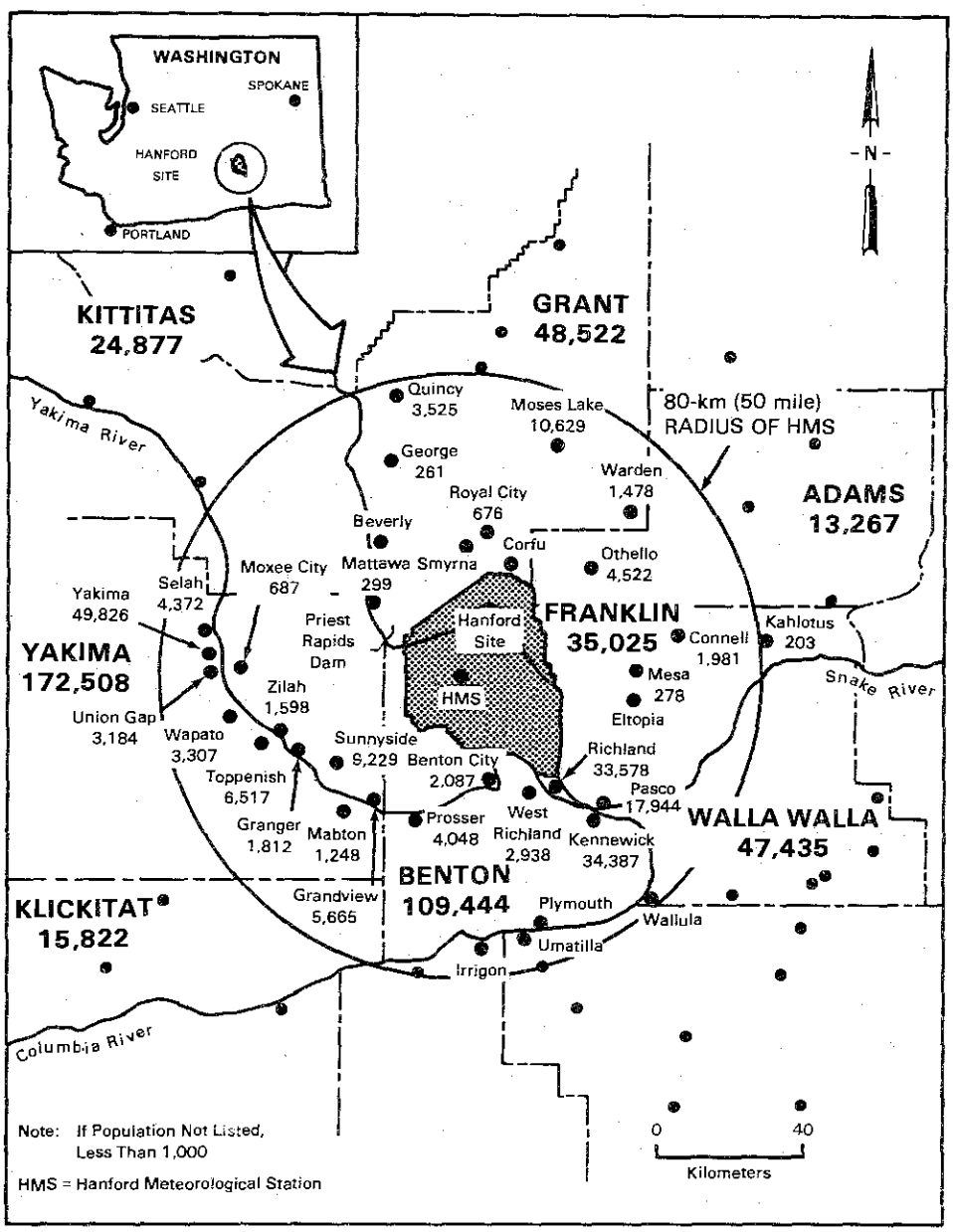

FIGURE 4.14. **U.S. Census Populations for 1980 of Cities Within 80 km of the Hanford Meteorology Station** (DOE 1982a)

The estimated population of Benton and Franklin Counties from 1981 to 1990 varies from a decline of about 8% to an increase of about 8%, depending on different assumed economic factors. These factors include the restart of construction of WPPSS reactors, possible changes in agricultural growth, or the start of new DOE-related projects (Watson et al. 1984).

4.8.3 Services

Education

All school districts in the Tri-Cities MSA offer first- through twelfth-grade education. The 1987 spring enrollment was about 27,300 students; the Kennewick District is the largest, with about 10,790 students.

Schools of higher education in the Tri-Cities include Columbia Basin Community College (CBC) in Pasco and the Tri-Cities University Center in Richland. Average enrollment at the community college as of the fall of 1986-1987 was about 5,900. The number of students at CBC has been fairly constant over the past several years. Current figures indicate an enrollment at the Tri-Cities University Center of about 1,100.

Fire and Police Protection

Each of the Tri-Cities maintains a full-time fire protection staff; other municipalities and rural fire districts typically have one full-time person aided by volunteer personnel. Mutual aid agreements exist among the municipal and rural fire departments and the Rockwell Hanford Fire Protection Department (NRC 1982). These provide for better fire protection for each jurisdiction by making backup personnel and equipment available from neighboring units.

The combined staff of the Richland, Kennewick and Pasco police departments is about 150; the smaller cities and the sheriffs' departments of Benton and Franklin Counties have another 80 police personnel. In addition, there are about 350 persons on the Hanford Site security force, administered by Westinghouse Hanford Company.

Water, Sewer and Solid Wastes

The Columbia River is the source of part or all of the municipal water supplies for each of the Tri-Cities. Each city operates its own treatment and distribution system. Richland directly uses about 15.6 million m^3 of Columbia River water annually for its domestic supply. An additional 10.4 million m^3 per year are pumped from the river for the recharge of wells that provide domestic water and for the irrigation of adjacent land. Kennewick withdraws about 4.7 million m^3 of water directly from the river for domestic supply during April through October. A well-collector system located near the Columbi River at Kennewick adds to this amount during the April-October period, and is the sole source of city water from November through March. Pasco withdraws about 7.6 million m^3 of water directly from the river annually.

In addition to the use of Columbia River water by the Tri-Cities, water is pumped from the river for irrigating agricultural lands downstream of the Hanford Site. The withdrawal of Columbia River water for agriculture in the region from the Hanford Site to 130 km downstream is about 585 million m^3 annually. The combined annual withdrawal of this irrigation

water and the domestic supplies for the Tri-Cities is about 623 million m^3. The urban population along this section of the river was about 91,000 during the 1980 census (Rand McNally 1985). Including the unreported rural population along the river brings the estimated number of people using Columbia River water within about 130 km downstream of the Site to about 100,000. This would be the population most likely affected by an accidental release of pollutants to the Columbia River at the Site.

Each of the Tri-Cities operates its own plant for primary and secondary sewage treatment. A new sewage treatment plant went into operation in Richland in October 1985. Pasco is nearing the limit of its system; Kennewick's system has some reserve capacity.

Solid refuse is disposed of in sanitary landfills. The City of Richland operates its own fill, while Kennewick and Pasco contract for this service with private operators. The capacity of existing landfills is adequate for existing and anticipated future needs through 1990.

Medical Facilities

Four general hospitals, located in Richland, Kennewick, Pasco, and Prosser, serve the region. Their combined capacity is about 320 beds, which exceeds current demand. There are also seven nursing homes in the area with a capacity of 411 beds, the Mid-Columbia Mental Health Center, and several minor emergency aid centers.

Transportation

The area is served by three major state highways and two interstate highways. The area is also served by two railroads and three commercial airlines. Barge service on the Columbia River connects the Tri-Cities downstream with the Portland, Oregon, area and the Pacific Ocean, and connects them upstream with Lewiston, Idaho, via the Snake River.

There are local traffic problems, particularly during periods of construction on the Site. Heavy rush-hour traffic creates bottlenecks, especially in Richland. Part of this congestion between Richland and Kennewick and Pasco has been alleviated since the Interstate Highway-82 bridge across the Columbia River was completed. This bridge provides an alternative and shorter route to Pasco and Franklin County from Richland and points west.

A public bus system has recently been established to serve the Tri-Cities and some facilities on the Site. A DOE-run bus service is also available from Richland to the Site for personnel employed at the federal facilities.

Parks and Recreation

There are 67 federal-, state-, county-, and city-maintained park facilities covering almost 50 km^2 in the Tri-Cities area. Most of these parks are located along the Columbia and Snake Rivers and provide camping, boating, swimming, and picnic facilities.

4.8.4 Indians and Indian Reservations

Within North America, the native people between the Cascade Mountains and the Northern Rocky Mountains made distinctive adaptations to the semiarid steppeland environment ringed by mountains and incised by the Columbia River drainage system. The particular subsistence

practices emphasized a way of life that followed a seasonal round of fishing, hunting, and gathering of natural foods. Common religious beliefs and social practices resulted from the mutual cross-utilization of subsistence resources throughout the aboriginal Plateau culture area that is now parts of the states of Washington, Oregon, and Idaho.

Elements of the traditional Plateau culture have been kept alive to varying degrees among present-day members of these Indian groups. The traditional religious beliefs of these Indians share many common elements; among these are guardian spirits and shamanistic curing. Basic beliefs are contained in an extensive body of mythological oral literature. Important beliefs include the following:

- The Earth and its natural resources are inherently sacred.
- Guardian spirits are essential to health and good fortune.
- Illness and misfortune are caused by malevolent spirit powers or soul loss.
- Disturbances to the Earth cause disruption in the spirit world.

Longhouse ceremonialism, incorporating many of these beliefs and involving first-foods feasts, marriages, funerals, memorials, and namings, is well established in the Indian reservation communities today.

The Hanford Site is located on lands ceded to the United States Government by the Yakima and Umatilla Indians and is adjacent to lands ceded by the Nez Perce Indians. The Yakima Indian Nation and the Confederated Tribes of the Umatilla Indian Reservation have reservations adjacent to the Hanford Site and claimed the land where the Site is now situated. Treaties with these entities in 1855 established the reservations and provided the basis and compensation under which the remainder of the lands claimed by these Indians was ceded to the United States. The treaties also provided for certain rights and privileges to these Indians for usage of the lands that had been ceded. The relationship of these reservations to the Hanford Site is shown in Figure 4.15. The reservations, the people and relevant portions of the treaties are described in the following subsections.

There are other Indian tribes in the area whose ceded lands did not include any portion of the Hanford Site. These include Indians of the Nez Perce Indian Reservation, the Spokane Indian Reservation, the Colville Indian Reservation, and the Warm Springs Indian Reservation. The Indians of these reservations and possibly others may make use of the Columbia River downstream of the Hanford Site for fishing.

4.8.4.1 Reservation for the Confederated Tribes and Bands of the Yakima Nation

The Yakima Indian Reservation occupies about 5,670 km^2 in the Yakima Valley of south-central Washington. Tribal headquarters are located in Toppenish, Washington. In 1974, approximately 62% of the reservation was tribally owned, with the balance in lands allotted to individual tribal members (20%) and non-Indian owned lands (18%) (DOC 1974). The Yakima Tribe has gradually been adding land to its holdings. The location of the wastes discussed in the HDW-EIS is 50 to 60 km east of the Yakima Indian Reservation boundary (see Figure 4.15).

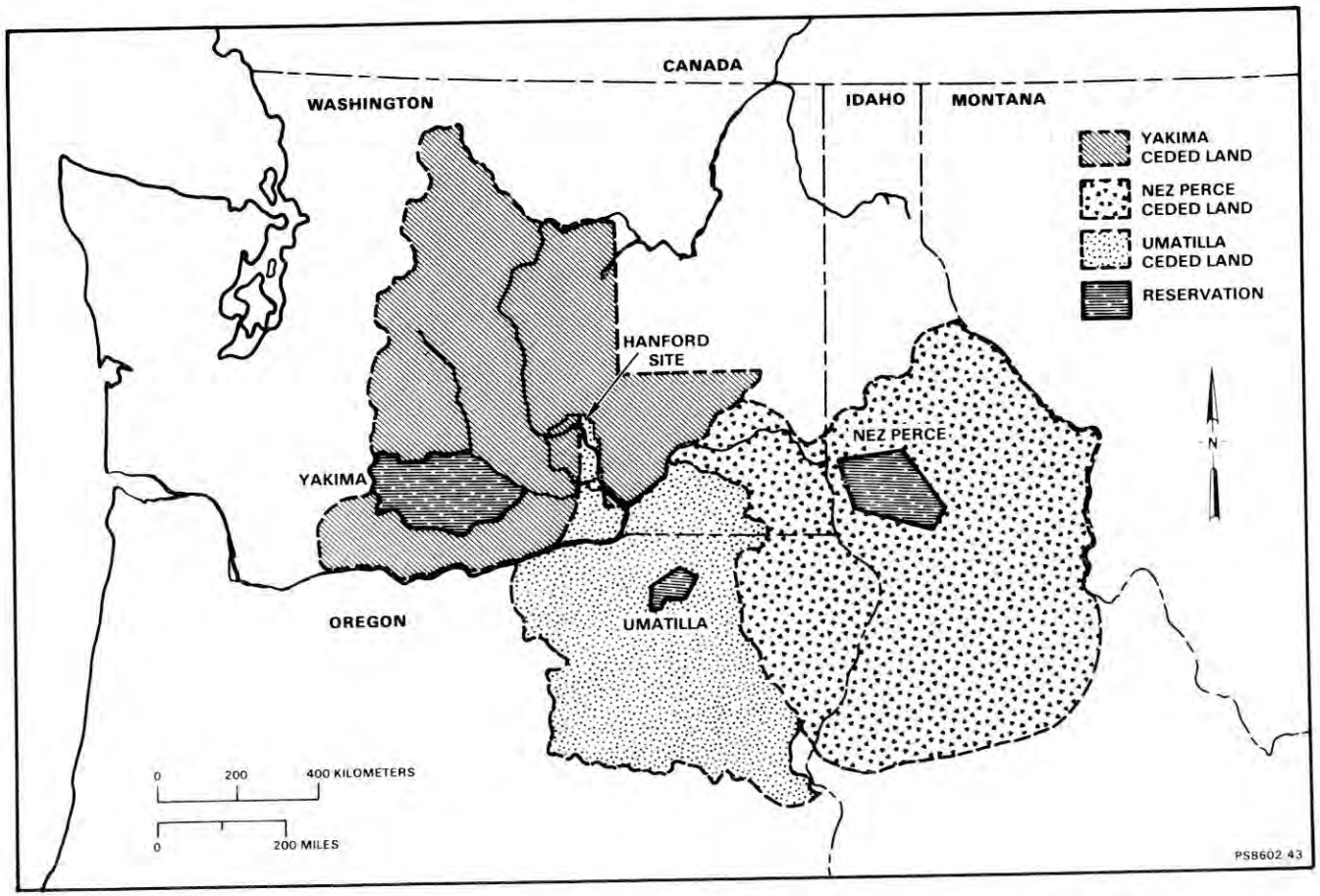

FIGURE 4.15. Ceded Lands and Reservations of Nearby Indian Tribes (DOE 1986)

The Yakima Indian Reservation includes an environmentally diverse area from Mount Adams (3,752 m) on the Cascade Mountain crest to the Yakima River at Mabton, Washington (218 m). The western half of the reservation is mostly forested land, with the eastern half divided almost equally between sagebrush/cheatgrass rangeland and partially irrigated agricultural cropland. Major water resources include the Yakima and Klickitat Rivers, which are important for crop irrigation and anadromous fisheries.

In 1985, the Indian population of the Yakima Reservation was estimated to be about 8,000. Indians are numerically a minority on the reservation, however. Estimates of Indian unemployment on the reservation have ranged up to 71%. Approximately, 1,800 tribal members were estimated to be employed in early 1987.

The reservation economy is based principally on forest products, agriculture, and livestock. The Yakima tribe receives income from timber sales, land leases for agriculture and grazing, and industrial land leases for businesses. The tribe also has a major investment in salmon fisheries. Resources on the reservation include 2,500 km^2 of forest, rangeland for 8,000 head of cattle, and over 575 km^2 of irrigable land. The Yakima River provides salmon fisheries and potential hydroelectric sites. A 32-ha industrial park occupied by manufacturers of wood products is located on the reservation, and other small industries and businesses are scattered throughout the reservation. Transportation resources include Interstate 82 and 560 km of paved roads; rail services are available in the major centers (Mabton, Toppenish, and Wapato, Washington), with a branch line to Zillah and White Swan, Washington. Health care and education services are available in Toppenish.

The traditional culture of the Yakima Indian Nation reflects the diversity of its constituent tribes and bands. The Confederated Tribes and Bands of the Yakima Nation are composed of 14 aboriginally distinct groups, including speakers of Sahaptian, Salishan, and Chinookan language families. The traditional beliefs of all of these Plateau Indians placed great value on the land and its natural resources. These beliefs were traditionally expressed through renewal rituals like the annual Salmon Feast and Root Feast. These ceremonial practices survive today as evidence of spiritual vitality.

According to the Yakimas, the Hanford Site is the place of the Yakima creation legend, and Gable Mountain is the place where young Yakima boys were sent alone to experience revelations about their destiny in serving their people, sometimes referred to as their "vision quest."

The major treaty affecting the Yakimas was the Treaty of 1855 (12 Stat 191). Following the Walla Walla Treaty Council of 1855 that established the treaty, but before the treaty could be ratified, the Yakima war broke out. It was not until after the war, in 1859, that the Treaty of 1855 with the Yakimas was ratified by Congress and signed into proclamation by President Buchanan. The treaty contains 11 articles that established the terms of the agreement between Confederated Tribes and the federal government concerning land cessions, establishment of the present reservation, compensation, land disposition and usage, and other conditions.

The Hanford Site is located in part on lands ceded to the United States Government by the Yakimas as part of the 1855 treaty agreement. As part of that agreement, the Yakimas were generally assured the right to fish at all of their usual and accustomed places. The treaty also extended the privilege, in common with citizens of the Territory, of hunting, gathering of roots and berries, and pasturing their horses and cattle on open and unclaimed lands.

When the Hanford Site was established in 1943, all of the land within which the wastes in the scope of this EIS are now located was obtained from private individuals, corporations or nonfederal governmental agencies; the land was not open and unclaimed at that time. Of the total Site, less than one-third was public domain, and most of the public holdings formed a pattern of every other section (thus a checkerboard pattern). With respect to Gable Mountain only a small portion of the northwest corner and a saddle across the mountain midway along the length was public domain in 1943. The Hanford Site today is a secured facility operated by the U.S. Department of Energy in the interest of national security and does not fall within the category of open and unclaimed land.

4.8.4.2 Reservation for the Confederated Tribes of the Umatilla Indian Reservation

The Umatilla Indian Reservation occupies approximately 700 km^2 west of the Blue Mountains in northeastern Oregon. The Tribal headquarters are in Mission, Oregon, while the Umatilla County seat and trade and service center are located in Pendleton, Oregon, approximately 0.8 km west of the reservation boundary. In 1974, approximately 6% of the reservation land was tribally owned, about 29% was individually allotted to tribal members, and 65% was non-Indian owned (DOC 1974). The boundary of the Umatilla Reservation is approximately 120 km southeast of the Hanford Site.

The Umatilla Reservation extends from the western flanks of the Blue Mountains (approximately 1,200 m in elevation) to the Umatilla River near Pendleton, Oregon (320 m in elevation). Much of the southeastern portion of the reservation is heavily timbered, whereas the northern and western cropland and pasture areas are rolling plains dissected by the east-west trending Umatilla River valley. The Umatilla River, a tributary of the Columbia River, is the key water resource. Its tributaries provide extensive steelhead spawning and rearing habitat.

In 1985, tribal population was estimated to be about 1,500. Unemployment has run between 39% and 47% on the reservation. Approximately 400 tribal members were employed in 1985.

The reservation economy is based substantially on agriculture. The Umatilla Tribe derives income from a tribal farming enterprise and a tribal leasing enterprise. Tribal lands provide resources for livestock grazing, timber harvest, and recreation. Tributaries of the Umatilla River have been recently targeted for upriver fall Chinook and spring Chinook enhancement projects. Economic activities on the reservation include a new grain elevator, a tribal bingo operation, and farming. Several projects are proposed, most significantly a 260-ha industrial park located on the reservation along Interstate 84. Other available

transportation resources include the Union Pacific Railroad, Amtrak, Pendleton Municipal Airport, and the Port of Umatilla on the Columbia River. The tribe provides outpatient health care and contracts with the local hospital and medical clinics for inpatient care. Education is provided primarily by three local school districts (Pendleton, Athena-Weston, and Pilot Rock).

The Indian people of the Umatilla Reservation are traditionally composed of the Sahaptian-speaking Umatilla and Walla Walla bands, and the linguistically distinct Cayuse. Like other Plateau Indian groups, these bands viewed the earth as holy and derived their subsistence from fishing, hunting and gathering. As did the Yakima, all groups observed annual renewal rituals commemorating the first roots of the season or the first salmon taken. The Salmon Feast and Root Feast are elements of the traditional religion that have survived to the present.

In 1855, the Umatilla, Cayuse, and Walla Walla bands signed a treaty with the Superintendent of Indian Affairs for the Territory of Washington and the Superintendent of Indian Affairs for the Territory of Oregon that was ratified by Congress in March 1859 and proclaimed by the President in April 1859. Through this treaty, the Confederated Bands ceded lands claimed in what is now southeastern Washington and northeastern Oregon, and the present Umatilla Reservation was established for their exclusive use. As with the Yakimas, the 1855 Treaty with the Confederated Bands contained 11 articles that delineated the terms of the compensation and other agreements (12 Stat 1945).

The Hanford Site is located in part on lands ceded to the United States Government by the Umatillas according to the 1855 treaty agreement. As part of their treaty agreement, the Umatillas were generally assured of the right to fish at all their usual and accustomed places. The treaty also extended the privilege, in common with citizens of the Territory, of hunting, gathering of roots and berries, and pasturing of their stock on open and unclaimed lands. As previously stated, the Hanford Site today is a secured facility operated by the U.S. Department of Energy in the interest of national security and does not fall within the category of open and unclaimed land.

4.8.4.3 Reservation for the Nez Perce Indian Tribe

The Nez Perce Indian Reservation is situated in the counties of Nez Perce, Clearwater, and Idaho in north-central Idaho (see Figure 4.15). The principal tribal headquarters is located at Lapwai, Idaho, with another center at Kamish, Idaho. The reservation consists of approximately 3,060 km^2 of which about 11.5% is tribally owned. About 210 km^2 are individually allotted to tribal members. The reservation is about 8 km from Lewiston, Idaho, and about 200 km east of the Hanford Site.

The Nez Perce Indian Reservation is composed of plateaus and mountains that are cut by many canyons. Elevations range from 200 m to about 1,300 m. Loess-covered plateaus lie in the north and central areas. South of these plateaus are the Blue Mountains, and to the east are the northern Rocky Mountains. From these mountains, the Clearwater, Salmon, Imnaha and Grand Ronde Rivers flow into the Snake River. Forty-three percent of the Nez Perce Indian Reservation is used for agriculture, 23% is commercial timber, and 24% is pasture. Conifer

forest vegetation is typical at higher elevations. Steppeland grasses characterize the vegetation in the valleys and bottomlands. Streams throughout the reservation support anadromous fishes.

In 1985, the Indian population of the Nez Perce Indian Reservation was estimated to be between 2,000 and 3,000. Resources on the reservation include over 100 k^2 of timbered land, much of this managed under the tribal Forest Development Program. There are approximately 150 km^2 of dryland crop production on the reservation, farmed mostly by non-Indians. Dworshak Reservoir and the Clearwater River are the primary water resources. The Nez Perce Tribe operates a printing and publications shop, a limestone quarry, a marina located in Orofino, Idaho, and a merchandise and grocery store. Nonetheless, unemployment among tribal members in 1985 was estimated at about 64% of the available work force. Transportation resources include U.S. Highway 12, which runs east-west through the reservation; also, train, bus and truck lines have stops on the reservation. Lewiston is served by commercial airlines and is the only seaport in Idaho. Health care is available primarily from the Lewiston Community Hospital.

The traditional culture of the Nez Perce Indians was similar to other Plateau peoples like the Umatillas and Yakimas. The Nez Perce were Sahaptian speakers who shared the basic religious elements of the Salmon and Root Feasts.

The original Nez Perce Reservation was established by the Walla Walla Treaty Council in 1855. Since the United States did not make any subsequent treaties in which all bands were present and able to speak for themselves, the fundamental rights of the Nez Perces and the obligations of the Federal Government to the Nez Perces stem from the Treaty of 1855. As with the Yakimas and Umatillas, that treaty included eleven articles that delineated the conditions, rights, and obligations between the Nez Perce Tribe and the United States Government.

4.8.5 Archaeological, Cultural and Historical Resources

In prehistoric times, the Columbia Basin was occupied by numerous camps and villages of the various Plateau Indian groups. Today, the Hanford reach of the Columbia River contains the only intact remaining evidence of these aboriginal cultures. Controlled access to the Hanford Site and the U.S. Department of Energy's policy of not publicizing the specific location of sites have protected these remaining sites from destruction by relic collectors.

There are 10 major historical properties on or adjoining the Hanford Site (DOE 1982a), and most of these are located on the islands or shoreline of the Columbia River. In addition, there are 128 archaeological sites on the Hanford Site, including open camps, fishing stations, house pit sites, cemeteries and flaking floors (NRC 1982). Five sites are located about two miles north of the 200 Areas near Gable Mountain and Gable Butte, and four others lie on the western part of the Site at Rattlesnake Springs and Snively Canyon; however, no

such sites are known to be located within the 200 Areas or the 6-km by 13-km disposal site boundary that includes the 200 Areas. The two sites in the vicinity of the 200 Areas were described in ERDA (1975) as follows:

Gable Mountain Locality

"The Gable Mountain Locality lies to the northeast of 200-E Area. It includes area in Sections 13, 14, 15, 22, 23, and 24, T.13N, R.26E., and Sections 18, 19, 20, and 21, T.13N, R.27E., W.M."

"Relander (1956) reports that this locality was one of the principal places where Indian boys and girls were sent on their spirit quests."

"A corner-notched projectile point was encountered."

Gable Butte Locality

"The Gable Butte Locality lies a short ways to the south of 100-B and 100-K Areas. It includes area in Sections 13 and 14, T.13N., R.25E., and Sections 18, 19, and 20, T.13N., R.26E., W.M."

"Several flakes and rock piles were found along the top of the ridge at the western end of the locality."

"Corner-notched projectile points were encountered from this locality."

Detailed descriptions of the location and character of other sites can be found in Rice (1968a,b) and ERDA (1975).

At present, nine archaeological properties on the Hanford Site are listed in the National Register of Historic Places. Other nearby historical places listed in the National Register of Historic Places--Washington State are the Franklin County Courthouse and the Pasco Carnegie Library in Pasco and the Pasco-Kennewick Bridge (Washington State 1982).

The Gable Mountain locality was nominated to the National Register of Historic Places by the Atomic Energy Commission in 1976. The application was returned by the Keeper of the National Register for further review and information, and was subsequently withdrawn by the Atomic Energy Commission because they were unable to provide additional information. The DOE intends to renominate Gable Mountain for the National Register of Historic Places in the near future. The DOE is currently consulting with concerned Indian tribes to determine how to minimize any future impacts on the Gable Butte-Gable Mountain localities from Site activities.

A Programmatic Memorandum of Agreement between the Advisory Council on Historic Preservation, the Washington State Office of Archaeology and Historic Preservation (SHPO), and the U.S. Department of Energy is being negotiated to outline procedures that will be followed in the management and treatment of cultural resources encountered during Site activities. In the interim, the Hanford Site has initiated consultation with SHPO. The SHPO affirmed that a state-of-the-art cultural resources survey should be conducted in each area of potential impact and that any cultural resources found during that survey should be evaluated and considered according to the Section 106 Process (36 CFR 800).

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