DOE/EIS-0110-D

DRAFT
ENVIRONMENTAL IMPACT STATEMENT

Central Waste Disposal Facility for Low-Level Radioactive Waste

Oak Ridge Reservation
Oak Ridge, Tennessee

September 1984

U.S. Department of Energy
Washington, D.C.

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COVER SHEET

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CENTRAL WASTE OISPOSAL FACILITY FOR LOW-LEVEL RADIOACTIVE WASTE, OAK RIDGE RESERVATION, OAK RIDGE, TENNESSEE

a) Lead Agency: U.S. Department of Energy (DOE)

b) Proposed Action: To construct and operate a Central Waste Disposal Facility (CWDF) for low-level radioactive waste and by-product material at West Chestnut Ridge within the Oak Ridge Reservation.

c) For additional copies or further information on this statement and program, please contact:

Mr. Doyle Brown, Program Manager
Nuclear Research and Development Division
U.S. Department of Energy
Oak Ridge Operations
P.O. Box E
Oak Ridge, Tennessee 37831
(615) 576-4876

For general information on DOE's Environmental Impact Statement process, please contact:

Dr. Robert J. Stern, Director
Office of Environmental Compliance
Office of Assistant Secretary for
Policy, Safety, and Environment
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585
(202) 252-4600

d) Designation: Draft EIS (DEIS)

e) Abstract: This statement assesses the environmental impacts of alternatives for the disposal of low-level waste and by-product material generated by the three major plants on the Oak Ridge Reservation (ORR). In addition to the no-action alternative, two classes of alternatives are evaluated: facility design alternatives and site alternatives. Two facility design alternatives are designated as reasonable design alternatives for study: engineered below-grade trench disposal and above-grade tumulus disposal. The environmental impacts of the two design alternatives are compared. Alternative sites within ORR are evaluated and three are identified as reasonable alternative sites--West Chestnut Ridge, Central Chestnut Ridge, and East Chestnut Ridge. The OOE preferred alternative is to construct and operate a below-grade disposal facility for low-level radioactive waste at West Chestnut Ridge. The environmental effects of

the proposed action and reasonable alternatives are evaluated relative to land use, air quality, water quality, ecological systems, health risk, endangered species, resource depletion, and the local social-economic system. This evaluation leads to the assessment that the overall environmental impacts at the three sites would be comparable, and that neither of the two alternative sites offers an obvious environmental advantage over the preferred site.

f) After consideration of public comments on the DEIS, a Final EIS (FEIS) will be prepared. A Record of Decision will be published in the Federal Register no sooner than 30 days after issuance of the Notice of Availability for the FEIS.

FOREWORD

This Draft Environmental Impact Statement (DEIS) is issued by the U.S. Department of Energy (DOE) in accordance with the National Environmental Policy Act of 1969 (NEPA), as implemented by the regulations promulgated by the Council on Environmental Quality (CEQ) (40 CFR 1500-1508, November 1978) and DOE's implementing guidelines (45 FR 20695, March 28, 1980, as ammended February 23, 1982, 47 FR 7976). DOE has prepared this DEIS to provide environmental input to the decision on the proposal to construct and operate a Central Waste Disposal Facility for the disposal of low-level waste and by-product material generated at three plants located on the DOE Oak Ridge Reservation. A Notice of Intent to prepare this DEIS was issued November 30, 1983. After considering all comments, DOE will issue a Final EIS (FEIS). DOE will issue a Record of Decision no sooner than 30 days after issuance of the Final EIS.

The format of this DEIS follows the suggested format in the CEQ regulations. Section 1 documents the purpose and need for a decision. Section 2 summarizes and compares alternatives and predicted environmental impacts. Section 3 summarizes the affected environment. Section 4 provides detailed information on analyses of the environmental consequences of the various alternatives. Section 5 presents the environmental permits, regulations, and approval. Section 6 presents the names and professional qualifications of the persons responsible for preparing the statement. More detailed descriptive information on waste characteristics and design alternatives is provided in several appendices.

SUMMARY

This Draft Environmental Impact Statement was prepared to assess the potential environmental impacts associated with the proposed construction and operation of a new Central Waste Disposal Facility (CWDF) for low-level radioactive waste (LLW) at the Oak Ridge Reservation (ORR), Oak Ridge, Tennessee. These impacts will be considered by the U.S. Department of Energy (DOE) in its decision on whether, where, and how to construct and operate such a facility. The proposed facility would be used for the disposal of low-level radioactive waste and by-product material generated by normal activities of the three DOE plants on the Oak Ridge Reservation--Oak Ridge National Laboratory (ORNL), Y-12 Production Plant (Y-12), and Oak Ridge Gaseous Diffusion Plant (ORGDP).

A scoping process was conducted by DOE to determine the alternatives to be analyzed and the significant issues to be analyzed in depth. A range of alternatives, including the four identified during the scoping process (no action, other sites within ORR, an above-ground disposal facility, and waste facilities at other DOE sites) was developed, and reasonable alternatives with regard to site and design were identified from this range. A rigorous exploration and objective evaluation of the alternatives in this range led to identification of three reasonable site alternatives--West Chestnut Ridge, Central Chestnut Ridge, and East Chestnut Ridge--and two design alternatives--below-grade engineered trenches and above-grade tumuli. From these, a preferred alternative was identified: construction of below-grade trenches on West Chestnut Ridge.

The no-action alternative was also examined in detail. There is an accumulation of LLW that will require disposal and--apart from shutting down all three plants within ORR (which would be a separate and unacceptable major federal action)--more waste will continue to accumulate. Hence, the no-action alternative is defined as a no-change action (or a minimum-change action when no change becomes impossible, i.e., after existing disposal facilities are filled to capacity). The no-action alternative merely defers the unavoidable action of developing a new waste disposal facility, and this deferral would increase the impacts with no consequent benefits.

The two most significant impacts identified in the analysis and assessment of environmental impacts are: (1) potential radiological impacts to individuals who might occupy the site after release for unrestricted use and to the population who depend on the Clinch River for drinking water; and (2) the commitment of land to use for radioactive waste disposal for an extended period of time until it is safe to release the site for unrestricted use.

The potential radiological impacts of greatest concern would occur at a time that was at least 100 years, and more likely several hundred years, after closure of the site. The analysis of impacts that might occur at this time requires the use of simplifying assumptions that introduce large uncertainties.

Conservative assumptions (i.e., assumptions that tend to overestimate the impacts) are made in order to take these uncertainties into account; hence, the radiological impact estimates are bounding values that are expected to exceed the actual future impacts by a factor of 10 or more. As a consequence, the bounding estimates of the impacts that an individual might incur from residential use of the site after release for unrestricted use exceed current radiation protection standards. Prior to release of the site for unrestricted use, a reassessment of the probable future impacts, based on monitoring and other data acquired during the period of institutional control, would be made and institutional control would be continued until the risk to an onsite resident would be within the acceptable limits specified by radiation protection standards.

Comparison of the radiological impacts for the two design alternatives selected for detailed study indicate that the maximum individual and collective radiation doses would be slightly greater for tumuli than for trenches. Within the range of uncertainty in the overall radiological impact estimates, the radiological impacts for the two design alternatives are essentially equivalent. The only significant difference is the more rapid erosion of the edges of the tumuli where the slope of the cover is greatest. The trench covers, being at ground level, are not subject to such erosion.

Implementation of either design alternative would expose workers and the public to a very small risk of injury and death from transportation of the wastes. It is estimated that 0.8 injuries and 0.5 deaths would be associated with transportation of wastes during the 40-year operation of the CWDF.

The cumulative radiological health effects to workers during operation, closure, and institutional care correspond to a probability of 0.005 that a single worker in the entire work force involved would die of cancer as a consequence of exposure to radioactivity from the waste. The health effects for the general population during this period would be negligible.

The health effects from exposure to radioactivity for the maximally exposed individual and for the population during the long term are estimated based on a pathway analysis for a case in which institutional controls are lifted and the site is released for unrestricted use 100 years after closure. The pathway analysis represents a worst-case analysis applicable to failure of all trench or tumulus design features and construction of a residence on the site immediately after the removal of institutional controls. Based on this analysis, a bounding estimate of the maximum annual risk of fatal cancer to an individual residing onsite would be 2×10^{-4}/yr for below-grade trenches. The risk for above-grade tumuli is comparable or less (for a credible drinking water scenario).

The long-term health effects for the general population will be from release of radionuclides into the Clinch River, which serves as a drinking water supply for many communities. A bounding estimate of the resulting lifetime risk of fatal cancer for an individual in the exposed population is 2×10^{-8} for below-grade trenches, which may be compared with a lifetime risk of 0.16 that this individual will die of cancer from other causes. This level of risk would continue for a few hundred years and then decrease to a completely negligible level. The population health effects for above-grade tumuli are estimated to be slightly greater, but are considered comparable when the uncertainty in the estimates is taken into account.

For the below-grade and above-grade design alternatives, if all controls cease, there would be eventual dispersion of the radioactive materials to the environment. Prediction of how and when this would occur, and the resulting environmental impacts, is highly speculative. In a 1,000-year time frame, neither erosive nor nonerosive land-use patterns (agriculture or natural succession) would result in complete erosion of the protective earthen cover over the wastes in the trench design. Only under a very unlikely erosive land-use pattern (agriculture, four-year crop rotation) would complete erosion of the protective cover of the tumulus occur prior to 1,000 years. The likelihood of gully erosion after controls are lifted is much greater for the above-grade alternative than for the below-grade alternative.

A comparison of the environmental impacts for the below-grade trenches at the preferred West Chestnut Ridge site with the alternative sites leads to the assessment that the overall environmental impacts would be comparable, and that the alternative sites offer no obvious environmental advantage over the preferred site.

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1. PURPOSE OF AND NEED FOR THE PROPOSED ACTION

1.1 PURPOSE OF THE PROPOSED ACTION

The proposed action is to design, construct, and operate a Central Waste Disposal Facility (CWDF) on the Oak Ridge Reservation (ORR) for disposal of low-level radioactive wastes generated at three U.S. Department of Energy (DOE) facilities: the Y-12 Production Plant (Y-12), the Oak Ridge Gaseous Diffusion Plant (ORGDP), and the Oak Ridge National Laboratory (ORNL). The purpose of the CWDF is to provide a long-term solution for the disposal of low-activity, high-volume radioactive solid wastes generated at the three DOE facilities.

1.2 NEED FOR ACTION

1.2.1 Introduction

The Y-12 and ORGDP plants are maintained on the ORR for the production of nuclear materials for national defense and research and development. The ORNL, at the same site, is involved in research and development. All three plants are within the Oak Ridge city limits.

The Y-12 Plant is located immediately adjacent to the city of Oak Ridge and has four major responsibilites: (1) production of nuclear weapons components, (2) processing of source and special nuclear materials, (3) support to the weapons-design laboratories, and (4) support to other government agencies. Activities associated with these functions include the production of lithium compounds, the recovery of enriched uranium from nonirradiated scrap materials, and the fabrication of uranium and other materials into finished parts and assemblies. Fabrication operations include vacuum casting, arc melting, powder compaction, rolling, forming, heat treating, machining, inspection, and testing.

The ORGOP is a complex of production, research, development, and support facilities located at the western edge of the city of Oak Ridge. The primary function of ORGDP is the enrichment of uranium hexafluoride (UF_6) in the uranium-235 isotope, and extensive efforts are also expended on research and development activities associated with laser isotopic separation and the gaseous diffusion and gas centrifuge processes. Numerous other activities (maintenance, nitrogen production, steam production, uranium recovery, administration, etc.) lend support to these primary functions and are thus essential to the operation of this plant.

The ORNL is a large multipurpose research laboratory whose basic mission is the discovery of new knowledge, both basic and applied, in all areas related to energy. To accomplish this mission, ORNL conducts research in all fields of modern science and technology. ORNL facilities consist of nuclear reactors, chemical pilot plants, research laboratories, radioisotope production laboratories, and support facilities.

Operations associated with the DOE facilities give rise to both radioactive and nonradioactive solid wastes. This Environmental Impact Statement (EIS) is concerned only with the disposal of low-level radioactive solid wastes from Y-12, ORGDP, and ORNL.

1.2.2 Summary Description of Waste to be Received from the Oak Ridge Plants

The CWDF would be expected to receive a total of approximately 11,000 m^3/yr (380,000 ft^3/yr) of solid low-level radioactive waste on a routine basis exclusive of grout and other waste generated on an intermittent basis from the three DOE plants. This waste is low-level waste (LLW) originating from the various research and development activities conducted at the three plants and from the production operations conducted at the Y-12 and ORGDP. Such waste has a surface dose rate of $\leq$200 mR/h and transuranic activity of not more than 100 nCi/g. This type of waste comprises about 90% of the total volume generated but contains only a few percent of the total activity of all wastes. Only this type of waste would be consigned to the CWDF. The wastes are essentially equivalent to Class A wastes as defined by the Nuclear Regulatory Commission in 10 CFR Part 61. The only significant difference is that the TRU limits will be 100 nanocuries per gram (nCi/g) rather than 10 nCi/g. Hazardous wastes as defined by the Resource Conservation and Recovery Act (RCRA) of 1976 will not be emplaced in the proposed CWDF. The waste inventory and characteristics of the wastes that typically might be expected to be disposed in the CWDF are listed in Appendix C.

Solid radioactive wastes are generated in a number of ways at the three Oak Ridge plants. The largest volume generated on a routine basis consists of glassware, paper, rags, or other miscellaneous materials that are either contaminated or suspected of being contaminated. Other sources include activities that produce solid residues from various physical and chemical processes. Contaminated items of equipment, machinery, tools, tanks, valves, pipes, etc. that are no longer needed and are uneconomical to decontaminate would also be disposed. Other types of radioactive solid waste are soil, concrete, and various types of building materials that have become contaminated as a result of leaks, spills, or other means.

Nonroutine waste generation at the three plants arises from dissimilar and unrelated activities. Some of the waste now exists in unprocessed form, awaiting disposition as discussed below, and additional volumes of waste may be designated for disposal at the CWDF in the future, pending future decisions regarding waste disposal. At ORNL, various facilities are being or will be decontaminated for decommissioning. Equipment and building materials from these facilities that retain low levels of radioactivity must be disposed, preferably in a waste-disposal facility that is designed to accommodate large volumes of waste. A potential major source of waste from Y-12 may be grouted sludges and soils produced during cleanup of the S-3 ponds. Routine sludges from other facilities may also be added. In addition, an incinerator is planned for construction at ORGDP for the disposal of radioactively contaminated polychlorinated biphenyls (PCBs) and other materials (U.S. Dept. Energy 1981). The ash from the combusted PCBs may be packaged for disposal in a

LLW-disposal facility. Defense program wastes are generated at Y-12 from a variety of classified operations. It should be recognized that facility production and remedial actions could increase or decrease these projected waste volumes and types of wastes.

1.2.3 Need for a Central Waste Disposal Facility at Oak Ridge

As part of a national effort to improve methods for disposing of radioactive wastes, DOE proposes to dispose of wastes generated by its three Oak Ridge plants in a CWDF at Oak Ridge. Several associated factors create an urgent need for such a disposal facility. Among the immediate factors is the curtailment of use of existing LLW-disposal facilities at Y-12, the need to process and dispose of radioactive sludges originating from liquid process wastes generated by Y-12 and ORGDP, and the realization of the near-term limitation of the disposal capacity currently existing at ORNL for normally generated LLW.

At ORNL, the currently used disposal site--Solid Waste Storage Area No. 6--has a remaining capacity to function for about 2 years (Section 4). Neither the Y-12 nor ORGDP has acceptable disposal facilities. DOE agreed with the state of Tennessee and the EPA to discontinue operation of the Y-12 LLW-disposal facility by July 1985 (U.S. Dept. Energy et al. 1983). Therefore, new storage and disposal capacity is needed not only for the near term but also for the long term (see Sections 2.1 and 4.4).

An additional impetus for the CWDF arises from the incentive to reduce disposal costs, which can be realized by utilization of a central facility for all three Oak Ridge plants. Currently, each plant operates its own LLW-disposal facility, resulting in additional costs associated with duplication of equipment and operations at each individual site.

The CWDF has been designed to meet existing and future needs for a period of up to 40 years. It will provide increased efficiency and capacity for disposal of solid low-level radioactive wastes and by-product materials generated by the Oak Ridge plants.

In support of this need and the interest of the public, this EIS is intended to ensure that potential environmental impacts associated with the construction, operation, closure, and custodial care of the proposed CWDF and its alternatives are properly addressed. This EIS has been prepared according to the requirements under Section 102(2)(c) of the National Environmental Policy Act of 1969 (NEPA) to provide environmental inputs to the decision regarding the proposed action and its reasonable alternatives.

1.3 ALTERNATIVES TO THE PROPOSED ACTION

During the scoping process for the CWDF, a number of potential alternatives to the proposed action were considered. In addition to the no-action alternative, two classes of alternatives were evaluated: facility design alternatives and site alternatives. Based on technical and public input, a facility design alternative--above-grade disposal--was determined to be a reasonable alternative for detailed study. Also, two sites within ORR were identified as alternative sites. Sites outside ORR were eliminated as not being reasonable (site) alternatives (see Section 2.1).

The DOE preferred alternative is to construct and operate a shallow-land disposal facility at West Chestnut Ridge within the ORR. If the preferred alternative is chosen, DOE will proceed with the design, construction, and operation of facilities to bury the wastes based on the reference design for a shallow-land (below-grade) facility.

REFERENCES (Section 1)

U.S. Department of Energy. 1981. Incineration Facility for Radioactively Contaminated Polychlorinated Biphenyls and Other Wastes. Oak Ridge Gaseous Diffusion Plant, Oak Ridge, Tennessee. DOE/EIS-00840. October.

U.S. Department of Energy, U.S. Environmental Protection Agency, and Tennessee Department of Health and Environment. 1983. Memorandum of Understanding Between the U.S. Department of Energy and the U.S. Environmental Protection Agency and State of Tennessee Department of Health and Environment Concerning Compliance with Pollution Control Standards at the Department of Energy Y-12 Plant, Anderson and Roane Counties, Tennessee. Signed May 26, 1983.

2. ANALYSIS OF ALTERNATIVES

The U.S. Department of Energy (DOE) has identified several alternatives including the proposed action for disposal of low-level radioactive waste (LLW) and by-product material generated by three plants located on the DOE Oak Ridge Reservation (ORR): the Oak Ridge National Laboratory (ORNL), the Y-12 Production Plant (Y-12), and the Oak Ridge Gaseous Diffusion Plant (ORGDP) (U.S. Dept. Energy 1983a). The proposed action is construction of a Central Waste Disposal Facility (CWDF) on a 508-ha (1253-acre) site including the buffer zone on West Chestnut Ridge for shallow-land burial (SLB) of the waste (i.e., emplacement in excavated trenches). Potential alternatives identified in the notice of intent are: (1) no action, i.e., cancellation of plans to construct and operate the CWDF; (2) utilization of a site(s) within ORR for the CWDF other than the West Chestnut Ridge site; (3) development of an above-grade radioactive-waste-disposal facility; and (4) reliance on waste facilities at other DOE sites. No other major alternatives were suggested during the public scoping, and none have been identified subsequently.

A rigorous exploration and objective evaluation of a range of potential alternatives, which include but are not restricted to those identified in the NOI, has been carried out in order to identify reasonable alternatives that merit detailed study. This identification and screening process is presented in Section 2.1. A summary comparison of the impacts of reasonable alternatives identified for detailed study, based on the detailed analyses presented in Section 4, is given in Section 2.2. Further technical details of the preferred alternative are presented in Appendix D of this document and in an engineering report by Ebasco Services Incorporated (1984).

2.1 SYSTEMATIC IDENTIFICATION OF REASONABLE ALTERNATIVES FOR DETAILED STUDY

A range of potential alternatives is presented in Figure 2.1. This range was developed from a systematic classification of means available for disposing of the waste generated by the three operating plants within ORR. The analysis used to identify reasonable alternatives for detailed study is presented below.

2.1.1 No Action

Cancellation of plans to construct and operate a CWDF constitutes the no-action alternative. The action involves management of existing wastes and waste that will continue to accrue; hence, the "no-action" alternative must be interpreted as "'no change' from current management direction or level of management intensity" (Council on Environmental Quality 1981). This interpretation is applicable for the immediate future; however, it must be modified in the longer term because circumstances do not permit "no change" from current management direction or intensity for a period longer than about two years

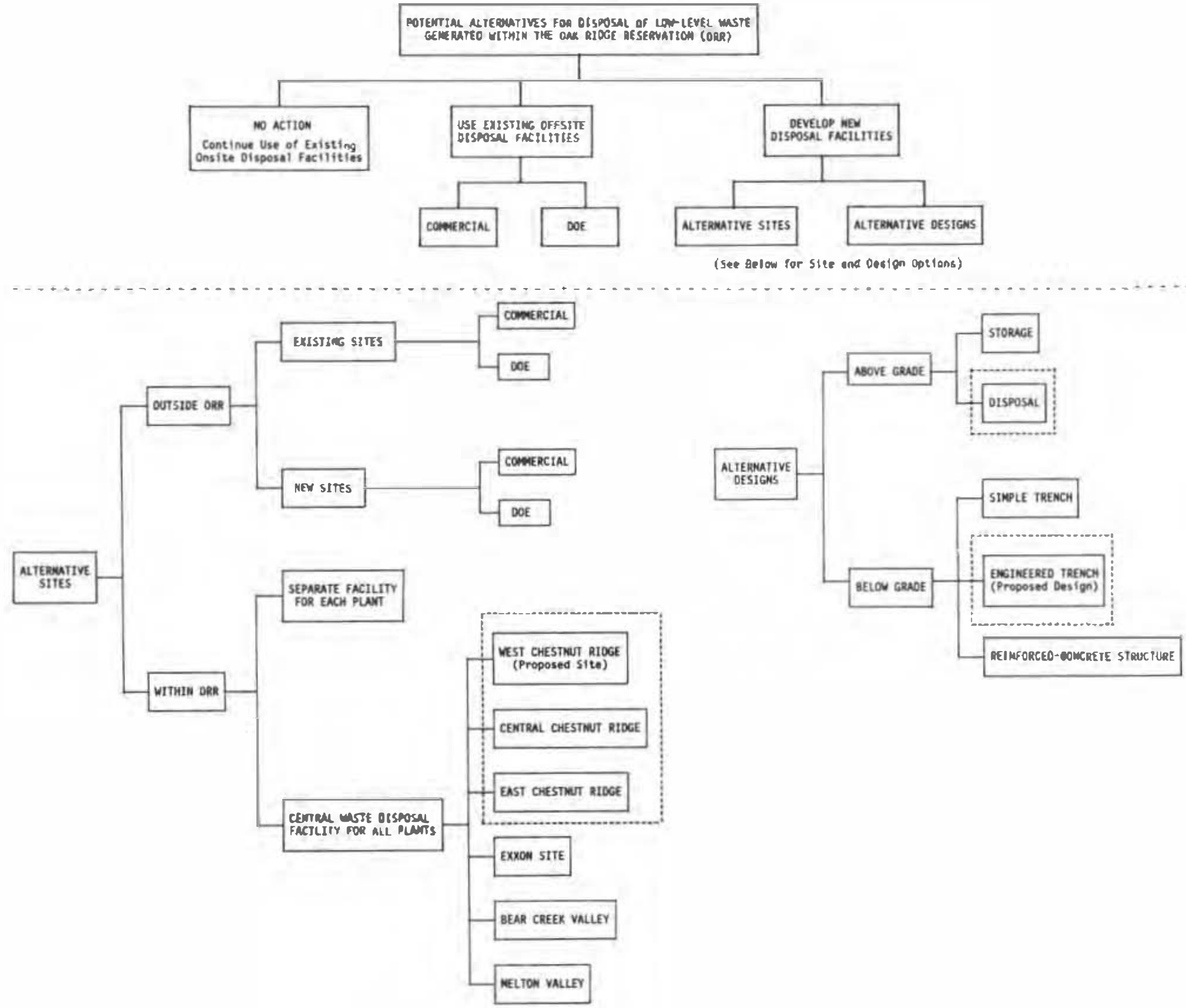

Figure 2.1. Range of Potential Alternatives That Were Screened in Identifying Reasonable Alternatives for Detailed Study. (Reasonable alternatives identified by the screening process are indicated by dashed-line boxes.)

(see Section 4.1). Beyond that time, some change in the action would be necessary. For this longer period, the no-action alternative has been defined as the alternative that involves the least change in action. The course of action considered as the no-action alternative may be specified as follows.

For the immediate future, the no-action alternative would consist of continued use of existing disposal facilities within ORR. Low-level waste (LLW) from ORNL would continue to be disposed at a site in Melton Valley designated as Solid Waste Storage Area No. 6 (SWSA-6). Nonclassified LLW from Y-12 and ORGDP is currently disposed in disposal pits located in Bear Creek Valley. Use of these pits must be discontinued because they are causing contamination of groundwater (McKinney 1983). A Memorandum of Understanding between DOE, the U.S. Environmental Protection Agency, and the State of Tennessee Department of Health and Environmental commits DOE to terminate use of the Y-12 Bear Creek disposal pits by August 1985 (U.S. Dept. Energy et al. 1983) (see Section 4.4). Disposal of Y-12 and ORGDP waste in the SWSA-6 disposal site used by ORNL is an available option that constitutes the least change from current practice and is defined as the no-action alternative when the Bear Creek disposal pits are no longer available.

Low-level waste will continue to accumulate from ongoing operations at ORNL, ORGOP, and Y-12; hence, alternative means for managing this waste will be necessary when SWSA-6 is filled to capacity. Shutting down the waste-generating activities would be a separate major federal action, which is not consistent with the concept of no action. (This possible option is excluded from the range of potential alternatives considered because it is obviously unacceptable in view of the continuing national need for the services and products provided by the research, development, and production facilities of ORNL, ORGDP, and Y-12. In addition, even if there were no further need, additional disposal space would be required for the backlog of wastes that already exist and for the waste that would result from decontamination and decommissioning.)

Options for managing the waste subsequent to closure of SWSA-6, other than those considered in connection with other alternatives, consist of extension of the capacity of existing disposal facilities within ORR or storage of the waste pending disposal at some future time. Extension of the capacity is not feasible; hence, the only reasonable option is storage. This option also represents the least possible change from current management practice under the circumstances that will occur when existing disposal facilities are filled to capacity. Thus, it constitutes the no-action alternative in the longer term.

It may be noted that, apart from the option of leaving the waste in temporary storage indefinitely (which would constitute a de facto conversion of the storage sites into disposal sites), the no-action alternative for management of LLW from ORR is equivalent to deferring the disposal action to some indefinite future time. The impacts from this alternative are discussed in Section 4.4 and summarized in Section 2.2.

2.1.2 Use of Existing Offsite Disposal Facilities

Use of existing disposal facilities outside ORR is one of the categories of potential alternatives considered for disposal of the waste generated within ORR. This category includes two potential alternatives: use of existing commercial disposal facilities and use of existing DOE disposal facilities at other locations. These two potential alternatives are discussed in Sections 2.1.2.1 and 2.1.2.2, respectively.

2.1.2.1 Commercial Facilities

There are three operating commercial disposal facilities within the United States. They are located in Barnwell, South Carolina; Beatty, Nevada; and Richland, Washington. Use of one of these facilities would be only a temporary measure because they will, within the next few years, become regional facilities operated under regional compacts as provided for under Public Law 96-573. These compacts, or actions taken under them, are not applicable to LLW from atomic energy defense activities or federal research and development activities ("DOE waste"). This introduces an unacceptable uncertainty in the continued availability of adequate means for LLW disposal. Current DOE policy does not permit disposal of DOE waste at commercial facilities. Other disadvantages of using an existing commercial site include: (1) the acceleration of need for new commercial disposal facilities; (2) the substantial increase in cost from transport of large quantities of waste on public highways over a considerable distance--500 km (300 mi) to Barnwell, 3200 km (2000 mi) to Beatty, and 3800 km (2400 mi) to Richland; and (3) the increase in risk from truck accidents. In view of the foregoing disadvantages, the alternative of disposal at an existing offsite commercial facility is not considered to be a reasonable alternative.

2.1.2.2 DOE Facilities

The five major existing DOE waste-disposal facilities (other than those within ORR) are: Hanford Reservation near Hanford, Washington; Idaho National Engineering Laboratory near Idaho Falls, Idaho; Nevada Test Site near Mercury, Nevada; Los Alamos National Laboratory near Los Alamos, New Mexico; and Savannah River Plant near Aiken, South Carolina (U.S. Dept. Energy 1983c). Low-level waste has, in the past, been buried at National Lead of Ohio near Cincinnati, Ohio; at the Paducah Gaseous Diffusion Plant near Paducah, Kentucky; and at the Portsmouth Gaseous Diffusion Plant near Portsmouth, Ohio (U.S. Dept. Energy 1983c--Figure 4.4). However, the LLW disposal facilities at these sites are either closed or too small to accommodate additional waste from ORR; hence, they are not considered to be reasonable prospective sites.

The alternative of transporting LLW from the Oak Ridge plants to one of the major DOE facilities for disposal does not have all of the disadvantages of disposal at an existing commercial site. Other DOE sites are also under DOE control; thus, the uncertainty related to changes in licensing regulations for commercial sites would not exist. However, the other disadvantages remain applicable (viz., reduction in operating lifetime of existing sites, substantially increased cost from transporting the waste, and risk from truck accidents), and there is the added disadvantage that disposal facilities at other DOE sites are designed, managed, and operated in conjunction with the disposal needs of DOE operations associated with these sites. Coordination of disposal operations with needs of research, development, and production operations at a distant site under different management could interfere with ongoing project activities and would lead to added indirect costs. Disposal at another DOE facility is not, therefore, considered to be a reasonable alternative.

2.1.3 Development of New Disposal Facilities

2.1.3.1 Alternative Sites

The procedure for identifying new commercial LLW disposal sites, developed by the U.S. Nuclear Regulatory Commission (NRC), proceeds in the following stepwise manner: (1) identification of a region of interest; (2) identification of candidate areas and potential sites within the region of interest; (3) identification of a slate of candidate sites; and (4) selection of a preferred site from the slate of candidate sites (Siefken et al. 1982; U.S. Nucl. Reg. Comm. 1983). The procedure developed by DOE for new DOE disposal sites is adopted from, and consistent with, the NRC procedure (U.S. Dept. Energy 1983b; Lee et al. 1983). The steps in the procedures may be characterized as a sequence that starts with a bounding of the problem by defining a limiting area (the region of interest) and then focuses, in successive steps, on smaller areas until a preferred site has been identified. The major portion of the site characterization studies are performed at the preferred site after selection from among the candidate sites. Only if the detailed site characterization studies identify unanticipated adverse conditions at the preferred site--which did not occur in the present circumstance--are detailed investigations performed at more than one site (Siefken et al. 1982--p. 10).

Application of the site-selection analysis to the problem of identifying a site for the CWDF may be broken down into two parts. The first part follows steps 1 and 2 of the procedure, and is implemented by comparing the advantages and disadvantages of locating a site inside or outside ORR. The comparison, presented in Section 2.1.3.1.1, leads to the conclusion that sites within ORR are the only reasonable alternatives. The second part is the identification of candidate sites and a preferred site within ORR. This part is based on the analysis of Lee et al. (1983) and is summarized in Section 2.1.3.1.2. The ORR is treated as the region of interest and the site-selection procedure is followed through to the identification of a preferred site for the CWDF.

2.1.3.1.1 Sites Outside the Oak Ridge Reservation

New Commercial Facilities. New commercial facilities must be developed in accordance with the provisions of the Low-Level Radioactive Waste Policy Act of 1980 (Public Law 96-573). This act provides for the establishment of regional compacts between states for the development and operation of waste-disposal sites for LLW generated by the states within a compact. These compacts, or actions taken under them, are not applicable to LLW from atomic energy defense activities or federal research and development activities [PL 96-573, Sec. 3(a),(b)]. The disadvantages cited in Section 2.1.2.1 for use of an existing commercial facility for disposal of LLW from ORR are also applicable to a new commercial facility. In addition, new commercial facilities will not be available in time to meet the need. Thus, use of a new commercial facility is not a reasonable alternative.

New Disposal Facility at an Existing DOE-Owned Site. A new DOE disposal facility would not be subject to the institutional restrictions that preclude further consideration of a new commercial site. It could be a facility on land that is currently owned and controlled by DOE, on federal land that could be transferred to DOE, or on land that is not currently owned by the federal government and would, therefore, have to be acquired before the facility could be constructed.

The nearest DOE-owned sites (other than ORR) are the Paducah Gaseous Diffusion Plant in Paducah, Kentucky; the Portsmouth Gaseous Diffusion Plant near Portsmouth, Ohio; National Lead of Ohio near Cincinnati, Ohio; and the Savannah River Plant near Aiken, South Carolina--all about 500 km (300 mi) from the ORR site. A LLW-disposal facility is in operation at the Savannah River Plant; hence a new facility might not be necessary there. The reasons for excluding use of this existing facility from further consideration are given in Section 2.1.2.2. The Paducah, Portsmouth, and National Lead of Ohio plants are not currently in use as major DOE waste-disposal facilities. Construction of a new disposal facility at one of these sites would incur delays and additional costs due to the need for coordinating project activities at two widely separated locations, in addition to the substantial cost of transport, increased accident risk, and other disadvantages noted for the Savannah River Plant. The cost and risk of transport become greater for more distant sites. On the basis of the foregoing considerations, construction of a new disposal facility at another site currently owned and controlled by DOE is not considered to be a reasonable alternative.

New Disposal Facility at a New DOE-Owned Site. Acquisition of a new DOE site for construction of a LLW-disposal facility outside ORR is one of the potential alternatives considered. In this alternative, a new disposal facility would be developed on a site not currently owned by DOE. This alternative includes the subalternatives of acquiring federal land from another government agency or purchasing land not presently owned by the federal government. The advantage of this potential alternative is that it would permit selection of a site with the most favorable natural environment for controlling migration of the radionuclides from the burial trenches. The decisive disadvantage, when considered as an alternative for disposal of waste generated within ORR, is the time that would be required before such a site could become operational, together with the uncertainty in the outcome of the selection and budgeting processes, as noted below.

The selection of a site to be purchased by DOE (or a DOE contractor) and developed for the sole purpose of serving as a LLW facility would be unprecedented, and subject to close scrutiny by the public and by elected state and federal officials. The political processes involved in meeting objections and reaching agreement on a preferred site could be expected to introduce delays of at least one year, and probably more. If the land were not currently owned by another federal agency, appropriation of funds in the federal budget for purchase of the site, which would also be subject to uncertainty if there were public resistance to the choice of site, could lead to additional delays of comparable magnitude. A separate environmental impact statement for the site and facility, based on a detailed environmental study, would be required and would take at least one year. Development of the facility would involve recruitment of management and staff and construction of support and service facilities (which would duplicate management, staff, and service facilities that are already in place at existing DOE facilities). This could be expected to add an additional year beyond the time that would be needed to construct a CWDF at ORR. The time required to develop a new facility would, therefore, be at least three or four years, and probably longer if serious opposition developed during the selection and budgeting steps of the process. Additional disposal facilities are urgently needed at ORR within two years (see Section 4.4).

In addition to the disadvantage that a new site could not be developed in time to meet the need, there are the disadvantages of substantially increased costs from transport of the waste from ORR to another site, and the increased risk of truck accidents, as discussed in Section 2.1.2 in connection with potential alternatives for disposal at an existing DOE site. The most suitable sites for LLW disposal are in arid regions of western United States. The transportation costs and traffic accident risks would be greatest for these sites because of the long transport distances involved. These disadvantages would be less for sites within the state of Tennessee or adjacent states, but the advantages would be less also. Political opposition to transporting LLW generated within Tennessee to a new DOE site in another state might introduce delays and make implementation of this option uncertain.

An exemplary site-selection study for a LLW disposal site, based on the state of Tennessee as the region of interest, has indicated that there are areas in western Tennessee with marginally superior environmental characteristics (U.S. Dept. Energy 1983b). This study did not, however, consider potential sites within the areas identified. Because of the considerable variance in environmental characteristics between different sites in an area, one cannot infer from a marginal advantage in area characteristics that sites outside ORR would be environmentally superior to those inside ORR.

In view of the foregoing considerations, in particular, the long lead time before the facility would be operational, the development of a new DOE-owned site outside ORR is not considered to be a reasonable alternative for disposal of LLW generated at ORR.

2.1.3.1.2 Sites Within the Oak Ridge Reservation

Separate Waste-Disposal Facility for Each Plant. The alternative of a separate waste-disposal facility for each plant offers the following advantages compared to a single CWDF: the tract for each facility could be smaller and the transport distance within ORR could be less. Disadvantages are that overall land requirements would be greater; development and operating costs would be greater because each disposal facility would require its own buffer zone, access roads, and support and monitoring facilities; and record-keeping and site-marking requirements to prevent future inappropriate use and intrusion would be increased. The consequences of these disadvantages are that the costs would be greater, the environmental impacts would be comparable or greater, and the constraints on future developments that might require large contiguous tracts of land would be greater. In view of the preponderance of disadvantages over advantages, and lack of any environmental advantages, the implementation of separate new disposal facilities for the individual plants is not considered to be a reasonable alternative.

Central Waste Disposal Facility for All Three Plants. An alternative-sites analysis for a CWDF has been carried out by Lee et al. (1983) and is used in this EIS as a basis for identifying a slate of candidate sites within ORR. In that analysis, Lee et al. selected ORR as the region of interest. Candidate areas within this region of interest were identified by exclusionary requirements that eliminated areas with unacceptable features (Lee et al.

1983--Table 3.2). Unacceptable features included floodplains and wetlands, inadequate soil thickness or unsaturated zone thickness, and lack of availability of an unused area. Screening requirements used for candidate-site identification include both exclusionary requirements and desirable features (Lee et al. 1983--Table 3.3). Exclusionary requirements include: slope exceeding 25%; areas close to existing plants, public roads, and reservation boundaries; and areas adjacent to residential developments. Karst topography is an undesirable feature, but it is not considered to be exclusionary unless the karst features are so evident and widespread that karst-free areas of sufficient size to accommodate the trenches are unlikely. Desirable features include: area greater than 80 ha (200 acres); slope less than 10%; easy access by road; proximity to waste generators; and availability of utilities.

The Oak Ridge Reservation is underlain by four different geologic strata that intersect the ground surface in bands extending in a southwest to northeast direction (see Section 3, Figures 3.4 and 3.5). Of the four major strata--Conasauga Group, Knox Group, Chickamauga Group, and Rome Formation--only the Knox Group and Conasauga Group have characteristics that are considered suitable for placement of a waste-disposal facility (Lee et al. 1983; Lomenick et al. 1983). These formations occur in three areas: Melton Valley, Chestnut Ridge, and Pine Ridge Knolls/Bear Creek Valley (between Pine Ridge and Chestnut Ridge--the eastern portion of this area is drained by Bear Creek, the western portion by Grassy Creek [U.S. Dept. Energy 1984--Figure 3.18]).

The current operating disposal site (SWSA-6) and two closed sites (SWSA-4 and SWSA-5) lie in Melton Valley. This area is currently under consideration for a new waste-disposal site for ORNL (SWSA-7). The potential sites that have been identified for SWSA-7 cover all of the remaining area in Melton Valley that would be suitable for disposal of LLW.

The use of potential SWSA-7 sites for the CWDF has been considered and rejected for two reasons. First, the areas suitable for construction of disposal trenches are small and fragmented. The largest contiguous area with a slope of 20% or less is 20 ha (50 acres), of which about 6.5 ha (16 acres) is sufficiently far above the water table (>5 m [15 ft]) to be suitable for disposal trenches (Lomenick et al. 1983). Several additional contiguous sites with acceptable slopes--ranging from 7 to 15 ha (15 to 40 acres) in area--have been identified, but the depth to the water table is not known; hence, the suitability of these sites for trenches is not known. If all of the nonclassified LLW generated within ORR, together with the contaminated sludge that must be removed from holding ponds, were placed in the SWSA-7 sites, the sites would be filled to capacity within a few years and the need for a new CWDF would merely be delayed.

The second reason is that SWSA-7 will be needed for LLW from ORNL that does not meet the waste-acceptance criteria for the CWDF. The CWDF is intended for the large volumes of LLW with very low radionuclide concentrations generated by all three plants. New facilities for the much smaller volumes of waste not suitable for the CWDF will be provided separately when SWSA-6 is filled to capacity. Although unsuitable for a CWDF because of the limited area available, SWSA-7 is expected to be suitable for construction of a facility that would provide greater confinement for disposal of the small volume of LLW that would not be accepted in the CWDF.

If the SWSA-7 site were used for the CWOF, a new site for the CWDF would have to be selected again within a few years when SWSA-7 was filled to capacity and, in addition, a new site for LLW that exceeded the waste-acceptance criteria for the CWDF would have to be located and developed. A site located in the Melton Valley area is not, therefore, considered to be a reasonable alternative for the CWDF.

A screening of the candidate areas (Lee et al. 1983) led to a preliminary identification of five candidate sites: two sites in the Pine Ridge Knolls/ Bear Creek Valley area (labeled "Exxon" and "Bear Creek Valley" in Figure 2.2) and three sites on Chestnut Ridge (labeled West Chestnut Ridge, Central Chestnut Ridge, and East Chestnut Ridge in Figure 2.2). The Central Chestnut Ridge site is divided into three sections--west, central, and east--for the purpose of screening, but it is treated as a single site for the purpose of potential development.

The preliminary slate of candidate sites was reviewed and compared on the basis of reconnaissance level data (from a literature survey and site visits) for the purpose of identifying a preferred site (Lee et al. 1983). The factors considered in the comparison were: hydrology, geology, soils, land use, socioeconomics, and ecology/meteorology. The results of a comparative ranking for each parameter are given in Table 2.1. It was found that the ranking differences were small, and the analysis did not provide sufficient discrimination to eliminate or establish clear superiority of any of the sites. A low ranking in Table 2.1 cannot, therefore, be interpreted to mean that a site is unsuitable for disposal, nor can a high ranking be interpreted to mean that a site is clearly preferable. A subsequent study, based on additional data and criteria, was undertaken in order to identify a final slate of candidate sites and select a preferred site.

Preliminary hydrological characterization of the Exxon site revealed a shallow water table about 4 m (12 ft) below the surface (U.S. Dept. Energy 1984). This is insufficient for construction of disposal trenches. Even if the proposed depth (9 m [30 ft]) were reduced, the depth would be insufficient when seasonal and longer-term fluctuations are taken into account. The portions of the Exxon site suitable for above-grade disposal, which must be at locations with a shallow grade that are not subject to flooding, are on knolls within the indicated site boundaries. Electric transmission lines and an interstate gas transmission line cross the site and restrict the area available for waste emplacement. A study of the feasibility of using the Exxon site for above-grade disposal of waste has been carried out for analyzing disposal alternatives for managing radioactive wastes and residues at the Niagara Falls Storage Site (U.S. Dept. Energy 1984--in that study the "Exxon" site is referred to as the "Pine Ridge Knolls" site). The waste-emplacement area needed for NFSS disposal is 12 ha (30 acres), which is considerably smaller than the 40 ha (100 acres) that would be required for the CWDF. (This area does not include service areas or the buffer zone.) It was found that a major technical uncertainty for NFSS waste disposal was whether or not there would be sufficient space on top of the knolls for constructing the tumuli. One may infer from this that the available area would be inadequate for the much greater area needed for a CWDF. On the basis of the foregoing considerations, the Exxon site is not considered to be a reasonable alternative for the CWOF.

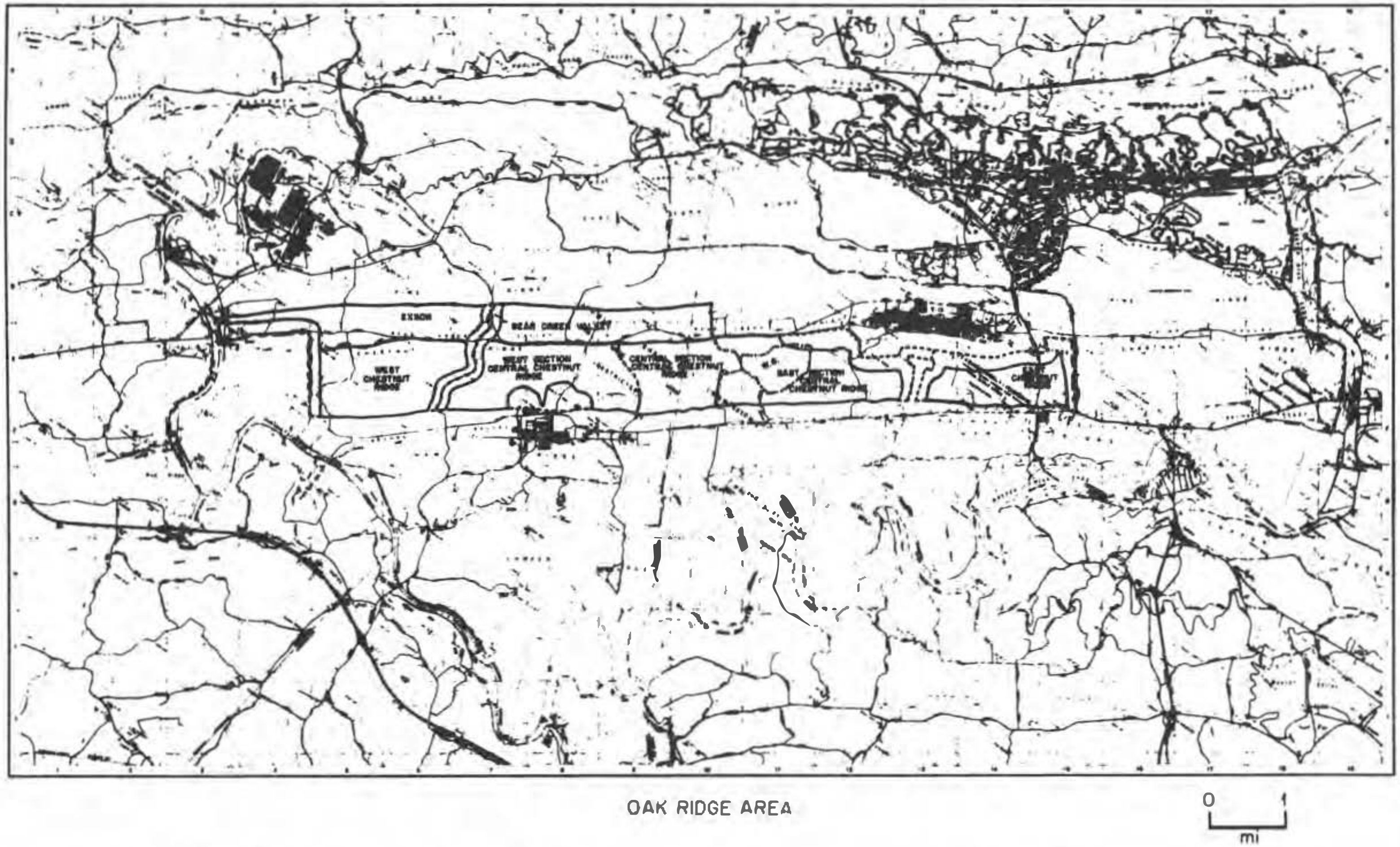

Figure 2.2. Preliminary Slate of Candidate Sites for a Central Waste Disposal Facility on the Oak Ridge Reservation. Source: Lee et al. (1983--Figure 3.2).

Table 2.1. Ranking of Candidate Sites within ORR with Respect to Site-Selection Parameters

Parameter:	Hydrology	Geology	Soil	Land Use	Socioeconomics	Ecology/ Meteorology
Significance:	High	High	Medium	Medium	Low	Low
Highest rank	East Chestnut Ridge	[Exxon	[Central Chestnut Ridge-Center	Bear Creek Valley	[Exxon	[Exxon
	Central Chestnut Ridge-West	Bear Creek Valley]	West Chestnut Ridge	[Central Chestnut Ridge-Central	Bear Creek Valley]	East Chestnut Ridge
	Central Chestnut Ridge-Center	[Central Chestnut Ridge-Center	East Chestnut Ridge	West Chestnut Ridge	Central Chestnut Ridge-Center	Central Chestnut Ridge-West]
	West Chestnut Ridge	West Chestnut Ridge]	Central Chestnut Ridge-East	East Chestnut Ridge	Central Chestnut Ridge-East	[Bear Creek Valley
	Central Chestnut Ridge-East	East Chestnut Ridge	Central Chestnut Ridge-West]	Exxon	East Chestnut Ridge	Central Chestnut Ridge-Center
	[Exxon	Central Chestnut Ridge-East	[Exxon	Central Chestnut Ridge-West]	West Chestnut Ridge	Central Chestnut Ridge-East
Lowest rank	Bear Creek Valley]	Central Chestnut Ridge-West	Bear Creek Valley]	Central Chestnut Ridge-East	Central Chestnut Ridge-West	West Chestnut Ridge]

[ ] = roughly equivalent.

Source: Lee et al. (1983--Table 3.11).

The hydrological characteristics of the Bear Creek Valley site (also located in the Conasauga Group) are similar to those for the Exxon site. Shallow depth to the water table and probable artesian conditions also render this site unsuitable for below-grade disposal in trenches.

The generally unfavorable hydrological condition appears to be characteristic of the entire Bear Creek Valley and has become the primary reason for discontinuing use of the Bear Creek disposal pits, which are located at the upper end of Bear Creek Valley close to the Y-12 Plant.

Suitable terrain on the site could be developed for above-grade disposal, but is considered unattractive since the shallow water table would require extensive subsurface drainage. Moreover, contaminated groundwater and surface water in the Bear Creek headwaters (McKinney 1983) would adversely impact the monitorability of a new waste disposal facility in that portion of Bear Creek Valley. Hydrologic discharges through the valley may contain variable and unpredictable concentrations (however low) of species that may be common to those that are contained in the CWDF wastes, thus hampering the required environmental monitoring program. This characteristic would render the site unsuitable for waste disposal as recognized in NRC regulations for commercial low-level waste facilities (10 CFR Part 61.50), which call for avoiding areas where nearby facilities significantly mask the environmental monitoring program. Monitorability and predictability (which depend on baseline monitoring data) are essential site characteristics for determining compliance with appropriate regulations. For this reason, and because of the shallow water table and the existence of sites with more suitable characteristics, the Bear Creek Valley site is not considered to be a reasonable alternative for the CWDF.

Preliminary geotechnical work led to identification of the West and Central Chestnut Ridge sites as candidate sites and reasonable alternatives for a CWDF. The East Chestnut Ridge site is similar to the West and Central Chestnut Ridge sites and is judged to be slightly superior in hydrological characteristics (Lee et al. 1982). The area suitable for waste emplacement is less than for the other sites, but probably sufficient for the CWDF, which requires an area of 40 ha (100 acres) for waste emplacement and about 20 ha (50 acres) for the service area and buffer zone. East Chestnut Ridge is, therefore, also considered to be one of the reasonable alternatives for the CWDF. A broad preliminary investigation was undertaken in order to provide a basis for identification of a preferred site.

Several nontechnical factors were considered to evaluate whether they would have a significant effect on the selection. The criteria considered were (1) usable acreage, (2) requirements for transportation of waste, (3) access to the site, and (4) availability of utilities. After consideration of these factors, it was concluded that the West Chestnut Ridge site was preferred over the other two sites, primarily on the basis of the combined merits of a larger area suitable for waste emplacement and greater ease of access. On the basis of this selection, detailed site characterization was conducted at the West Chestnut Ridge site.

2.1.3.2 Alternative Designs

The two major design alternatives considered are (1) an above-grade structure in which all of the waste is at or above grade level, and (2) a below-grade structure in which all of the waste is below grade level.* Variants of these two major alternatives, as described below, are also considered as potential alternatives. A third alternative, intermediate between the bounding alternatives, is a facility in which some of the waste is placed below grade and some of the waste is placed above grade. This design is used in France (Van Kote 1982) and is appropriate when both low-activity and high-activity LLW are placed in the same facility. The high-activity LLW is placed below grade in a concrete-walled "basement" and grouted to form a below-grade concrete monolith, and the low-activity LLW is placed above grade. This design is not specifically considered because the analysis needed for an assessment is provided by the separate analyses of above-grade and below-grade structures, and candidate waste for the CWDF is all low-activity LLW for which a two-tiered design is not necessary.

The potential alternative designs are intended to span a reasonable range of design parameters that will meet the performance objectives in a cost-effective manner. The performance objectives are to provide containing structures that: (1) minimize water infiltration; (2) minimize trench subsidence; (3) minimize biointrusion by plants and animals; (4) minimize the likelihood of human intrusion; and (5) maintain the first four performance objectives over the time period during which the waste remains hazardous. The major design parameters that can be varied in order to achieve these performance objectives are: (1) placement--with respect to grade level and distance from bottom of waste layer to water table; (2) overall site water control--by grading, trench placement, etc.; (3) cover design--thickness, cover materials, and emplacement of biobarriers; (4) sidewall design (thickness and material)--use of clay, membrane, or other material to control infiltration and intrusion; (5) bottom design--use of gravel bed or other permeable material and drains to facilitate drainage of any infiltrating water; (6) backfill material--use of sand or grout to control infiltration and minimize subsidence; and (7) waste container design.

2.1.3.2.1 Above-Grade Designs

Storage. A variant of the concept of above-grade disposal that was considered and rejected is above-grade storage for an extended period (~100 years) followed by permanent disposal. The storage/disposal concept for an above-grade structure is not a reasonable alternative because storage introduces additional costs and risks without compensating benefits; ultimately, above- or below-grade disposal would still be necessary.

Disposal. Two potential alternative above-grade designs were considered. The basic design would consist of tumuli patterned after those used in French waste-disposal operations (Lavie and Barthoux 1982; Van Kote 1982; Lavie and Marque 1983). The floor of each tumulus would be a concrete slab at grade level, draining into a sump. The walls would be formed by concrete cylinders stacked to a height of about 6 m (20 ft). The waste emplaced in this unit

*The "grade" and the "ground" are not necessarily the same; an above-grade structure can be covered with a contoured layer of soil that becomes the ground level and places the waste "below ground"; it would still be "above grade" because the grade is defined by the elevation of contiguous ground.

would have to be put in containers, compacted, or grouted in order to prevent slumping after capping. After filling, each tumulus would be backfilled with gravel and capped. The cap would consist of a sequence of layers of clay, sand, a plastic membrane, soil, cobblestones and gravel, and topsoil to minimize water infiltration and discourage intrusion. Each tumulus would have a height of about 9 m (30 ft) above the surrounding land. This potential alternative is considered reasonable.

The other potential above-grade alternative is a concrete monolith formed by stacking the waste in containers on a concrete pad, grouting the stack as successive levels are emplaced, and encasing the stack with a concrete cap that would be covered with a layer of soil sufficient to support vegetation and provide protection from weathering. Grouting may be accomplished by building a concrete wall or a dike around the waste and pumping in the liquid grout through a hose. The monolithic concrete tumulus would provide more effective protection from inadvertent intrusion, a reduction in water infiltration and consequent leaching of radionuclides from the waste, and greater protection from dispersal by erosion. However, the cost would be much greater. Because of the large volume and low activity of the waste for which the CWDF is intended, the more elaborate confinement capabilities of a monolith are considered to be unnecessary, so that the added cost would not be justifiable. The monolithic concrete tumulus is not, therefore, considered to be a reasonable alternative to the tumulus design described above.

2.1.3.2.2 Below-Grade Designs

Three potential alternative below-grade designs were considered: (1) a simple trench with no engineered features; (2) an engineered trench designed to reduce water infiltration and the probability of intrusion; and (3) an underground reinforced-concrete structure.

The first below-grade alternative design is a simple design that provides no barrier for water infiltration or biotic (including human) intrusion. A typical design would be an 8-m (25-ft) deep trench, with waste voids backfilled by excavated material; a plain cap, also of material excavated from the trench; and a topsoil layer to support revegetation. This design represents the least-costly bounding case. Although a trench of simple design might be able to meet performance objectives for protection of public health and safety (see Section 4), implementation of such a design is inconsistent with the DOE policy that radiation exposure to individuals and population groups be limited to levels that are as-low-as-reasonably-achievable (ALARA) (DOE Order 5480.1A, Chapter XI). The risk of exposure can be reduced at reasonable cost by using an engineered trench rather than a trench of simple design that makes no provision for reducing water infiltration or the probability of human intrusion. The simple trench alternative is not, therefore, considered to be a reasonable design for the CWDF.

The second design is the preferred design alternative and proposed design and provides for control of water infiltration and intrusion (Ebasco Services 1984). It would consist of a sand floor with a gravel drain for removing water entering the trench from the sides or any water that infiltrated through the waste (so that water would not collect in the trench and remain in contact with the waste); sloping sides with drainage mats to divert water entering the trench sides directly to the bottom of the trench; an engineered cover consisting of a membrane liner to prevent water infiltration; an intruder-resistant layer of 0.6 m (2 ft) of sand, cobbles, and boulders; and 1.8 m (6 ft) of compacted earth fill covered by topsoil to allow revegetation. The ground surface and surrounding grade would be contoured to facilitate runoff and divert surface water away from the trench. Although membrane liners for the sides and the use of clay or bentonite for side liners and cover are not now contemplated, they are not excluded from consideration if subsequent studies and future experience should indicate the need. This proposed design with appropriate maintenance is expected to maintain isolation integrity for the near term (100 years following closure--except the membrane liner, for which data are lacking with respect to performance beyond a period of about 30 years). It cannot be assumed that this design will provide a barrier to water infiltration in the long term.

The third design, an underground reinforced-concrete structure, would provide an effective barrier to water infiltration and migration of the radionuclides for an extended period of time--possibly of the order of 500 years or more, although this cannot be verified because there are no engineering data available regarding the integrity of structures with respect to water infiltration for time periods of this magnitude. Long-term structural stability and near-complete protection from inadvertent intrusion could be provided by high-quality reinforced-concrete sidewalls and cover, with grouting of the emplaced waste to provide a monolithic concrete structure. Because cracking of the concrete--which would permit water infiltration--could occur, additional layers outside the concrete would be needed. A layer of asphalt would tend to seal cracks and be resistant to biotic intrusion by roots and burrowing animals. Asphalt can degrade with time, but the rate of degradation for a protected layer would be much slower than for an exposed layer. A layer of bentonite clay outside the asphalt could serve to provide additional protection. Penetration and degradation of the clay layer by biotic intrusion (plants and burrowing animals) could be minimized by using a deeper trench in which the top of the clay layer would be 3 m (10 ft) or more below the grade surface. Although the clay layer would not be an effective water barrier during periods of extended drought when it would shrink and crack, it could be expected to reseal as the soil water content returned to normal. A human intruder barrier of boulders and riprap could be placed above the clay layer to reduce the probability of biointrusion and inadvertent human intrusion. (No protection can be provided against intentional human intrusion.) The trench bottom would be a layer of sand. A barrier to water infiltration on the trench bottom is undesirable because any water that does infiltrate should be allowed to drain out as easily as possible. The optimum design corresponds to an inverted water-tight container over the waste that prevents water infiltration through the top and sides. Placement of the trench bottom well above the water table would be an important design consideration. The soil surface would be above the original grade and contoured to provide optimum runoff.

The third design alternative is a bounding design that would provide the greatest long-term isolation that is currently possible using near-surface disposal with state-of-the-art engineering practices. Elaborate structures similar to the kind described above constitute a class of design alternatives known as "greater-confinement disposal" (GCD).* They are considerably more costly than a typical design for shallow-land burial (SLB), such as the second alternative, and are intended for the small fraction of LLW that presents a greater hazard, primarily because of high radionuclide concentrations. Waste of this kind--commonly referred to as "GCD waste"--will not be accepted at the CWDF. Furthermore, elaborate engineered structures cannot reduce the long-term risks from very long-lived radionuclides, such as U-238 which has a half-life of 4.5×10^9 years, because there is no structure or design that can provide confinement over such long time periods. (U-238, at low concentrations, is a principal contaminant of a considerable fraction of the waste intended for the CWDF--see Appendix C). For such radionuclides, the only feasible objective is to control the release rate in order to ensure that the concentration in the environment remains low enough for the risk to be insignificant. Use of a GCD design would increase the cost by an estimated factor of 2 or 3 with very little concomitant reduction in environmental consequences--in particular, the health risks (Gilbert and Luner 1984). Thus, GCD is not a reasonable alternative for the waste that would be accepted in the CWDF.

2.1.3.2.3 Other Design Considerations

Design considerations other than those discussed above include waste processing, waste packaging, and backfilling materials and procedures. Waste processing (compaction, solidification, and/or incineration of the waste) and waste packaging can affect performance of a disposal facility. It can increase the stability of the waste (thereby reducing the likelihood of increased water infiltration due to slumping of the trench cover) and the rate of leaching. Incineration reduces the volume of trash, but has the disadvantage of increasing the radionuclide concentration. Methods for improving waste processing and packaging will be investigated as a part of the ongoing DOE program for management of low-level waste. The improvements in performance that can result from current practicable means of waste processing and packaging would not affect the relative ranking of the sites and designs considered herein or the need for a CWDF and will not, therefore, be examined in detail.

Backfilling alternatives refer to the materials and procedures used to fill the interstices between the waste packages and provide a cover between the top of the uppermost waste or waste packages and the cap. Backfilling procedures and materials can have a significant effect on the performance of a disposal facility, and may be considered to be a part of the facility design.

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*The term "greater-confinement disposal" is applied to methods of near-surface disposal that provide greater confinement than standard shallow-land burial practice and are intended for high-activity LLW. Examples of GCD are deep trenches, improved waste forms (e.g., encapsulation in concrete or a polymeric medium), engineered concrete structures, boreholes, and hydrofracture (Gilbert and Luner 1984). Under the NRC's classification scheme for commercial low-level waste, LLW that meets the NRC waste acceptance criteria for Class A or Class B waste does not require GCD; waste that exceeds the NRC waste acceptance criteria for Class C waste always requires GCD; Class C waste may or may not require GCD, depending on the natural retention characteristics of the disposal site.

Three alternatives are considered. One is use of the excavated material from the trenches. The second, which would reduce the likelihood of voids between the waste packages, is the use of dry sand. The third is the use of grout, which would result in a concrete monolith encapsulating the waste. This monolith would actually be a honeycomb structure unless grouting or a similar process were used for waste packaging. Grouting is not considered necessary for the LLW that would be accepted in a CWDF, and the differences in performance for the other backfilling alternatives are not large enough to affect the estimated impacts; hence, further analysis of the backfilling alternatives is not addressed in this EIS.

2.2 COMPARISON OF ENVIRONMENTAL IMPACTS OF REASONABLE ALTERNATIVES

On the basis of the screening process described above, three alternative sites--West Chestnut Ridge, Central Chestnut Ridge, and East Chestnut Ridge--and two alternative designs--a below-grade trench and an above-grade tumulus--have been identified as reasonable alternatives. These alternatives are identified by dashed boxes in Figure 2.1. The West Chestnut Ridge site was selected as the preferred alternative, and the below-grade trench design was selected as the preferred design. Thus, the preferred alternative for the CWDF, which is also the proposed action, is construction of below-grade trenches on West Chestnut Ridge. A summary comparison of the reasonable alternatives for a CWDF is given below and summarized in Tables 2.2 and 2.3.

The environmental impacts for the two design alternatives at the preferred site (West Chestnut Ridge) were examined using the results of the detailed site characterization, and the results are summarized and compared in terms of short-term and long-term impacts in Table 2.2. The short-term impacts are those related to the construction, operation, closure, and maintenance and monitoring activities during the institutional-control period. These impacts would occur within 100 years after closure. During this period, containment structures would be maintained, radioactive releases to the environment would be monitored, and periodic corrective remedial actions would be taken, as necessary. Human access to the waste-management areas would be limited, and the federal government would continue to own the sites and use them solely for waste-management purposes. At the end of the 100-year institutional-control period, DOE would review the monitoring and operating data and determine whether or not the institutional controls can continue.

Long-term impacts are those that would occur during the time periods extending beyond the 100-year period and are related to effects of long-term integrity of the waste containment, possible radionuclide migration from the disposal site, and land-use commitment. At some time during this period, monitoring, maintenance, and corrective actions would cease. Access, land-use, and ownership controls would be lost as well. Human intrusion into the wastes is assumed to occur after the institutional-control period.

The short-term impacts for both design alternatives would be similar because most of the activities would be the same. During this time period, construction-related impacts would probably disturb about 38 ha (94 acres) of wildlife habitat and temporarily affect a portion of the local environment. Construction activities would be planned to mitigate occurrence of aquatic impacts, and a monitoring program would be conducted during construction and

Table 2.2. Comparison of Environmental Impacts of Alternative Designs†[1]

Environmental Parameters	Below-Grade Trench (Preferred)	Above-Grade Tumulus
SHORT-TERM IMPACTS		
Hydrologic:	Soil erosion resulting in turbidity and sedimentation in Ish, New Zion, and Grassy creeks--during construction only.	Impacts similar to but smaller than below-grade
Ecologic:	Loss of 8% of trees within CWOF boundary.	Same
Transportation:		
Nonoccupational radiation dose in normal operation, mrem/yr (% of natural background)	≤ 0.002 (0.001%)	Same
Occupational radiation dose in normal operation, mrem/yr (% of DOE occupational limit)	≤ 20 (0.4%)	Same
Nonradiological injuries in 40 yr of operation	0.8	Same
Nonradiological deaths in 40 yr of operation	0.5	Same
Occupational radiation dose to trenchworker, mrem/yr (% of DOE occupational limit)	≤ 500 (10%)	30-50% greater than below-grade
Occupational radiation dose to maintenance worker during 5-yr active-maintenance (closure) period, mrem/yr (% of background)	10 (8%)	Same
Occupational radiation dose during 100-yr institutional control period, mrem/yr (% of background)	4 (3%)	Same
LONG-TERM IMPACTS		
Maximum individual whole-body radiation dose to onsite resident, mrem/yr	375	2300
Maximum radiation dose to critical organ (bone) of onsite resident, mrem/yr	2500	6400
Maximum whole-body, individual radiation dose from drinking water supplied by Clinch River (50-yr commitment from 1 yr of ingestion), mrem/yr	0.08	11
Whole-body population dose from drinking water supplied by Clinch River, person-rem/yr	0.6	80
Land use	Preemption of 64 ha (160 acres) of land from alternative uses	Same
Erosion of averaged slope of tumulus or trench after 500 years (agricultural use, worst-case scenario), meters	0.2	2.0

†[1] The comparison is made for both designs located on West Chestnut Ridge, the preferred site.

Table 2.3. Comparison of Environmental Impacts of Alternative Sites for Below-Grade Trench

Environmental Parameters	West Chestnut Ridge	Central Chestnut Ridge	East Chestnut Ridge
SHORT-TERM IMPACTS			
Hydrologic:	Soil erosion resulting in turbidity and sedimentation in affected creeks--during construction only.	Comparable	Slightly less
Ecologic:	Loss of 8% of trees within CWOF boundary.	Comparable	Slightly less
Transportation:			
Nonoccupational radiation dose in normal operation, mrem/yr (% of natural background)	≦ 0.002 (0.001%)		
Occupational radiation dose in normal operation, mrem/yr (% of DOE occupational limit)	≦ 20 (0.4%)	Slightly less	Slightly less
Nonradiological injuries in 40 yr of operation	0.8		
Nonradiological deaths in 40 yr of operation	0.5		
Occupational radiation dose to trenchworker, mrem/yr (% of DOE occupational limit)	≦ 500 (10%)		
Occupational radiation dose to maintenance worker during 5-yr active-maintenance (closure) period, mrem/yr (% of background)	10 (8%)	Comparable	Comparable
Occupational radiation dose during 100-yr institutional control period, mrem/yr (% of background)	4 (3%)		
LONG-TERM IMPACTS			
Maximum individual whole-body radiation dose to onsite resident, mrem/yr	375		
Maximum radiation dose to critical organ (bone) of onsite resident, mrem/yr	2500		
Maximum whole-body, individual radiation dose from drinking water supplied by Clinch River (50-yr commitment from 1 yr of ingestion), mrem/yr	0.08	Comparable	Comparable
Whole-body population dose from drinking water supplied by Clinch River, person-rem/yr	0.6		
Land use	Preemption of 64 ha (160 acres) of land from alternative uses	Greater	Slightly greater
Erosion of averaged slope of tumulus or trench after 500 years (agricultural use, worst-case scenario), meters	0.2	Comparable	Comparable

operation to ensure minimum ecological impact (Section 4.1.1.2.1, Appendix D, Section D.5.5).

Operational impacts include transportation of the wastes to the CWDF and disposal of these wastes. These impacts would also be the same for either design alternative. Radiological estimates of the maximum population exposure during routine transport, occupational exposure during disposal, and maximum individual exposure in the event of an accident--made on the basis of conservative assumptions--indicate that exposure risks would be very small compared with exposures from background radiation. Because of the low rate of waste shipments, injuries and fatalities due to transportation accidents would also be small (see Tables 2.2 and 2.3 and Section 4.1.2).

The assessment of long-term radiological impacts is more difficult and much less certain than the assessment of short-term radiological impacts. The potential releases of radionuclides or their transport pathways for nuclides over long-term periods are uncertain. The pattern of activities that determine the radiation dose received by the maximally exposed individual cannot be reliably predicted. Probabilities and times of occurrences for rare geologic events and for natural processes in the distant future cannot be accurately predicted. Simplifying assumptions must be introduced in order to estimate the long-term impacts; these assumptions must be conservative in order to obtain bounding estimates. The long-term radiological impacts were analyzed based on the conservative assumption that institutional controls are lifted 100 years after the site is closed and a breakdown of the integrity of the trench or tumulus cover and subsequent migration of the radionuclides to surface waters and groundwater occurs immediately afterward.

During the long term, if all controls ceased, the cover would continue to erode and would not be repaired. For the above-grade alternative, the cover is projected to erode about 2 m (7 ft) in 500 years and 3.4 m (11 ft) in 1000 years under the most erosive land use (an unlikely event). For the below-grade alternative, the cover is projected to erode about 0.2 m (0.7 ft) in 500 years and 0.7 m (2.3 ft) in 1000 years, also under the most erosive land use (Section 4.2.1.1).

The dominant long-term risk occurs for a scenario in which the site is released for unrestricted use 100 years after closure, failure of the trench or tumulus occurs immediately, and an individual builds a house on top of the trench or tumulus and lives in it. The maximum whole-body dose estimated for this onsite-resident scenario is 375 mrem/yr for a below-grade trench and 2300 mrem/yr for an above-grade tumulus (Section 4.2.3.2). The maximum bone dose (the critical organ) is 2500 mrem/yr and 6400 mrem/yr for trenches and tumuli, respectively. The estimate for tumuli is based on the unrealistic bounding assumption that all drinking water is obtained from Ish Creek; for the more realistic assumption that drinking water is obtained from a well, the maximum individual whole-body and bone doses for tumuli drop to 375 mrem/yr and 1100 mrem/yr, respectively.

With the exception of impacts to individuals residing onsite, the radiological estimates indicate that long-term impacts to the public from implementation of either design alternative would be relatively small compared to impacts attributable to natural background radiation (Section 4.2.3.3).

Long-term impacts can be reduced by extending the period of institutional control and continuing to monitor and take corrective actions, as needed. Impacts to a person drinking contaminated well or surface water can be mitigated by instituting controls against use of the well or surface water near the burial area.

The impacts for the below-grade trench are compared for the three sites in Table 2.3. Relative to short-term ecological impacts, the West Chestnut Ridge and Central Chestnut Ridge sites are considered to be equivalent because of the similarity of habitats present. Ecological impacts for the East Chestnut Ridge site are considered to be slightly less than those for either of the other two sites. This is based on the presence of more extensive areas of old-field habitat and pastures within the ECR site. Construction-related impacts would be less extensive on the ECR site because removal of trees would not be needed. Ecological concern over forest fragmentation (Section 4.1.1.2.1) would also be avoided.

It is expected that the transportation impacts (nonradiological and radiological) would be slightly less if the CWDF were sited at either the East Chestnut Ridge site or the Central Chestnut Ridge site rather than at the West Chestnut Ridge site. This is because the transportation risk for a given type of waste depends primarily on the truck-miles the waste is transported, and both Central Chestnut Ridge and East Chestnut Ridge are closer to Y-12 (Section 3.1), which has the largest waste fraction. It should be noted that the transportation analysis for the West Chestnut Ridge site shows that the radiological impacts are extremely low and small compared to fluctuations in background dose. Also, the accidents and resulting injuries and fatalities anticipated are extremely small.

Because the disposal activities carried out would be the same at all three sites, the occupational radiation dose associated with those disposal activities would be the same at all three Chestnut Ridge locations. The long-term radiological impacts for all three sites are considered to be equivalent because of the similarity of the geohydrological characteristics of all sites on Chestnut Ridge (Section 4.2.3).

Land use impacts would be greater for Central Chestnut Ridge and slightly greater for East Chestnut Ridge relative to West Chestnut Ridge. Over half of ECR and most of the eastern section of CCR are contained within the Y-12 security area. Much of the west and central sections of CCR are contained within the security area for ORNL. Extensive aquatic research areas exist throughout CCR. Additionally, an intensive research project, including atmospheric monitoring, is being conducted in the Walker Branch watershed on CCR. Construction activities, including dust emission, within several kilometers of the site could adversely affect this research. Terrestrial research areas are relatively uniformly dispersed throughout Chestnut Ridge. Two small natural areas exist within CCR, and a portion of WCR and most of CCR are contained within the U.S. Department of Energy Environmental Research Park (Section 4.3.3). As the soil types on all three sites of Chestnut Ridge are similar, the erosion rates would all be equivalent (Section 4.2.1.1).

Thus, comparison of the environmental impacts for the below-grade trenches at the preferred West Chestnut Ridge site with the impacts that would occur for the same design alternative at the alternative sites leads to the assessment that the overall environmental impacts would be comparable, and the alternative sites offer no obvious environmental advantage over the preferred site.

The no-action alternative is equivalent to a delayed-action alternative that requires interim storage of the wastes; hence, the radiological impacts would be greater by the magnitude of the impacts due to storage. The extra waste handling, maintenance of storage facilities, and monitoring would lead to significant cost increases and some increase in risk. No compensating advantages to offset the disadvantages of the no-action alternative have been identified (Section 4.4).

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3. AFFECTED ENVIRONMENT

3.1 SITE LOCATIONS AND CHARACTERISTICS

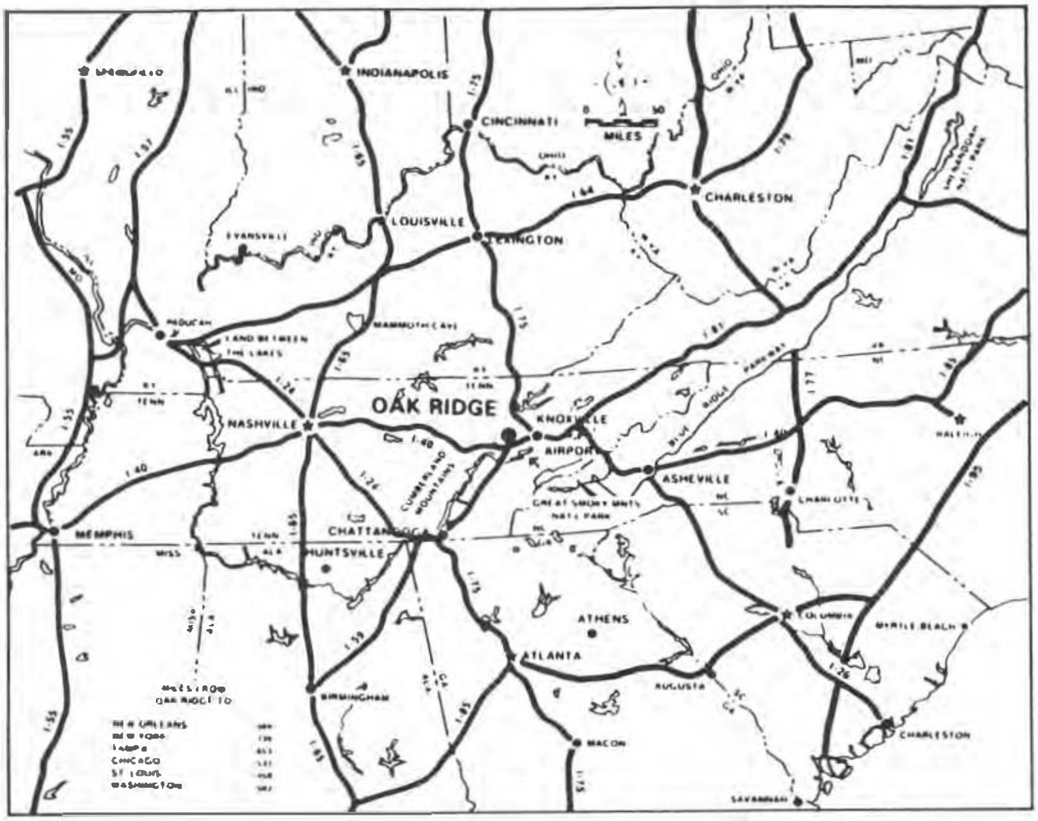
Two design alternatives and three sites have been identified for study and comparison based on the site-screening process discussed in Section 2.1. The preferred site alternative is on West Chestnut Ridge (WCR). The alternative sites are on Central Chestnut Ridge (CCR) and East Chestnut Ridge (ECR). The site characteristics of West Chestnut Ridge have been studied in several detailed investigations, including: areal geologic mapping, geomorphy observations, soil and bedrock investigations, soil geochemical and minerological analyses, geohydrologic testing, groundwater fluctuation monitoring, and surface water discharge and precipitation monitoring. Extensive data tabulations and detailed discussions of individual aspects of the site characterization of West Chestnut Ridge have been reported, and a synthesis of the information has been presented by Ketelle and Huff (1984). In the following sections, site characteristics pertinent to the evaluation of potential impacts to the environment for the three site alternatives are presented.

It should be noted that because West Chestnut Ridge is the preferred site, more detailed information on site characteristics is available. However, because the preferred site and the alternative sites are adjacent to each other, they share many of the same site characteristics. To the extent that they differ significantly and might affect the environmental impacts, these site characteristics of the alternative sites will be noted.

The preferred site, West Chestnut Ridge, and the two alternative sites, Central Chestnut Ridge and East Chestnut Ridge, are located in Oak Ridge, Tennessee (Figure 3.1)--which is about 68 km (40 mi) from the North Carolina border to the southeast, 115 km (65 mi) from the Georgia border to the south, and 76 km (45 mi) from the Kentucky border to the north. The city of Oak Ridge is about 14 km (8 mi) to the northeast of the site, and the city of Knoxville is about 42 km (25 mi) to the east.

The preferred site, including a buffer zone, covers an area of approximately 508 ha (1253 acres) on West Chestnut Ridge within the DOE Oak Ridge Reservation (ORR)--bounded by Bear Creek Road to the north, Tennessee Highway 95 to the east, and New Zion Patrol Road to the south and west (which is a restricted access DOE patrol road). The preferred site (Figure 3.1) is approximately 3 km (2 mi) from Oak Ridge National Laboratory (ORNL), 13 km (8 mi) from the Y-12 Production Plant (Y-12), and 5 km (3 mi) from the Oak Ridge Gaseous Diffusion Plant (ORGDP); it is easily accessible by the roadway system surrounding the site area.

Prior to conversion of the area to a federal reservation, the WCR site was wooded and undeveloped except as farmland. In the 40-year period since the ORR was converted for federal use, the WCR site has remained essentially



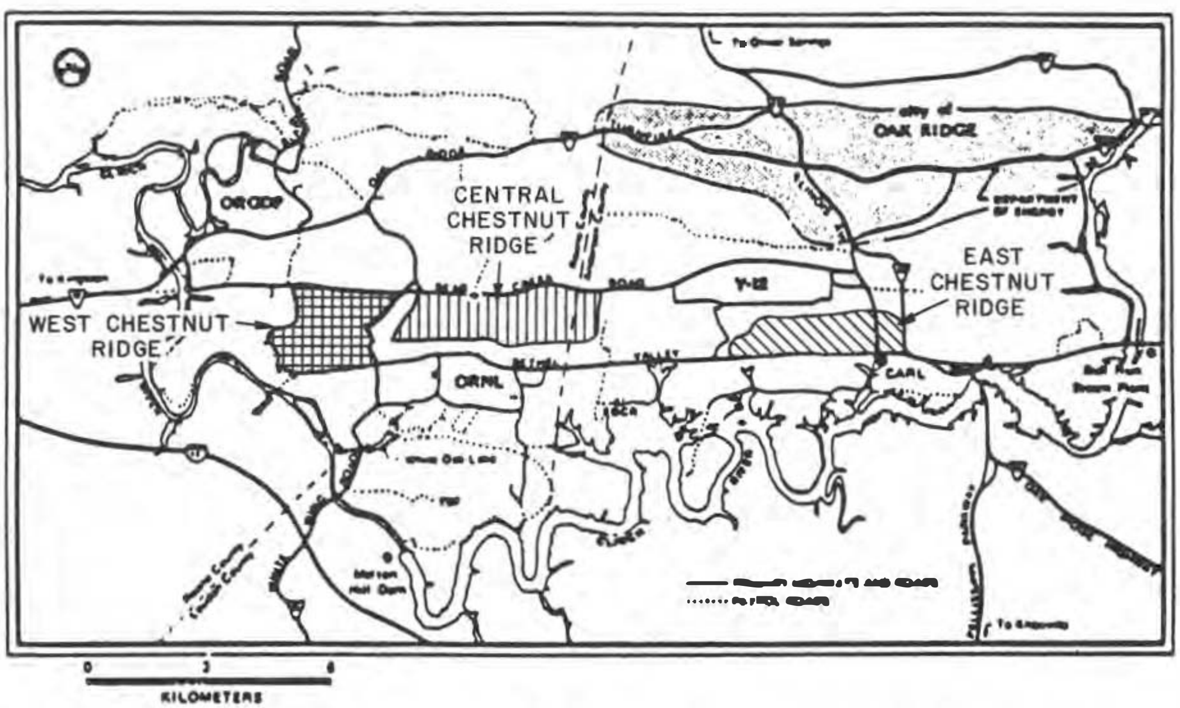


Figure 3.1. Location of Oak Ridge and the Chestnut Ridge Sites. Source: Adapted from Boyle et al. (1982) and Ketelle and Huff (1984).

wooded and undeveloped, except for upgrading of the New Zion Patrol Road and of minor roads that traverse the site. Secondary forest growth has occurred upon most of the land that was farmed. A portion of the Oak Ridge National Environmental Research Park occupies more than half of the WCR site (Boyle et al. 1982).

The CCR alternative site, including a buffer zone, covers a generally rectangular area of about 80 ha (200 acres) on Central Chestnut Ridge within ORR. It is bounded by Bear Creek Road to the north, Bethel Valley Road to the south, Tennessee Highway 95 to the west, and the White Oak Creek watershed divide to the east. The CCR alternative site is adjacent to ORNL, approximately 7 km (4 mi) from Y-12, and 7 km (4 mi) from ORGOP. It is accessible by the roadway system in the area. The CCR site is located along the central portion of Chestnut Ridge on the ORR, and has remained wooded since the ORR was converted for federal use. Secondary forest growth has occurred on most of the land that was farmed prior to federal ownership. The site is within the Oak Ridge National Environmental Research Park (Boyle et al. 1982).

The ECR alternative site is located on East Chestnut Ridge within the ORR. It is bounded by Y-12 and Union Valley Road to the north, Bethel Valley road to the south, the McCoy Branch watershed divide to the west, and the Scarboro Creek watershed divide to the east. The ECR site is located adjacent to Y-12, approximately 8 km (5 mi) from ORNL, and 13 km (8 mi) from ORGOP. Over 50% of ECR consists of pastures and old fields, with the remainder consisting of wooded habitat. East Chestnut Ridge is part of the security area for Y-12, and contains a classified disposal area.

3.2 GEOLOGY AND SEISMOLOGY

3.2.1 Site Topography

Chestnut Ridge is located in the Appalachian Highland Physiographic Division of the eastern United States. Within the division, areas of distinctively different lithology, stratigraphy, structure, and geomorphic history are divided into physiographic provinces (Figure 3.2).

The sites are located in the Valley and Ridge physiographic province, between the Blue Ridge province to the east and the Cumberland Plateau, part of the Appalachian Plateau physiographic province, to the west. This subregion is characterized by a series of northeast-southwest trending ridges and valleys that have formed by the combined influences of the regional geologic structure and weathering and erosional processes. The long, narrow ridges are breached at irregular intervals by stream channels that otherwise follow the trend of the valleys. The valleys have been eroded in areas underlain by the less resistant limestone and shale strata.

Topography in the area is typical of topography in other Knox Group outcrop belts of the northwestern portion of the Valley and Ridge province. Surface elevations in the area (Figure 3.3) range from about 226 m (740 ft) MSL at the Clinch River to about 329 m (1080 ft) MSL at the summit of the Chestnut Ridge (Tenn. Val. Auth. 1974; Ketelle and Huff 1984). The difference in elevation between the top of a ridge and the base of the adjacent valley is typically about 60 m (200 ft). Generally, the northwest slopes of the ridges

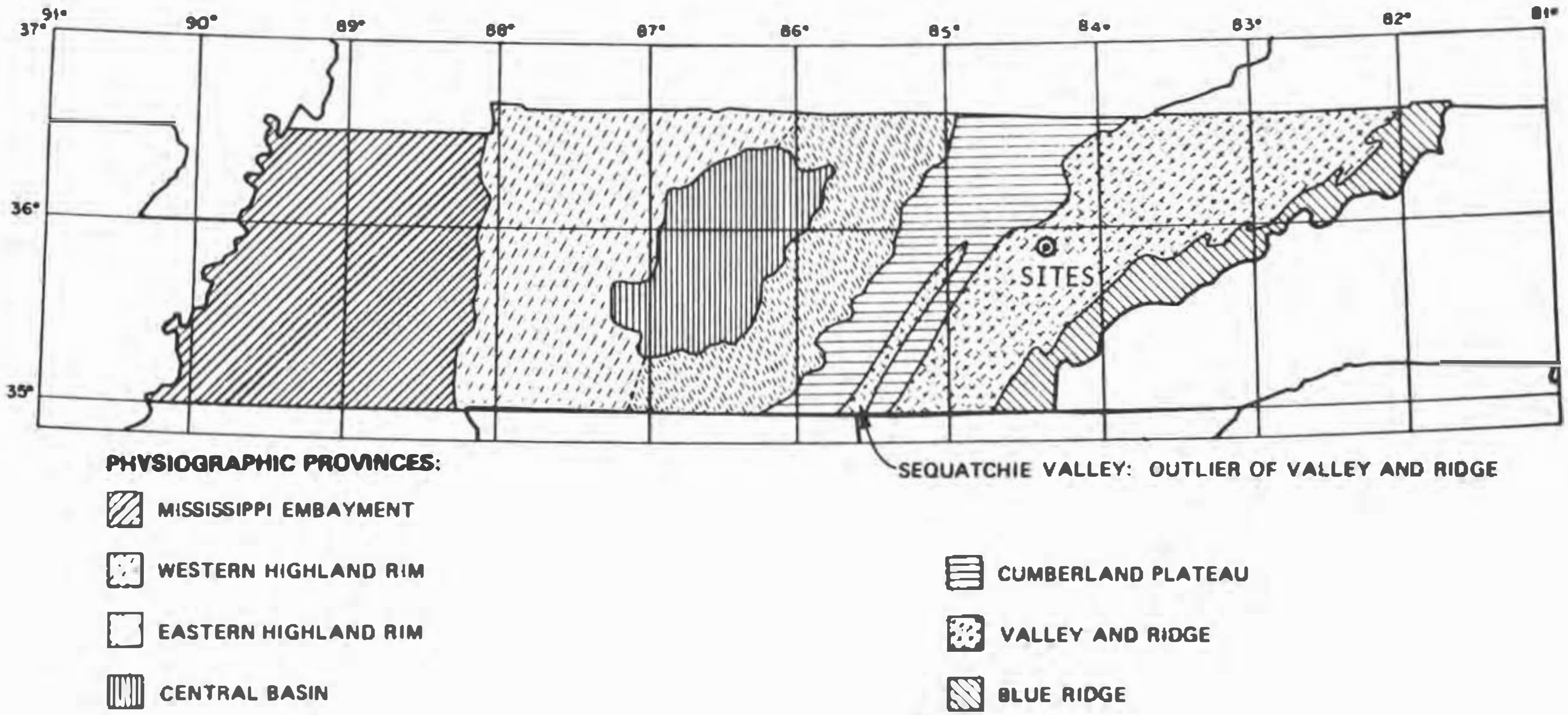


Figure 3.2. Physiographic Map of Tennessee.
Source: Boyle et al. (1982).

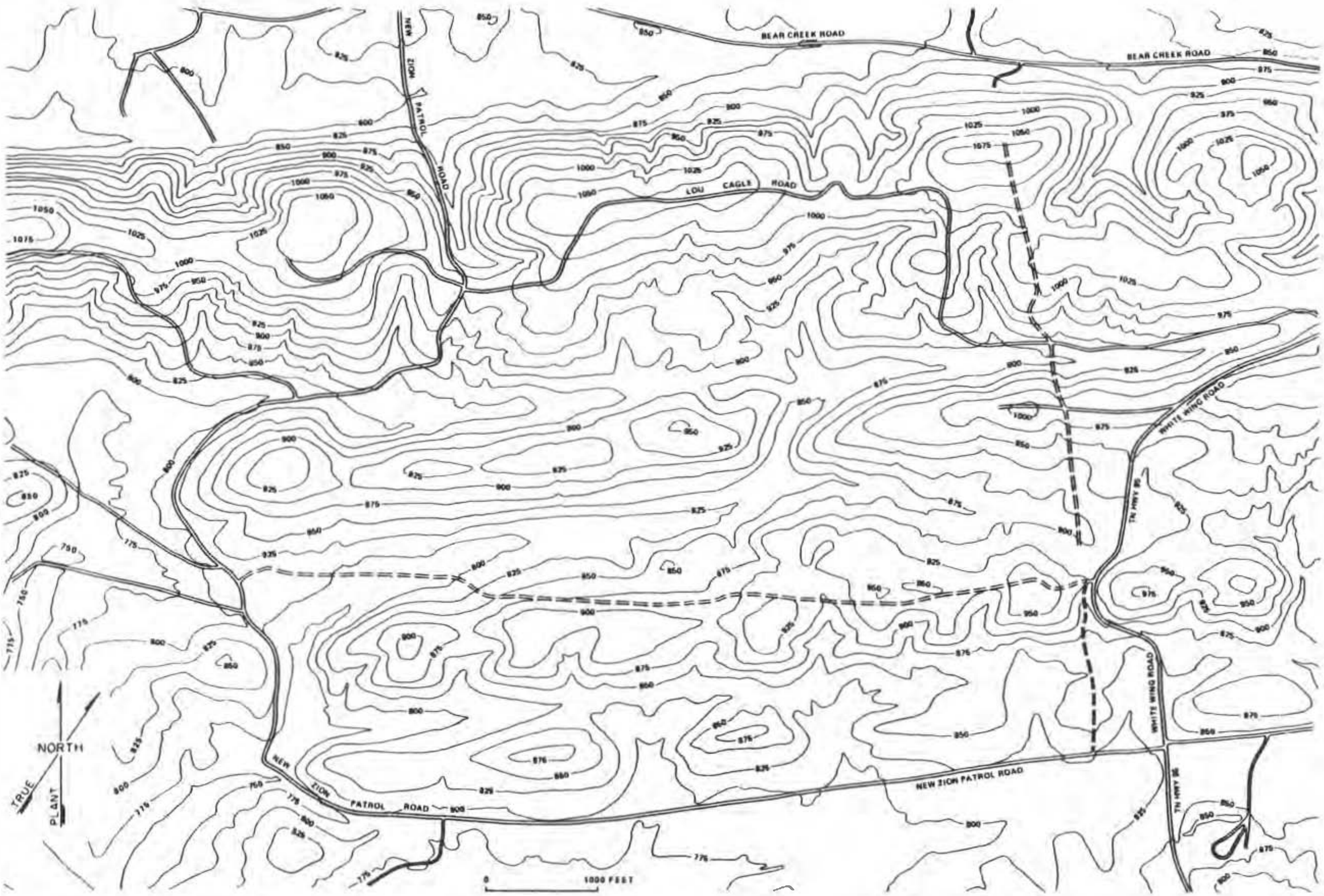


Figure 3.3-a. Topography of the West Chestnut Ridge Site.
Source: Ketelle and Huff (1984).

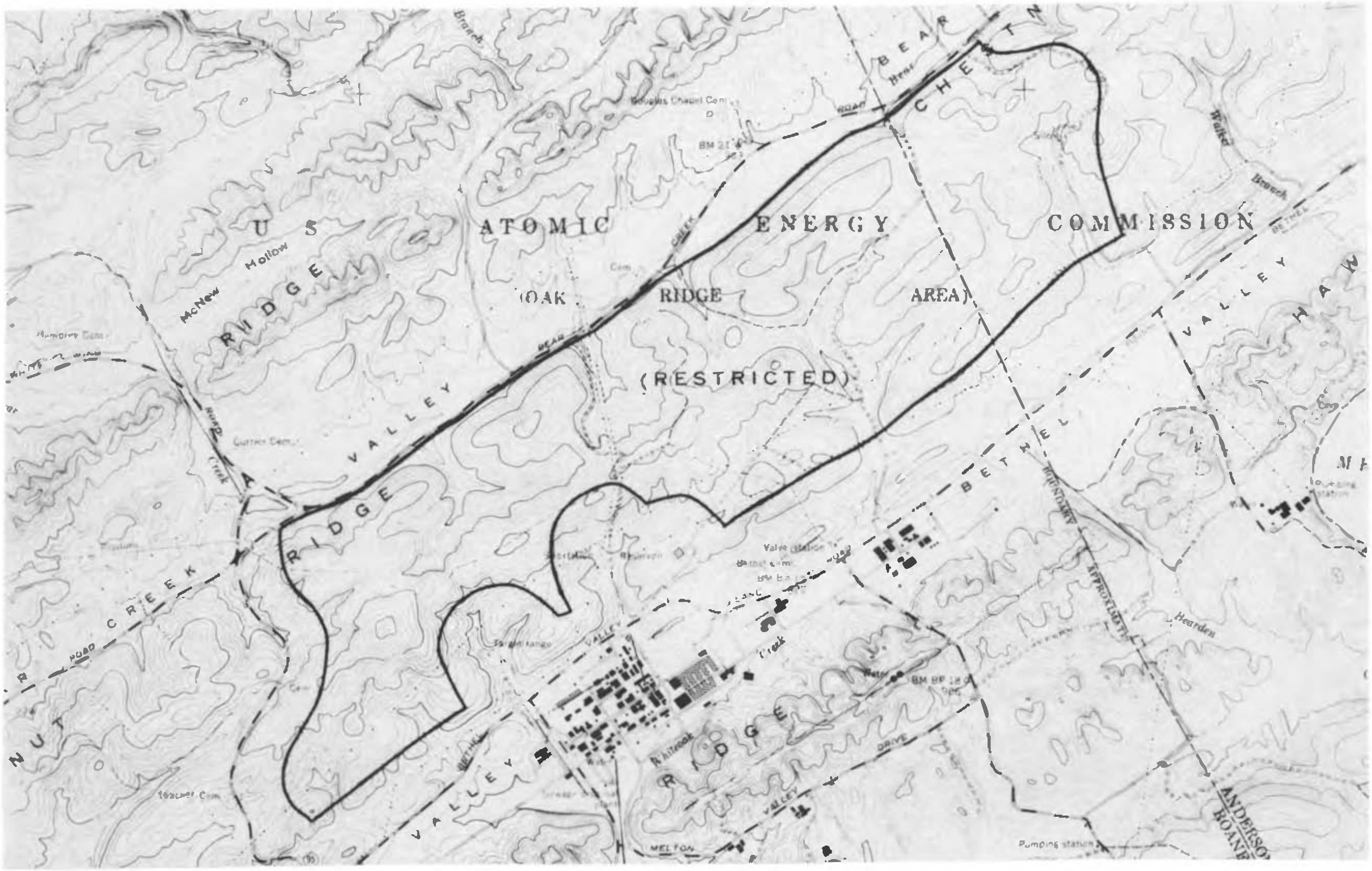


Figure 3.3-b. Topography of the Central Chestnut Ridge Site.

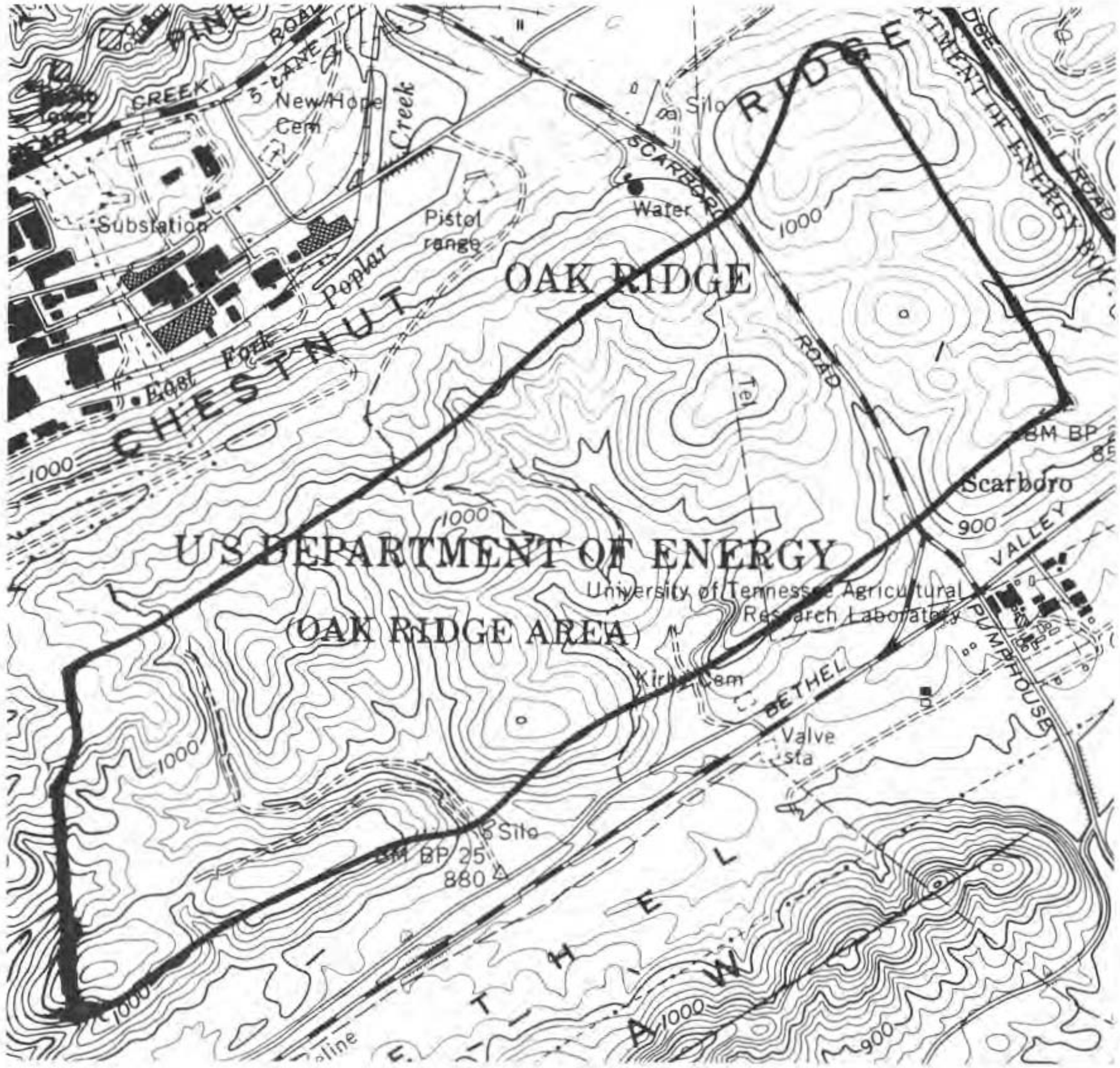


Figure 3.3-c. Topography of the East Chestnut Ridge Site.

and valleys are steeper than the southeast-facing slopes because of the southeasterly dipping strata that underlie the area.

3.2.2 Soils and Geology

Several investigations (Woodward-Clyde 1984; Lee et al. 1984; Daniel and Broderick 1983; Seeley and Kelmers 1984; Ketelle and Huff 1984) have been conducted at the WCR site to determine the soil characteristics. The results of these investigations are summarized as follows. The typical soil types of the Valley and Ridge province, as in much of the Southeast, are red-yellow podzols, reddish-brown laterites, or lithosols. The soils have been derived from insoluble fractions of the parent bedrock--clay minerals, chert, and quartz sand--and are predominantly clay with traces of some fine to coarse sand and chert gravel. Minor amounts of silts and clayey sands and gravels have also been encountered. The soils are usually moist, strongly leached, acidic, and low in organic content, and they have high sorption and ion-exchange capacities. Local soils within the area generally exhibit a wide range of both physical and chemical properties.

The thickness of the soil on West Chestnut Ridge site is typically 24 m (80 ft), but it is often as small as 3 m (10 ft) or as large as 49 m (160 ft) (Woodward-Clyde 1984). In general, the thinner soil layers are found at the lower ground surface elevations and the thicker soil layers at the higher ground surface elevations. Water moisture content in the soil is generally less than 20% near the ground surface and increases to about 40% at a depth of about 27 m (90 ft). The degree of saturation, which is defined as the ratio of the volume of water to the volume of pores, ranges from about 50 to 95% in the upper 3 m (10 ft) of soil and about 95% at depths below 3 m (10 ft) (Daniel and Broderick 1984). These values are typical of fine-grained soils. Results of sampling and testing of areal soils indicated that soils near the surface are generally overconsolidated and have high bearing strength (Woodward-Clyde 1984). As depth increases, soils become normally consolidated. The average unit weight of the soils is about 1890 kg/m^3 (118 lb/ft^3). Field-test data indicate that permeability of the soils varies over short distances and decreases as the depth increases.

Based on preliminary data, the soil thickness at the CCR site is comparable to WCR. The general expectation is that at the ECR site the overburden in the copper ridge formation (Knox Group) will be thick.

The average permeability of the residual soils is about 6×10^{-6} cm/s (2.4×10^{-6} in./s) in the upper 3 m (10 ft), and it decreases to about 6×10^{-8} cm/s (2.4×10^{-8} in./s) at depth in excess of 20 m (65 ft) (Woodward-Clyde 1984; Ketelle and Huff 1984). However, the engineering geology of the WCR site suggests that layers of relatively pervious soils with permeability of 5×10^{-4} cm/s (2×10^{-4} in./s) away be present within the residual soils (Woodward-Clyde 1984; Ketelle and Huff 1984).

The bedrock that is exposed over most of the ORR consists of nearly 2,400 m (8,000 ft) of Lower and Middle Paleozoic sandstones, siltstones, shales, and cherty carbonates. Folding and faulting of these units during the late Paleozoic Era resulted in the alteration of these rock types and the creation of an imbricate pattern of units inclined like shingles to the southeast (Figure 3.4). Subsequent differential erosion of these units resulted in

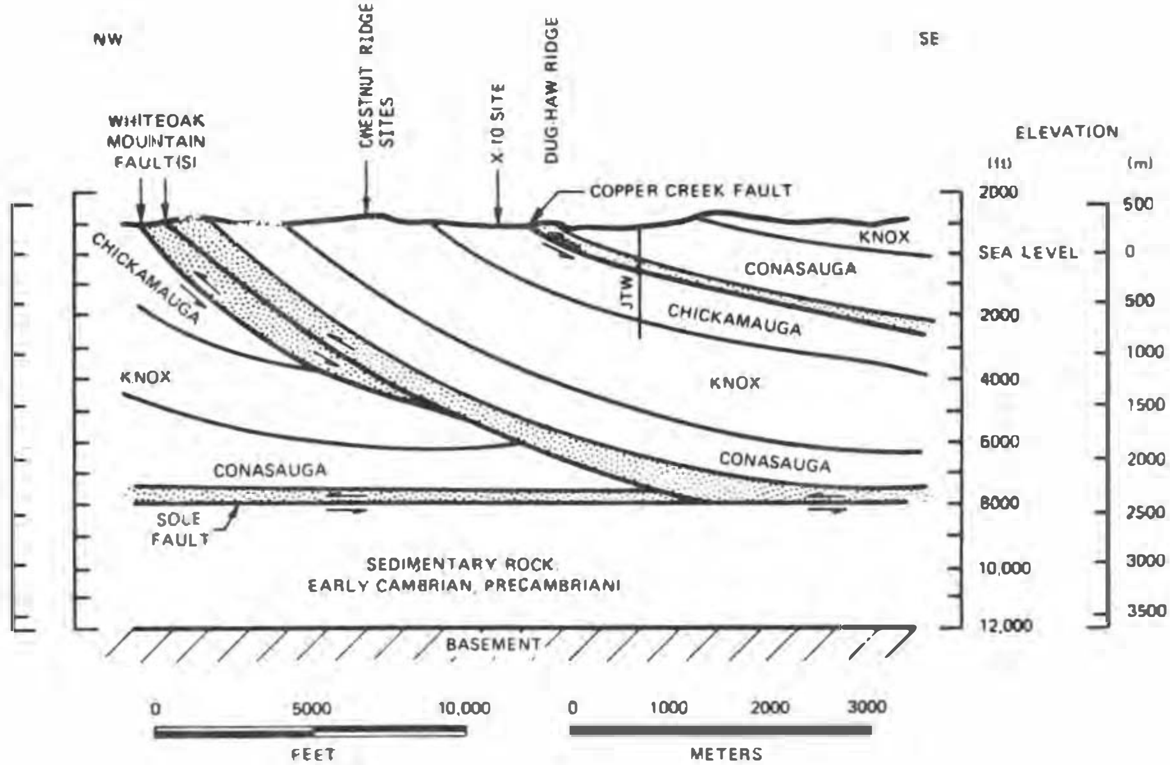


Figure 3.4. Geologic Cross Section of the Chestnut Ridge Sites. Source: Adapted from Boyle et al. (1982).

the trellis drainage pattern and the ridge and valley topography (Boyle et al. 1982). In general, the ridges in the Oak Ridge area are formed by the Rome and Knox Group formations and the valleys are underlain by the Conasauga and Chickamauga groups (Figure 3.5). Detailed descriptions of these rock units are presented in an ORNL report (Boyle et al. 1982). Figure 3.5 also shows the location of the two major thrust faults in the area, which are discussed in Section 3.2.3.

Chestnut Ridge (West, Central and East sites) is underlain by the Knox Group, primarily cherty dolomites of Cambrian and Ordovician Age. The Bethel Valley to the south is underlain principally by limestones and shales of the Ordovician Chickamauga Group. Bear Creek Valley immediately north of Chestnut Ridge is underlain by calcareous shales and interlayered limestones and siltstones of the Conasauga Group (Figure 3.5).

Although the Knox Group formation has a low permeability and porosity in the unweathered state, this group is susceptible to solutioning--especially along fractures caused by folding and faulting. Karst features observed on West Chestnut Ridge include solution planes, dolines, disappearing streams, swallow holes, and sinkholes. Location of karst features that are evident at the ground surface are shown in Figure 3.6 for the West Chestnut Ridge site (Ketelle 1982; Ketelle and Huff 1984). The karst features appear to have formed over five major stratigraphic horizons in bedrock that are undergoing

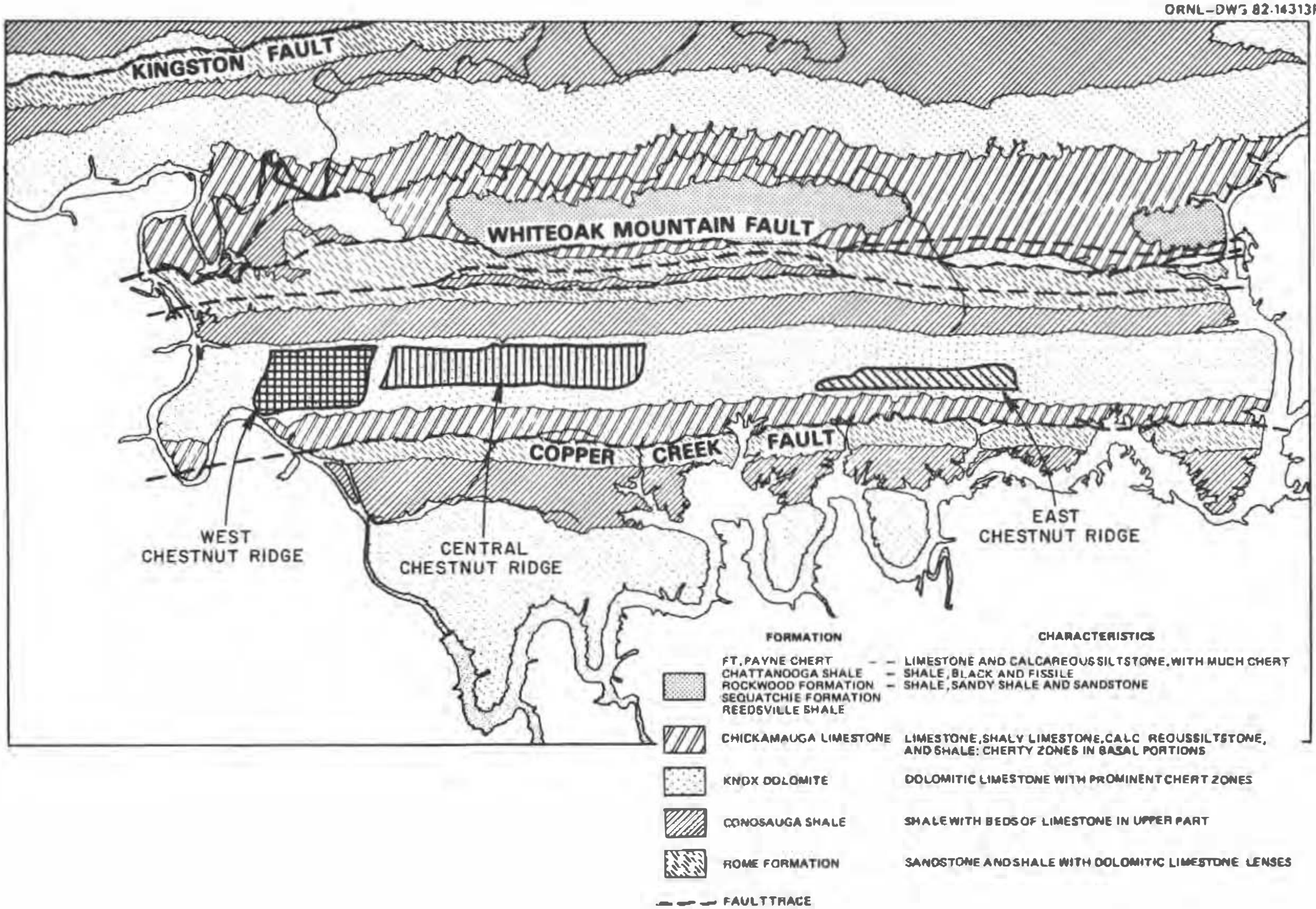


Figure 3.5. Map Showing the Geologic Formations and Major Fault Zones at the Oak Ridge Reservation. Source: Boyle et al. (1982).

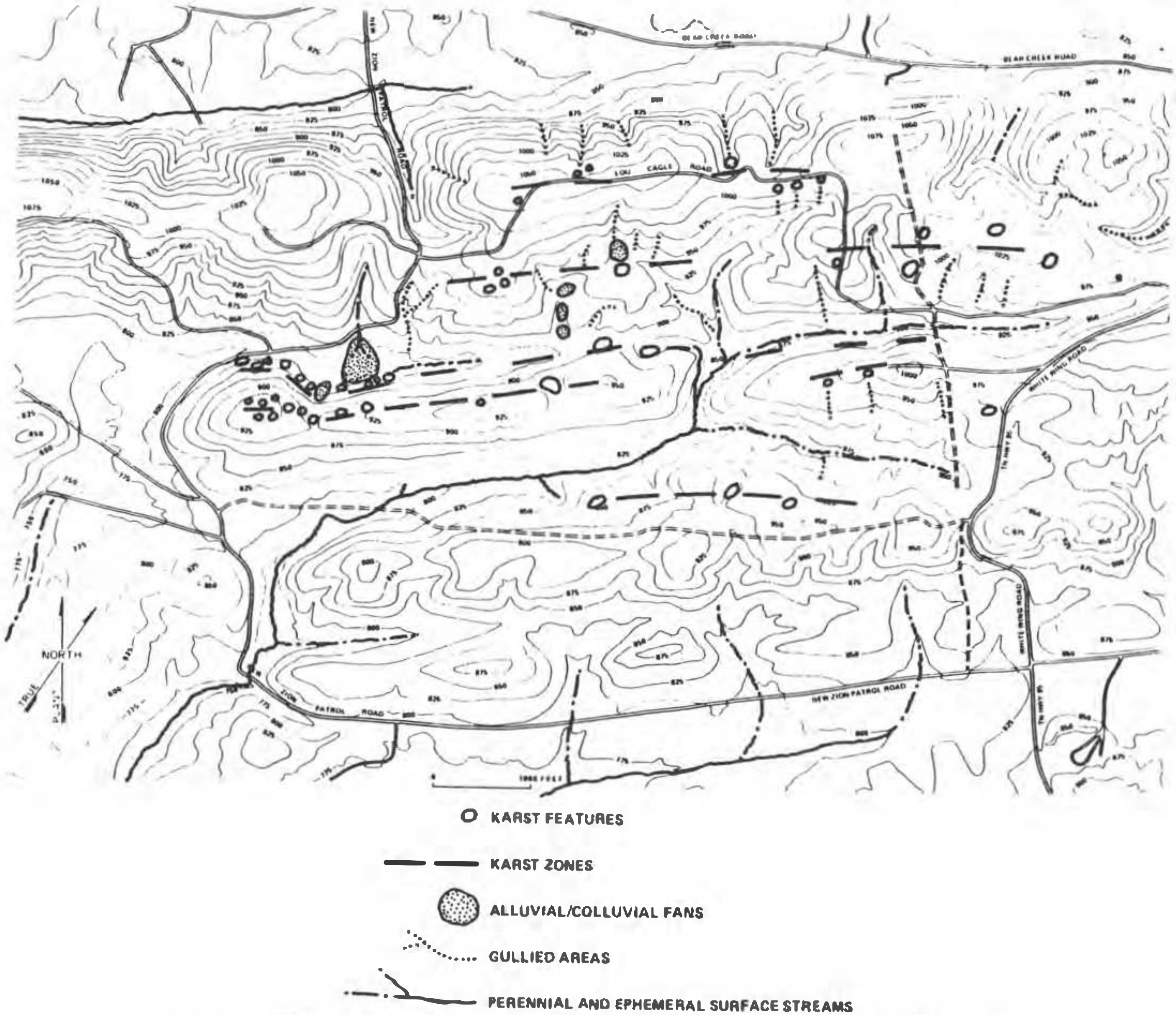


Figure 3.6. Geomorphic Features on the West Chestnut Ridge Site.
Source: Ketelle and Huff (1984).

gradual dissolution. These horizons are generally oriented parallel to the strike of the bedrock and occur principally on the north sides of slopes in Chestnut Ridge. The karst features for East Chestnut Ridge have been obscured by agricultural and land clearing activities.

The Knox dolomite is generally solid and massive where unweathered, but its transmissivity has been considerably increased in some places by fracturing. Sinkholes and caverns have been formed by enlargement of the fractures by dissolution. Results from pumping-well tests at WCR indicate that transmissivity for weathered rock is approximately 1.3 m^2/day (14 ft^2/day) (Woodward-Clyde 1984). The corresponding average permeability would be about 2×10^{-4} cm/s (8×10^{-5} in./s). The permeability for unweathered rock, which is generally found at depths exceeding 61 m (200 ft), would be about 1×10^{-4} cm/s (4×10^{-5} in./s) (Woodward-Clyde 1984; Ketelle and Huff 1984).

Although comparable data are not available for the Central and East Chestnut Ridge sites, the underlying formations are similar and thus there is no reason to believe that conditions would be significantly different from those at West Chestnut Ridge.

3.2.3 Seismology

Based on the historic distribution of Modified Mercalli (MM) intensities associated with known seismic events in the United States, the U.S. Coast and Geodetic Survey designates eastern Tennessee as having a Zone 2 seismic risk, which implies the potential for moderate damage from earthquakes (Algermissen 1969). This region lies within the Southern Appalachian Seismo-Tectonic Province, which is characterized by a series of northeast-to-southwest-trending folds and thrust faults in Paleozoic rocks.

The ORR is crossed by two major thrust faults: the Copper Creek fault in the southeastern part of the Reservation, and the Whiteoak Mountain fault in the northwestern part (Figure 3.5). The strata and the faults dip to the southeast at angles commonly between 30° and 40°. The Copper Creek Fault extends northeastward across the entire width of ORR, bringing the Rome formation to the surface throughout its length. The Whiteoak Mountain fault in the Oak Ridge area exhibits several subsidiary features including branch faults, a syncline northwest of the fault, and two disturbances of the Knox Group dolomite sequence. The nearest trace of the Whiteoak Mountain fault system is 0.3 km (0.2 mi) northeast of the site. Data from outcrops and deep boreholes in the vicinity of the site indicate that the Whiteoak Mountain fault and its subsidiaries are deeper than 610 m (2700 ft). No evidence of post-Paleozoic activity associated with these faults has been found (U.S. Nucl. Reg. Comm. 1977, 1982). Generally, no correlation between the minor seismic activity occurring in the region and known tectonic structures has been confirmed.

Based on the epicenters and intensities of all major recorded earthquakes within a 320-km (200-mi) radius of ORNL, the probabilities and intensities of seismic events for the ORR have been determined (U.S. Dept. Energy 1980; Beavers et al. 1982; Fitzpatrick 1982). The maximum earthquake for the region (an event with a 16% probability of occurring once in 50 years) was predicted as having a maximum acceleration of 15% g, an intensity of VI to VIII MM, and a Richter magnitude of 4.7.

3.3 HYDROLOGY

3.3.1 Surface Water

Water that drains from the ORR enters the Clinch River and is subsequently conveyed to the Tennessee River (Figure 3.7). The Tennessee River is the eighth largest in the United States and drains an area of about 105,000 km^2 (40,900 mi^2). The Clinch River is the source of most water used in the Oak Ridge area. From it are drawn supplies for Clinton, Oak Ridge, and DOE facilities. The only water intakes on the Clinch River downstream of the WCR site are those near the K-25 plant. Wastewaters from these areas are discharged to the Clinch River.

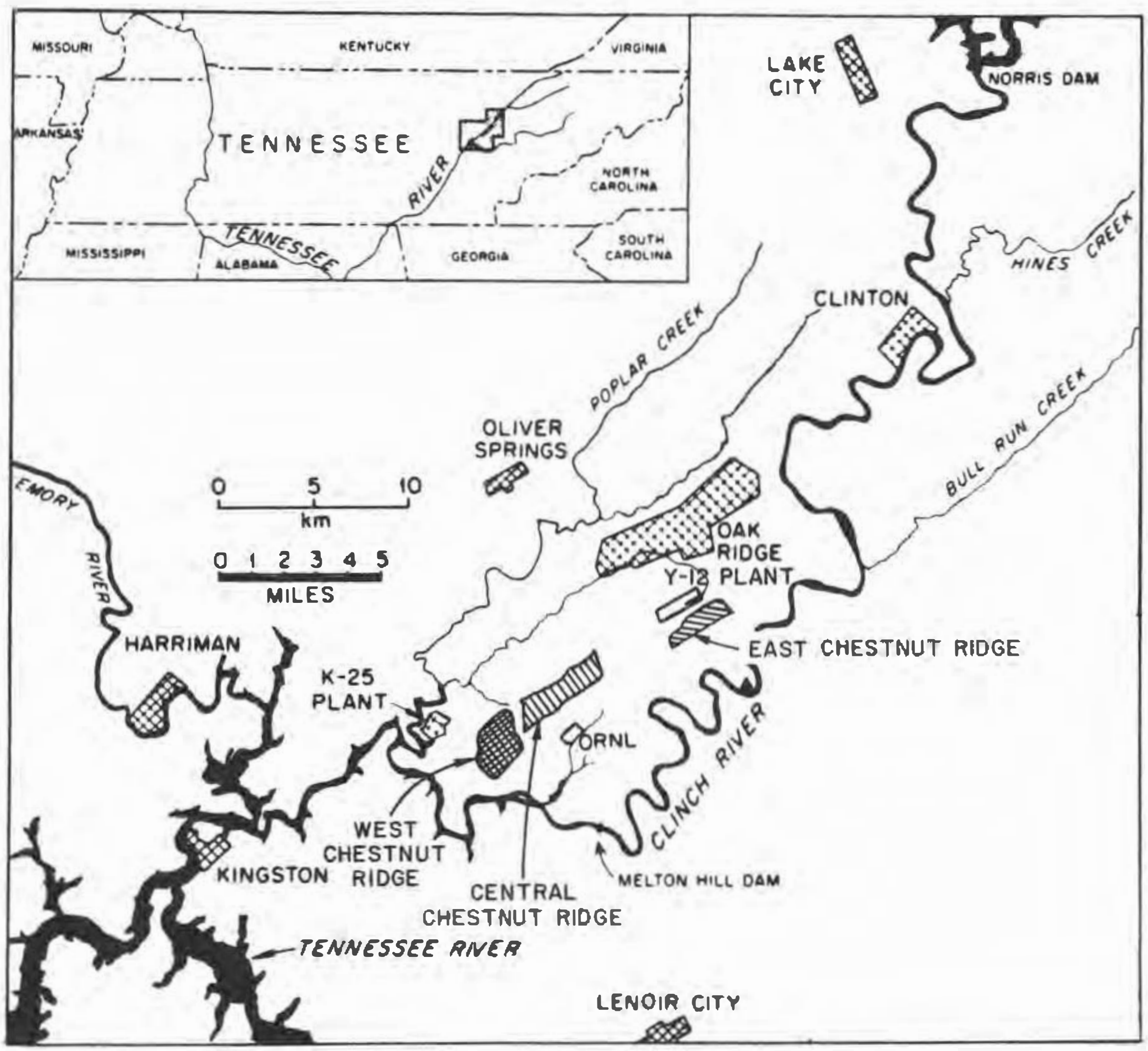


Figure 3.7. Surface Waters of the Oak Ridge Area.
Source: Adapted from Boyle et al. (1982).

The area around Chestnut Ridge is drained by some smaller creeks, all of which are tributaries of the Clinch River (Figure 3.8). Ish Creek, which is the main stream within the WCR site, drains the central and northeastern sections of that site. Water in the creek flows to the Clinch River to the south of the site area. New Zion Creek, which is a disappearing stream (a stream that flows into a bedrock cavity system), receives runoff from the western part of the site. The northern part of Chestnut Ridge is drained by a series of fairly steep, short valleys that are tributary to Grassy Creek. Grassy Creek flows southwesterly into the Clinch River.

The area around Central Chestnut Ridge is also drained by smaller streams that are tributaries of the Clinch River. White Oak Creek drains most of the site and flows south through the ORNL facility before discharging to the Clinch River downstream of the Melton Hill Dam. Portions of the central and eastern sections of the CCR site are drained by Bearden Creek and Walker Branch, which flow south and discharge to the Clinch River above Melton Hill Dam. The northern part of the site is drained by minor tributaries of Bear Creek. Bear Creek flows west before discharging to Popular Creek and the Clinch River at the ORGDP.

The area around East Chestnut Ridge is also drained by small tributary streams of the Clinch River. Kerr Hollow Branch and Scarboro Creek flow east and south through ECR, respectively. They are the principal drainages in ECR. The two streams have their confluence at an embayment area of the Clinch River. The western portion of the ECR is drained by McCoy Branch, which flows south and discharges to the Clinch River above Melton Hill Dam.

Clinch River flow is principally regulated by Norris Dam, located about 90 river km (55 river mi) upstream from the preferred site. However, the immediate influence on river flow in the site vicinity is Melton Hill Dam, which is located about 8 river km (5 river mi) upstream from the WCR site. The annual average flow below the Melton Hill Dam is about 132 m^3/s (4,651 cfs) (Lowery et al. 1983). The maximum hourly average release was 1230 m^3/s (43,400 cfs), and the maximum daily average release was 760 m^3/s (26,900 cfs). River flow in the site vicinity can be upstream, downstream, or quiescent, depending on the mode of operation of dams on the Clinch and Tennessee rivers. Through controlled discharges, the dams have greatly reduced the potential for flooding. The Tennessee Valley Authority has conducted studies relative to flooding within the Oak Ridge area (U.S. Dept. Energy 1980). These studies can be used to evaluate potential flood hazards to the proposed disposal site at West Chestnut Ridge. The flood-prone areas--based on regulation of discharges through Norris, Melton Hill, and Watts Bar dams--are shown in Figure 3.9 (U.S. Dept. Energy 1980). The proposed disposal facility, which would be located at the minimum elevation of 244 m (800 ft) MSL, is not in a floodplain at the preferred site or either of the two alternative sites.

In July 1982, six streamflow gaging stations were established on Ish Creek and one on a small tributary to Grassy Creek (Figure 3.8) (Huff et al. 1983). In September 1983, permanent weirs and automatic recording equipment were installed at three sites (Stations 1, 3, and 4) on Ish Creek, at the site (Station 7) on the Grassy Creek tributary, and at an additional station (on New Zion Creek, which is a disappearing stream (Figure 3.7) (Elmore et al. 1983). Flow data collected from all the stations are useful in characterizing the hydrologic condition at the WCR site. The time-weighted annual mean flows

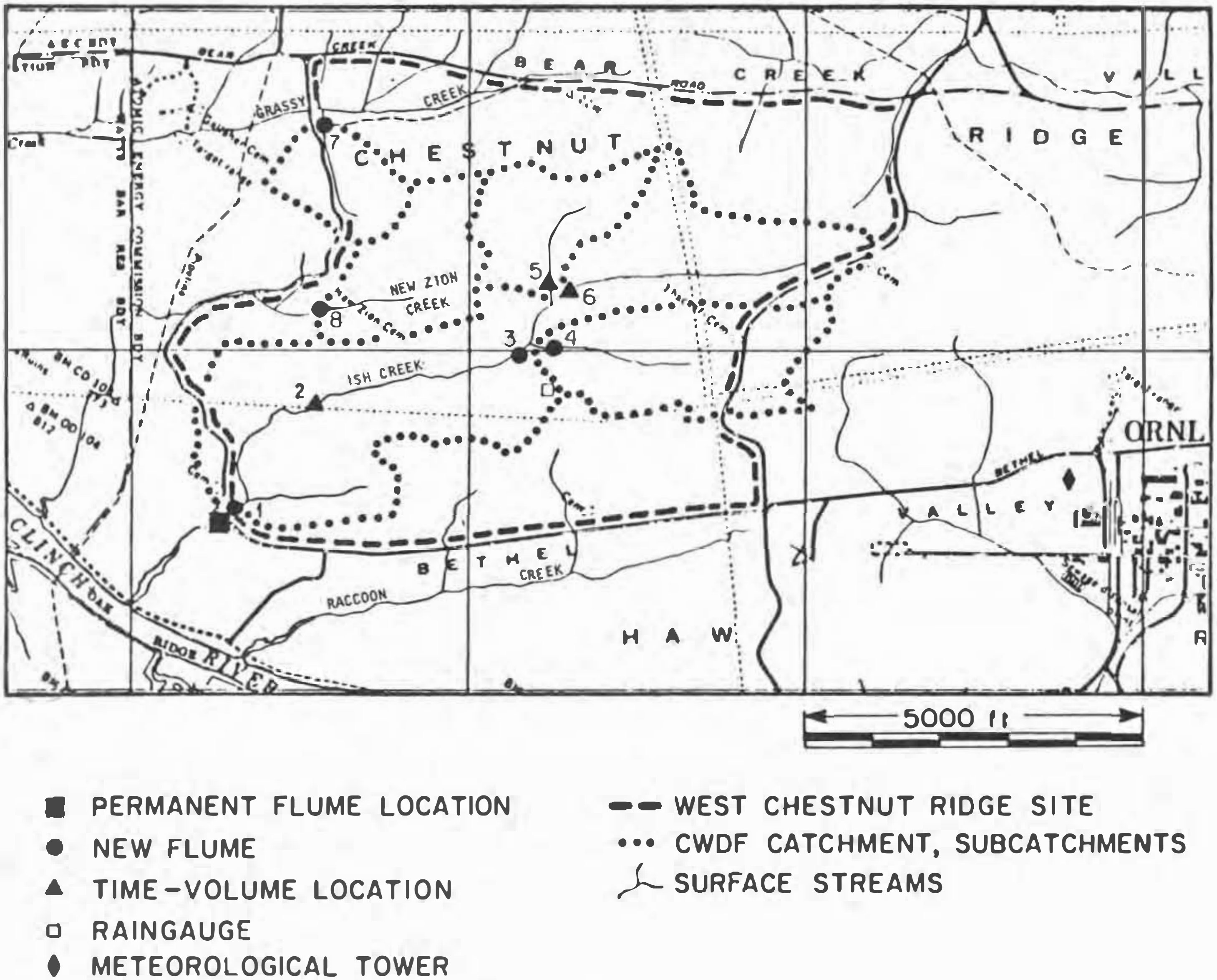


Figure 3.8. Location of Streamflow Gaging Stations on the West Chestnut Ridge Site. Source: Adapted from Elmore et al. (1983).

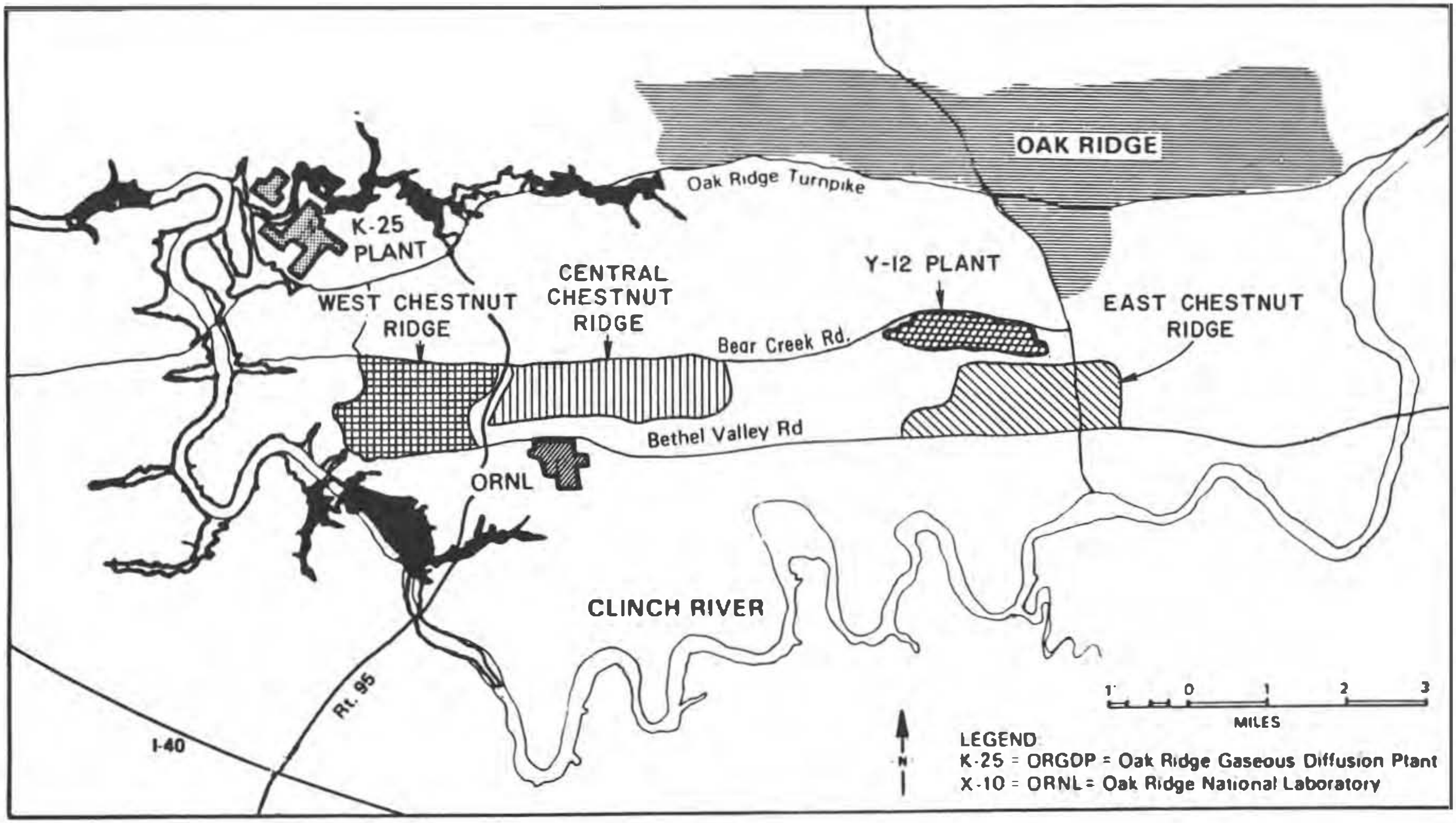


Figure 3.9. Flood Hazard Potential in the Chestnut Ridge Area.
Source: Adapted from Alexander (1979) and U.S. Energy Research and Development Administration (1975a).

at all gaging stations (Elmore et al. 1983) are summarized in Table 3.1. It should be noted that time-weighted averages refer to the assumption that each measurement represents the average flow rate for approximately two weeks. Because these values generally do not represent storm events adequately, they are best used for relative comparisons among sites. They generally underestimate total flows.

Table 3.1. Time-Weighted Annual Mean Flows at Ish Creek Gaging Stations

Station	Annual Mean Flow (L/s) 15 Jul 82 - 11 Jul 83	8 Oct 82 - 30 Sep 83
1	38.9	39.1
2	21.8	21.9
3	14.0	14.0
4	3.2	3.1
5	1.9	1.9
6	3.9	3.9
7	1.6	1.6

Source: Elmore et al. (1983).

In general, the water quality of the Clinch River and most of its tributaries is highly turbid, moderately hard, and slightly basic. The surface water in the vicinity of the ORR has been routinely monitored through the use of a network of stream sampling points and by sampling the point-source discharges into the stream. Water samples are collected in the Clinch River for analysis of both radioactive and nonradioactive substances. Data on radioactive and chemical concentrations measured in the river are presented in reports of Boyle et al. (1982) and Union Carbide Corporation (1983).

Results of the sampling analysis indicate that the levels of pollution by both radioactive and chemical substances are relatively low. The average concentration of radionuclides in the Clinch River was determined to be less than one percent of the applicable concentration guide for uncontrolled areas (Union Carbide Corp. 1983). Analysis of nonradioactive substances indicates that the average concentrations of most substances were in compliance with water quality guidelines. However, the concentrations of cadmium, copper, iron, lead, mercury, nickel, silver, and zinc exceed the EPA criteria for protection of aquatic life and the average concentrations of iron and manganese exceed drinking water standards (Boyle et al. 1982; Union Carbide Corp. 1983).

Only limited sampling has been conducted on Ish Creek and on a tributary to Grassy Creek to characterize water quality. Two sets of data, representing low-flow and high-flow conditions, are available. Measurements of pH, temperature, conductivity, and dissolved oxygen are presented in Table 3.2. No sampling of the headwater of White Oak Creek, Bearden Creek, or the minor tributaries of Bear Creek that drain through CCR have been performed. White Oak Creek is routinely monitored downstream of ORNL, where incidents of significant pollution have been detected and documented (Boyle et al. 1982). ORNL has been issued a notice of non-compliance by the state of Tennessee (October 26, 1983) and is engaged in a program of corrective action to bring ORNL in compliance with existing recommendations. No recent monitoring of the streams in ECR have been conducted.

Table 3.2. Values of Physicochemical Variables at Ish Creek Gaging Stations

	Water Temperature (°C)		Conductivity (μS/cm)		pH		Dissolved Oxygen (mg/L)
Station	4/18/83	9/11/83	4/18/83	9/11/83	4/18/83	9/11/83	4/18/83
1	9.6	21.5	125	282	7.5	7.1	-
2	10.1	20.5	92	229	6.7	7.3	-
3	11.7	23.4	50	164	6.3	7.2	-
4	10.5	21.3	63	27	6.5	6.3	8.1
5	11.1	21.7	66	54	6.5	7.0	-
6	10.5	22.3	26	41	5.9	6.0	-
7	10.6	18.4	195	288	8.4	7.4	-

Source: Elmore et al. (1983).

The use of surface water in the ORR area includes withdrawals for industrial and public supplies, as well as commercial and navigation activities, and recreational activities such as fishing and swimming. Three pumping stations are located on the Clinch River downstream of the WCR site. Makeup water for the ORGDP recirculating cooling system is withdrawn at River Kilometers (RK) 11.5 and 13 [River Miles (RM) 18.5 and 21.1]. None of this water is used for potable purposes. At RK 14.5 (RM 23.3), 0.13 m^3/s (2.85 Mgd) of water is withdrawn for potable and process purposes at ORGDP. This intake is about 8 km (5 mi) downstream of the confluence of Ish Creek and Clinch River.

There are nine public water systems serving about 91,500 people that withdraw surface water within a 32-km (20-mi) radius of the WCR site (Boyle et al. 1982). Of these nine systems, only Kingston (population 4,440) is downstream of the Ish Creek discharge point. The intake for Kingston is located on the Tennessee River at RK 914.2 (RM 568.2), about 0.6 river km (0.4 river mi) above the confluence of the Clinch and Tennessee rivers and about 33.3 river km (20 river mi) below the Ish Creek discharge point. The average withdrawal rate at Kingston is about 0.014 m^3/s (0.31 Mgd).

3.3.2 Groundwater

In the Valley and Ridge physiographic province of Tennessee, groundwater generally occurs either in bedrock formations or in residual soil accumulations near the bedrock surface. Alluvial aquifers are of minor importance in the region. Porosity in the shales and carbonate rocks that predominate the region is attributed to fractures and solution cavities. The volume of groundwater storage and discharge varies widely from aquifer to aquifer, according to rock type.

In the Oak Ridge area, the Knox Group is the principal water-bearing unit and the shale and sandstone rocks of the Rome formation are the poorest aquifers. Chestnut Ridge is underlain by the Knox Group (see Section 3.2), and the hydrogeologic setting in this area is complicated. Some site characterization studies have been undertaken (Woodward-Clyde 1984). The results of these studies indicate that most of the Chestnut Ridge area is covered by thick overburden, which is more than 21-m (70-ft) thick in many areas. The overburden has a high silt and clay content that would provide substantial sorptive and ion-exchange capacities. The field-study results also indicate that the Chestnut Ridge area is underlain by a network of developed karst (i.e., sinkholes and other solution features). Although the complexity and extent of this network is not known, it is generally believed that groundwater flow in the area is controlled by solution cavities and fractures.

Observation of springs and disappearing streams also suggests that the surface drainage in the area tends to be linked directly to the groundwater. Based on field investigations of springs issuing from the Knox Group (DeBuchananne and Richardson 1956), 86 of 416 springs inventoried were estimated to yield more than 107 L/s (1700 gpm) and 82 were estimated to yield between 24 and 107 L/s (380 and 1700 gpm). These data suggest that there is a large volume of water moving through the Knox Group.

Groundwater movement in the Knox Group of the Valley and Ridge physiographic region of east Tennessee has been characterized by studies conducted by Hollyday and Goddard (1979). They found that recharge to the groundwater system at topographic highs moves across geologic strike to low areas as well as along strike in higher-permeability beds. In the Chestnut Ridge area, this pattern probably flows from topographic highs to lower valley positions to the southeast, and then along flowlines that parallel valley axes (and geologic strike). Because of the complex fracture patterns, folds, and faults in the area--as well as the thick overburden that conceals these features--determination of detailed, small-scale flow patterns is not feasible. However, the general pattern of groundwater movement along strike to the Clinch River is indicated by hydraulic gradients in that direction.

Recently, groundwater characteristics in the West Chestnut Ridge area were studied by Woodward-Clyde Consultants (1984). They installed several observation wells to measure water levels in soils and bedrock and to determine groundwater flow paths. The study results indicate that the groundwater table in the site area ranges from about 6 m (20 ft) for a ground surface elevation of 238 m (780 ft) MSL to about 24 m (80 ft) at elevation 305 m (1000 ft) MSL. The depth to the groundwater level increases markedly at locations where the ground surface elevation exceeds 305 m (1000 ft) MSL. The thickness of the bedrock aquifer varies, with a typical value ranging from 7.6 to 15 m (25 to 50 ft) (Woodward-Clyde 1984). The transmission of water through site soils and bedrock is generally very fast. Within both the soil and bedrock aquifers, flow is from the higher topographic areas toward the lower areas. Gradients indicate flow toward the nearest perennial surface water features.

The use of groundwater for industrial and drinking water supplies in the Oak Ridge area is somewhat limited. Most of the water supplies are drawn from surface water sources (Boyle et al. 1982). However, in rural areas not served by public water supply systems, single-family wells are commonly used. The locations of some water wells in the Oak Ridge vicinity are shown in Figure 3.10. Most of the wells in the Chestnut Ridge area are south of the Clinch River. One study (Exxon Nuclear Co. 1976) has indicated that the incised meander of the river in bedrock represents a major topographic feature that prevents any groundwater flow from passing beneath the river. Groundwater beneath the ORR area generally migrates along strike and discharge to surface water bodies (Boyle et al. 1982). There are no known public or private water supply wells located along the groundwater pathway between the Chestnut Ridge sites and the Clinch River.

3.4 CLIMATE AND METEOROLOGY

3.4.1 Descriptive Regional Climatology

The ORR is located in the "Great Valley" of eastern Tennessee, which is broad and funnel-shaped and contains the Tennessee River and its tributaries, including the Clinch River. The area in the immediate vicinity of Chestnut Ridge may be characterized as rolling hills. The weather and climate in the Oak Ridge vicinity are greatly influenced by local and regional terrain. The prevailing wind directions in the valley are highly dependent on features of the local terrain, reflecting the airflow channeling brought about by the orientation of the valleys and ridges of the southern Appalachians. Winds are generally either up-valley from the west or southwest or down-valley from the east or northeast in alignment with ridges in a northeast-southwest line.

The Cumberland and Great Smoky mountains provide a continental climate. This moderating influence is evident in the temperature at Oak Ridge, which seldom rises above 100°F or drops below 0°F.

The climate of Oak Ridge has several effects that are important to the operation of burial grounds (Jacobs et al. 1980). In some areas, the high precipitation causes the water table to occur at shallow depths and accounts for seasonally large streamflow. Stream density is high and groundwater residence time is short. Rainfall affects the composition of the natural vegetative cover. Large amounts of acid leachate infiltrate the ground from decaying vegetation, resulting in lower soil pH and influencing the nature of the clay minerals formed.

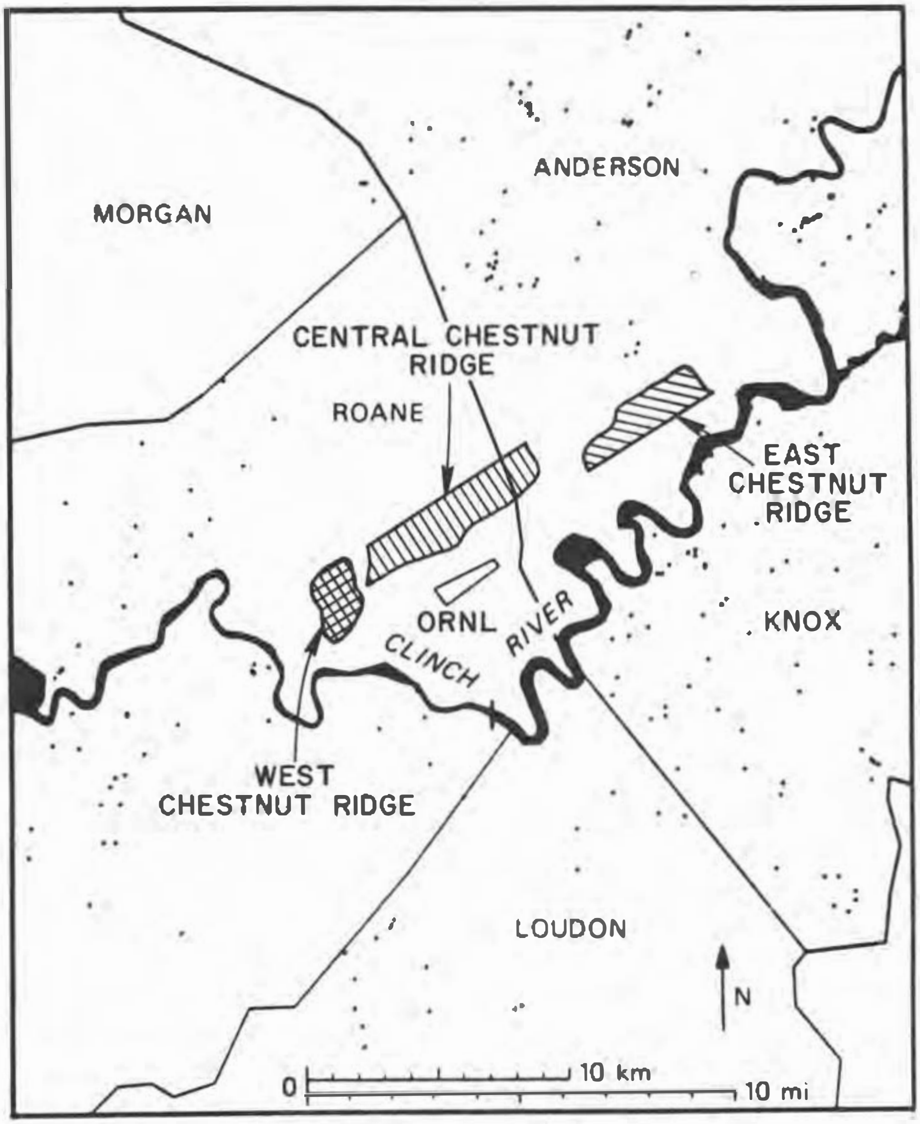


Figure 3.10. Locations of Water Wells in the Chestnut Ridge Area. Source: Adapted from Boyle et al. (1982).

3.4.2 Local Meteorology

No meteorological measurement stations are located on Chestnut Ridge; therefore, local conditions are inferred from data taken at nearby meteorological stations. The nearest meteorological data stations currently in operation include (1) a 100-m tower near the intersection of Bethel Valley Road and Tennessee Highway 95, (2) surface observations in the city of Oak Ridge by the U.S. Weather Bureau and National Weather Service (data since 1947), (3) the meteorological station at the Clinch River Breeder site, (U.S. Nucl. Reg. Comm. 1982), and (4) the meteorological station operated by the NUS Corporation for Exxon (Exxon Nucl. Co. 1977); all are within 11 km (7 mi) of ORNL.

The most relevant data to the Chestnut Ridge sites are those collected at the 100-m tower. It is the closest operating meteorological tower to the sites and has similar terrain features. Data exist from January-December 1983 and are available in hour-by-hour format (wind speed, wind direction, atmospheric stability, and precipitation). Data were available at the 10, 30, and 100 m elevations. The data at the 10 m level (meteorological tower C) were processed to STAR format as input into radionuclide transport calculations in the atmosphere. This format provides the frequency of occurrence of meteorological conditions based on ranges in stability, wind speed, and wind direction.

Temperatures at the meteorological station in the city of Oak Ridge seldom rise above 37.8°C (100°F) or drop below -17.8°C (0°F). Temperatures in the valley can usually vary a few degrees from place to place. The annual mean temperature at Oak Ridge is 14.2°C (57.6°F); monthly means range from 2.9°C (37.2°F) in January to 28°C (77°F) in July. A summary of the monthly temperature record is given in Table 3.3.

Table 3.3. Temperature Record for the City of Oak Ridge, Tennessee, 1947-1980

Month	Mean†[1] Daily Maximum (°C)	Mean†[1] Daily Minimum (°C)	Monthly Mean (°C)	Record Maximum (°C)	Record Minimum (°C)
January	8.4	-1.6	2.9	23.9	-22.8
February	10.2	-0.8	4.6	26.1	-17.2
March	14.8	2.4	8.8	29.4	-17.2
April	21.4	7.9	14.7	32.8	-4.4
May	26.1	12.5	19.0	33.9	-1.1
June	29.7	17.2	22.9	38.3	3.9
July	30.8	19.1	24.8	40.6	10.0
August	30.4	18.5	24.3	37.8	10.6
September	27.5	14.8	21.1	38.9	0.6
October	21.7	8.4	14.7	32.2	-6.1
November	14.4	2.4	8.4	28.3	-17.8
December	9.1	-1.1	4.2	23.3	-19.4
Annual	20.3	8.3	14.2	40.6	-22.8

†[1] Mean based on record for period 1941-1970.

Source: Data from National Oceanic and Atmospheric Administration (1981).

Eastern Tennessee typically receives substantial amounts of precipitation throughout the year, with peak amounts at Oak Ridge falling from December through March and a secondary peak occurring during July. The vast majority of precipitation (140 cm [55 in.] of water annually) in Oak Ridge is rain. Because freezing temperatures seldom persist for more than a few days, any snow and ice that does accumulate will thaw rapidly. A quantitative summary of the precipitation record for Oak Ridge is presented in Table 3.4.

Table 3.4. Precipitation Record for the City of Oak Ridge, Tennessee, 1947-1980

	Water equivalent (cm)				Snow, ice pellets (cm)	
Month	Mean	Maximum	Minimum	24-h Maximum	Maximum	24-h Maximum
January	14.07	33.71	4.72	10.80	24.4	21.1
February	12.06	26.59	2.13	7.47	43.7	23.1
March	15.57	31.09	5.41	12.04	53.3	30.5
April	10.87	24.66	2.24	15.85	0.8	0.8
May	10.77	26.49	2.08	11.20	-	-
June	10.46	20.55	2.16	9.40	-	-
July	13.74	48.95	3.94	12.47	-	-
August	9.68	26.57	1.37	19.00	-	-
September	9.19	23.11	1.04	8.71	-	-
October	7.34	17.65	Trace	6.76	Trace	Trace
November	11.71	31.04	3.48	13.44	16.5	16.5
December	14.22	26.19	1.70	13.00	37.6	27.4
Annual	139.7	193.9	94.07	-	108.0	

Source: Data from National Oceanic and Atmospheric Administration (1981).

The wind climatology of the ORNL area is caused by the combined influences of synoptic weather systems and the region's complex terrain. As a result, wind speeds are often increased (due to the physical channeling effect of the region's mountains and ridges) and are directed predominantly up or down the valley. However, even within an area the size of the ORR, the wind can vary considerably. The wind records for the ORNL, Y-12, and ORGDP sites during the 5-year period of 1956-1960 indicate a much higher frequency of northeast wind at ORGDP than at either ORNL or Y-12 (Hilsmeier 1963). The wind roses (figures showing frequency of occurrence of wind direction sectors and wind speed classes) for ORNL during this 5-year period (for both lapse and inversion conditions) are shown in Figures 3.11 and 3.12 (Boyle et al. 1982). These figures graphically show the predominance of the southwest and northeast winds

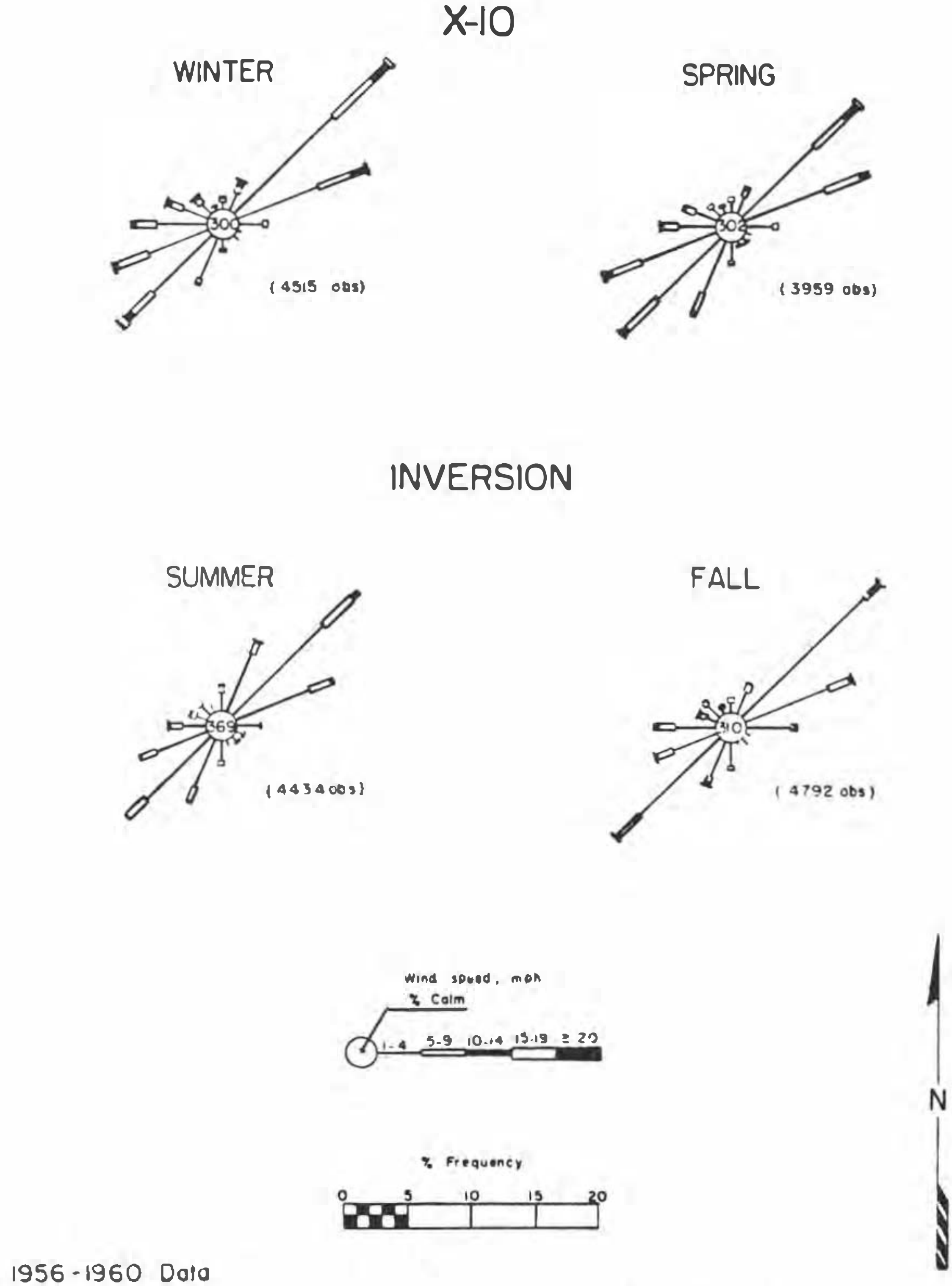


Figure 3.11. Wind Roses for ORNL Site Under Inversion Conditions for Each Season, 1956-1960. Source: Boyle et al. (1982).

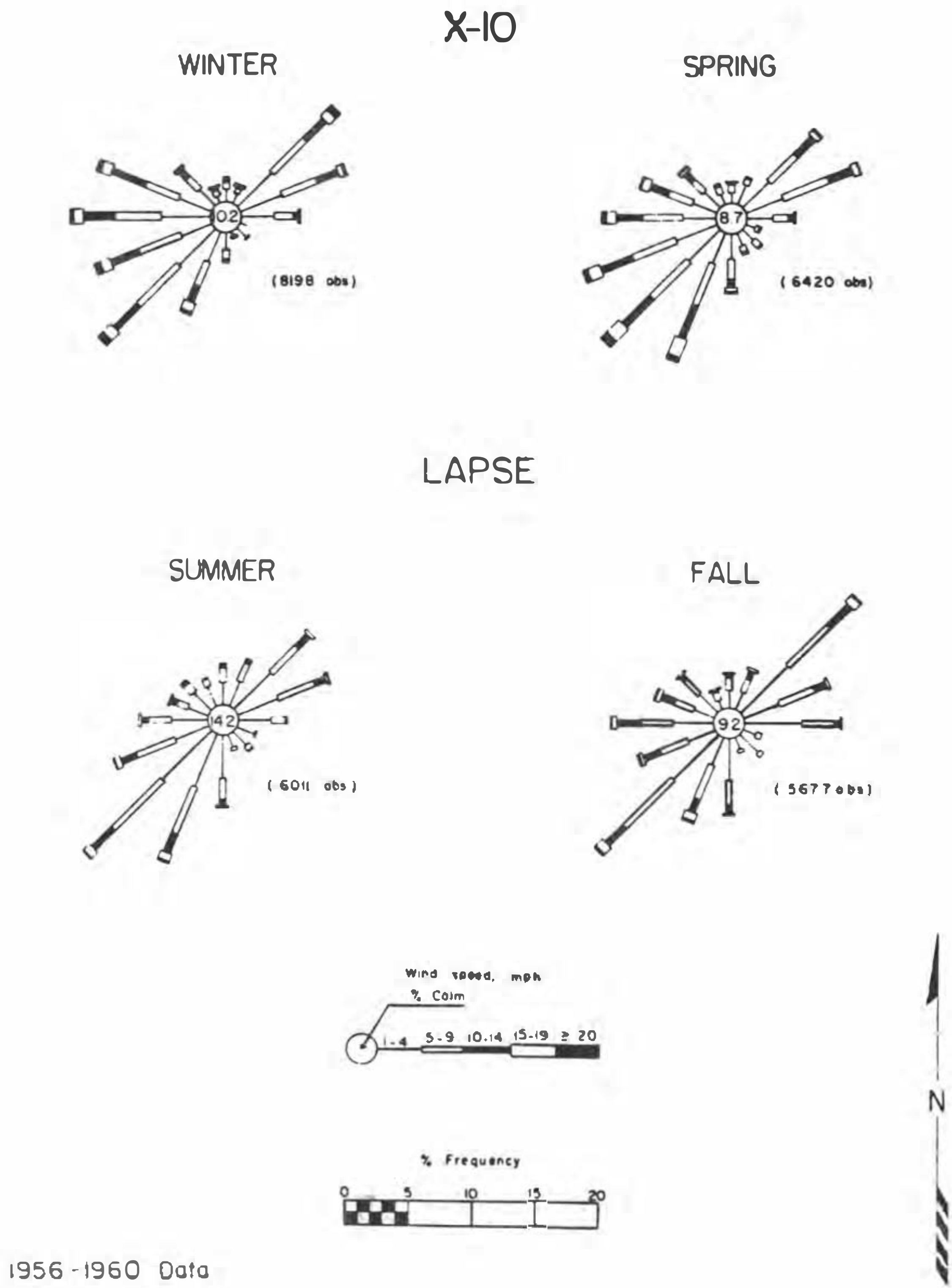


Figure 3.12. Wind Roses for the ORNL Site Under Lapse Conditions for Each Season, 1956-1960. Source: Boyle et al. (1982).

under lapse and inversion atmospheric stability conditions. These data were obtained at a meteorological tower at the ORNL site.

3.4.3 Ambient Air Quality

Of the EPA's five criteria pollutants (TSP, SO_2, NOx, CO, and O_3), all but CO have been subject to ambient concentration monitoring within a roughly 20-km radius of ORNL during the period 1976-1980. 8ased on 1980 monitoring data, the air quality in the ORNL vicinity was within federal primary ambient air quality standards for SO_2 and TSP and within standards for NO_2 and ozone. The EPA has classified the Oak Ridge area as nonattainment for NO_2 and ozone, unclassified for CO, and attainment for SO_2 and TSP. Although the air quality in the ORNL vicinity has recently met federal air quality standards, these standards have not been met for enough time to allow reclassification of the area as attainment for NO_2 and ozone.

Of main interest are the ambient levels of NOx and TSP. The CWDF project involves construction which inevitably leads to some fugitive dust release during dry periods. Also, the increased vehicle activity during construction and operation will affect the NOx and TSP concentrations in the vicinity of the CWDF site during construction and operation. The remainder of this section identifies the most relevant data for NOx and TSP in the vicinity of Chestnut Ridge.

The Local Air Monitoring (LAM) network at ORNL consists of 23 monitoring sites within the ORNL complex in Bethel and Melton valleys. Five of these LAM sites were used to collect TSP samples during 1980. The results of this local TSP monitoring with comparison to federal standards are shown in Table 3.5. The 1980 annual average TSP concentrations at these five sites were well below the federal TSP standards and thus within acceptable limits.

Table 3.5. Annual Average Total Suspended Particulate (TSP) Concentrations Observed at ORNL Local Air Monitoring (LAM) Network Sites, 1980†[1]

Site	Annual Average TSP Concentration (μg/m^3)
LAM-1	44
LAM-2	40
LAM-6	42
LAM-7	44
LAM-15	38

†[1] The primary ambient air quality standard is 75 μg/m^3 (annual geometric mean).

Source: Data from Auxier and Davis (1981).

NOx concentrations in the vicinity of Oak Ridge varied from 32-45 μg/m^3 in terms of annual arithmetic mean. The air quality standard for oxides of nitrogen expressed as nitrogen dioxide (NO_2) is 100 μg/m^3 (annual arithmetic mean).

More detailed information on climate, local meteorology, and ambient air quality of the Oak Ridge area can be found in Jacobs et al. (1980), Boyle et al. (1982), and Fitzpatrick (1982).

3.5 ECOLOGY

3.5.1 Terrestrial Ecology

The Oak Ridge Reservation (ORR) lies within the boundaries of the oak-hickory forest section of the Temperate Deciduous Forest Biome (Bailey 1978; Galvin 1979). Generally, this biome is characterized by tall broad-leaved trees that form a dense canopy in summer. A well-developed understory of trees and shrubs also exists and, prior to full canopy development, a dense herbaceous layer occurs in spring. The forest floor is covered with a dense litter of branches and leaves. The dominant plant association on the ORR is the oak-hickory forest (Kitchings and Mann 1976), but the actual plant community types are diverse. The percent composition of major habitats found on the ORR is presented in Table 3.6. These habitats, particularly the forested habitats, have been discussed in other documents pertaining to ORR (Kitchings and Mann 1976; Exxon Nucl. Co. 1977; U.S. Nucl. Reg. Comm. 1977; Boyle et al. 1982).

The 15,000-ha (37,000-acre) ORR was primarily an agricultural area prior to federal acquisition in 1942. After the land was withdrawn from public access, most of the ORR was allowed to revert to natural plant cover, which is predominately forestland (>11,735 ha [29,000 acres]). Timber management and select experimental manipulations are the major influences currently existing on or near Chestnut Ridge, whereas other practices such as maintenance of transmission line corridors and cultivated grasslands also selectively control vegetative development and succession on the ORR. A transmission line corridor exists on the WCR and CCR sites. The habitats occurring on the existing ORR waste sites are cultivated grasslands, which are dominated by grass species including fescue, bluegrass, and orchard grass.

The major plant community occurring on West and Central Chestnut Ridge is the upland hardwoods (Kitchings and Mann 1976). Important tree species include oak (chestnut, white, black, northern red, scarlet, and post), hickory, ash, tulip poplar, red maple, black gum, dogwood, and beech. Many common east Tennessee wildflowers are also essentially restricted to upland hardwood forests. Additional habitats occurring on Chestnut Ridge include pine (both natural stands and plantations) and early successional grassland/shrubland (associated with rights-of-way). The East Chestnut Ridge area in particular is rich in pastures and old fields, with over 50% consisting of such habitats. The vegetation types and their occurrence on the three designated disposal areas within the preferred WCR site are listed in Table 3.7. No unusual mature or pristine habitats occur on the WCR or ECR disposal areas. Dahlman et al. (1977) listed two small natural areas on the CCR, but did not describe them.

Table 3.6. Estimated Percent Abundance of Various Habitats on the Oak Ridge Reservation and the West Chestnut Ridge Site†[1]

Habitat	Percent					
	Oak Ridge Reservation†[2]		WCR Vicinity†[3]		WCR Site†[4]	
Pine	29.8		34.2		47.3	
Plantations		14.8		16.4		41.3
Natural stands		15.0		17.8		6.0
Cedar and open scrub	3.7		0.9		0.0	
Hardwoods	51.0		49.7		48.9	
Upland hardwoods		48.1		49.7		48.9
Bottomland hardwoods		2.5		0.0		0.0
Scrub hardwoods		0.4		0.0		0.0
Swamp or marsh	0.1		0.0		0.0	
Fields, old-field, pasture, lawns	7.6		6.8		0.0	
Roads	2.6		3.5		NE†[5]	
Rights-of-way	5.3		4.8		3.8	

†[1] Percent abundance of various habitats on the Central and East Chestnut Ridge Sites cannot be provided with certainty as exact disposal areas have not been identified. Habitat composition can be expected to be similar to the WCR vicinity for the CCR site, but the ECR site contains >50% fields and pastures.

†[2] Facility areas within fences not included. There are no facility areas on the WCR site.

†[3] West Chestnut Ridge buffer zone (see Appendix D, Figure 0.1).

†[4] Three designated disposal areas of the WCR site (see Appendix 0, Figure 0.1).

†[5] No estimate.

Source: Boyle et al. (1982).

Table 3.7. Vegetation Types on the Three Designated Disposal Areas Within the West Chestnut Ridge Site

Vegetation Type†[1]	Vegetation Type (ha) per Designated Disposal Area A	B	C	Total
Pine Plantations:				
LOB	-	6.9	8.0	14.9
LOB-WP	6.6	-	-	6.6
Natural Pine Stands:				
VP-SLP-NRO-WO-POP	-	1.5	-	1.5
SLP-VP-HIC-POP	1.2	-	0.3	1.5
Upland Hardwoods:				
WO-NRO-SRO	5.6	-	-	5.6
HIC-RO-WO-MAP-ASH	1.0	1.0	-	2.0
NRO-SRO-VP-SLP-POP-MAP-HIC	-	-	3.9	3.9
WO-NRO-SRO-CO-POP	0.3	-	-	0.3
CO-NRO-SRO-HIC	3.7	-	-	3.7
NRO-SRO-CO-WO-HIC	9.5	-	-	9.5
NRO-SRO-WO-POP	-	4.7	2.5	7.2
Rights-of-Way (Powerline) and Roads	1.0	2.0	2.0	5.0
Clearcut and Abandoned Fields	-	-	2.2	2.2
TOTAL	29	16.0	19	64

†[1] LOB = Loblolly pine, WP = White pine, VP = Virginia pine, SLP = Shortleaf pine, NRO = Northern red oak, WO = White oak, POP = Yellow poplar, HIC = Hickory, SRO = Southern red oak, RO = Red oak, MAP = Maple, ASH = Ash, CO = Chestnut oak.

Source: Data from Type-Map of Management Compartment No. 15 (Undated) and Oak Ridge National Laboratory (1984).

The species of mammals, birds, and herpetofauna, as well as their preferred habitats, that occur in the ORR have been listed by Kitchings and Mann (1976). About 50 of the 70 mammal species that occur in Tennessee have ranges that could include ORR. Mammals common to hardwood forests include red and gray fox, bobcat, long-tailed weasel, white-tailed deer, opossum, white-footed mouse, eastern chipmunk, and golden mouse (Kitchings and Mann 1976; Oak Ridge Natl. Lab. 1984). Pine plantations can maintain a small-mammal community especially if a dense understory of honeysuckle and other vines exists that provides food and cover, especially in winter (Exxon Nucl. Co. 1977). Mammals common to old fields and pastures include the house mouse, eastern harvest mouse, shorttail shrew, and cottontail rabbit (Beckwith 1955; Burt 1964).

More than 250 bird species have been reported from eastern Tennessee. Many of these species utilize habitat similar to that occurring on Chestnut

Ridge, either as seasonal or permanent residents. Bird species typical of hardwood and hardwood-pine habitats include: red-eyed vireo, yellow-shafted flicker, woodpecker (red-bellied, downy, and hairy), American crow, bluejay, warbler (Kentucky, pine, and prairie) Indigo bunting, wood thrush, Swainson's thrush, ovenbird, yellow-breasted chat, Carolina chickadee, tufted titmouse, scarlet tanager, and summer tanager. Upland game birds include: northern bobwhite, wild turkey, American woodcock, and mourning dove. Also common to the Chestnut Ridge area are the red-tailed hawk, black vulture, turkey vulture, eastern screech-owl, great horned owl, and barred owl (Kitchings and Mann 1976; Exxon Nucl. Co. 1977). Many birds do not prefer pine plantations (Kitchings and Mann 1976). Species expected to be most numerous are pine warblers and white-throated sparrows, although the latter is a migratory species and would only occur in the ORR for about half the year. Bird species common in old fields and pastures include eastern meadowlark, song sparrow, chipping sparrow, field sparrow, common grackle, starling, and bobwhite (Robbins et al. 1966).

The herpetofauna of ORR has been studied by Johnson (1964). Typical species found on Chestnut Ridge include American toad, Fowler's toad, eastern narrow-mouthed toad, red-spotted newt, leopard frog, gray treefrog, eastern box turtle, northern copperhead, black racer, rat snake, worm snake, five-lined skink, and northern fence lizard.

3.5.2 Aquatic Ecology

The ORR is in the lower part of the Clinch River drainage basin. The Clinch River bounds the ORR on the south and west for about 63 km (39 mi), extending from Clinch River mile (CRM) 49 on Melton Hill Reservoir to CRM 10, which is downstream from the mouth of Poplar Creek (Figure 3.13).

The major surface waters on ORR are small streams that originate from springs in the limestone on the ridge slopes. Two permanent creeks, Ish and Grassy, have their headwaters in the West Chestnut Ridge area; four permanent creeks (Bear Creek, White Oak Creek, Bearden Creek, and Walker Branch) have their headwaters in the Central Chestnut Ridge area; and three creeks (McCoy Branch, Kerr Hollow Branch, and Scarboro Creek) have their headwaters in the East Chestnut Ridge area (Figure 3.13). Grassy Creek originates from a series of hardwater springs, is only about 4.0 km (2.5 mi) long, and has a drainage basin of approximately 4.9 km^2 (1.9 mi^2). Grassy Creek flows in a south-westerly direction into the Clinch River at CRM 14.6. As is typical of small streams, most of Grassy Creek has alternating riffle and pool habitats with substrates consisting of rock, gravel, sand, and mud. However, the lower 0.72 km (0.45 mi) of the creek is essentially an embayment of the Clinch River. The embayment has its own characteristic biota that more closely approximates the biota of the Clinch River, and it undoubtedly serves as a spawning area for Clinch River fish species that migrate into backwaters or up tributaries (Exxon Nucl. Co. 1977).

The biota of Grassy Creek have been surveyed by Exxon Nuclear Company (1977) with subsequent fish surveys conducted by Oak Ridge National Laboratory (1984). The predominant macrophyte in Grassy Creek is watercress. Both phytoplankton and zooplankton are limited in the creek, except in the embayment area where the more pool-like conditions allow for development of a planktonic community. Diatoms dominate the periphyton. The benthic community is highly diverse with up to 39 genera of aquatic insects alone. The embayment

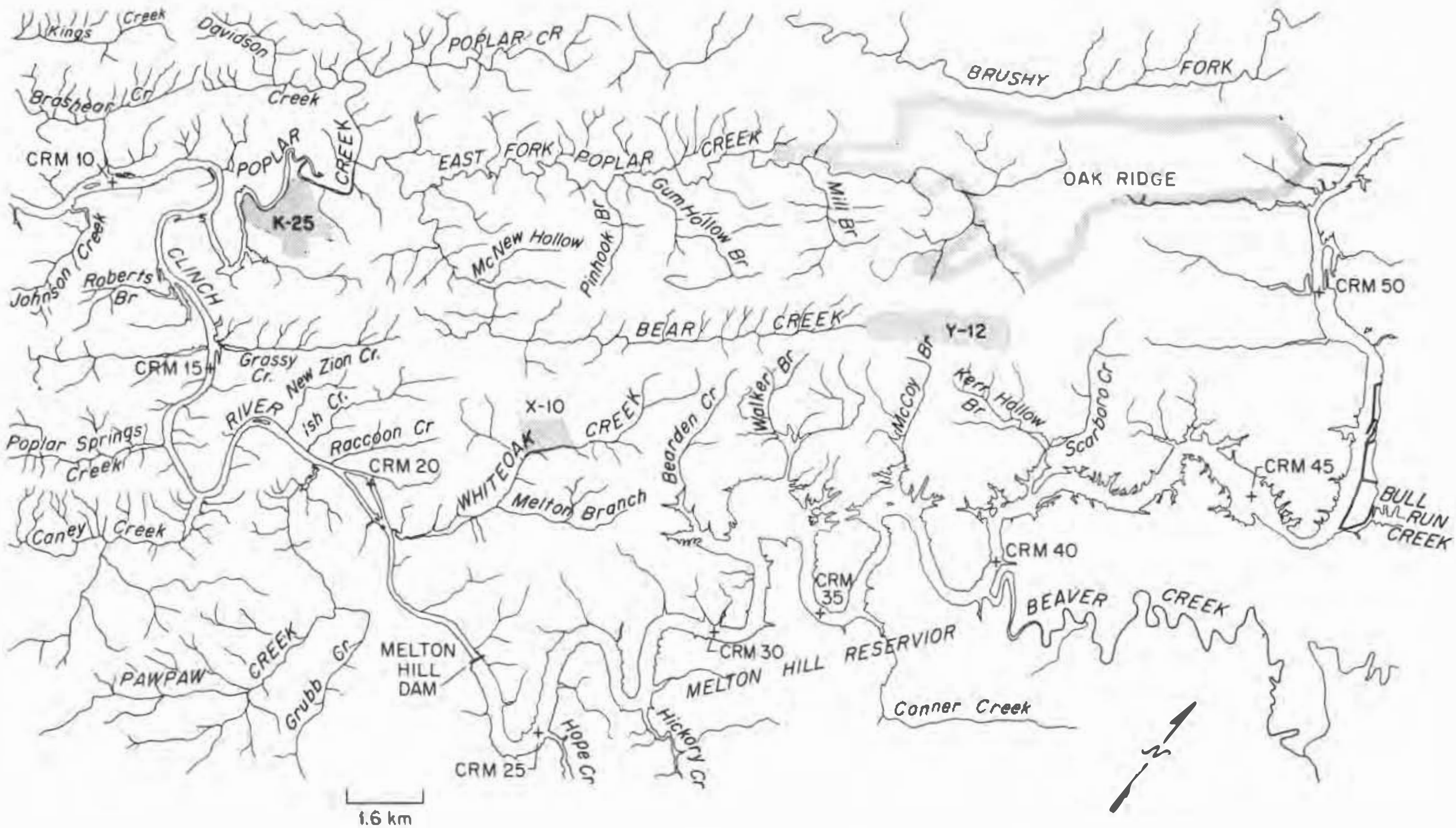


Figure 3.13. Aquatic Environments on and Contiguous with the Oak Ridge Reservation. Source: Dahlman et al. (1977).

area contains species similar to those occurring in the Clinch River whereas the upper reaches of Grassy Creek contains species indicative of a pristine, uncontaminated stream. Fish species of Grassy Creek include three species in the upper reach (white sucker, blacknose dace, and creek chub--with only the latter two being common), 15 species in the middle reach (including sunfish, blacknose dace, bluntnose minnow, common shiner, spotfin shiner, darter, and banded sculpin), and 31 species in the lower reach. In the embayment area, bluegill is the dominant game fish, carp is the dominant rough fish, and shad (threadfin and gizzard) is the dominant forage fish. In all, 40 species of fish have been collected. Only six of the species collected in the lower reach were also found upstream in Grassy Creek. The remaining 25 species are commonly found in the Clinch River (Exxon Nucl. Co. 1977).

Ish Creek is a low-gradient stream with shallow pools and riffles. Main channel substrates are predominately sand and fine gravel, with occasional areas of large rubble. The bank areas are comprised mostly of silt, mud, and detritus. Fish were collected once during December 1983 and once during January 1984 from three locations in Ish Creek (Figure 3.14). Six species were collected (redbreast sunfish, common shiner, bluntnose minnow, mountain redbelly dace, blacknose dace, and creek chub). The number of species collected increased from three upstream, to four at the middle site, to six at the downstream site. The blacknose dace was the most abundant species; and the blacknose dace, mountain redbelly dace, and creek chub were the only species collected from all three sample sites (Oak Ridge Natl. Lab. 1984). Invertebrates of Ish Creek are numerically dominated by snails and midges (Newbold 1978). Overall, a moderately diverse invertebrate fauna occurs in the creek, with species and densities similar to those reported for other small, undisturbed streams on ORR (Cushman et al. 1975; Dahlman et al. 1977).

Two intermittent (wet-weather) creeks also occur in the West Chestnut Ridge vicinity (Figure 3.13). New Zion Creek has its headwaters near New Zion Cemetery and could be directly affected by surface discharges from the proposed CWDF. The other creek, Raccoon Creek, is separated from the WCR site by an intervening ridge. Substrates of New Zion Creek consist mainly of clay and detritus with sand, silt, and fine gravel in the shallow pools. During surveys conducted in December 1983 and January 1984 (Oak Ridge Natl. Lab. 1984), no fish species were collected from the New Zion Creek and only three species were collected at one site in Raccoon Creek (Figure 3.14). Bluegill, bluntnose minnow, and mosquitofish were collected, but only the bluegill was common.

The upper portion of White Oak Creek is similar to the upper reaches of the other permanent creeks in the Chestnut Ridge vicinity. However, only the stoneroller and blacknose dace were commonly collected. Additionally, only 24 taxa of macroinvertebrates were found; although this represented the greatest diversity found in the White Oak Creek basin (Boyle et al. 1982). The remainder of White Oak Creek contains a biotic composition largely influenced by ORNL, White Oak Lake, and/or the Clinch River. Benthic diversity is somewhat restricted and dominated by midge larvae. Predominant fish species include bluegill, redear sunfish, gizzard shad, mosquito fish, largemouth bass, channel catfish, and carp.

The biota of the other streams in CCR and ECR have not been investigated to date. However, it can be assumed that the streams in CCR and ECR are similar to Grassy or Ish creeks at WCR. The upper reaches of the streams

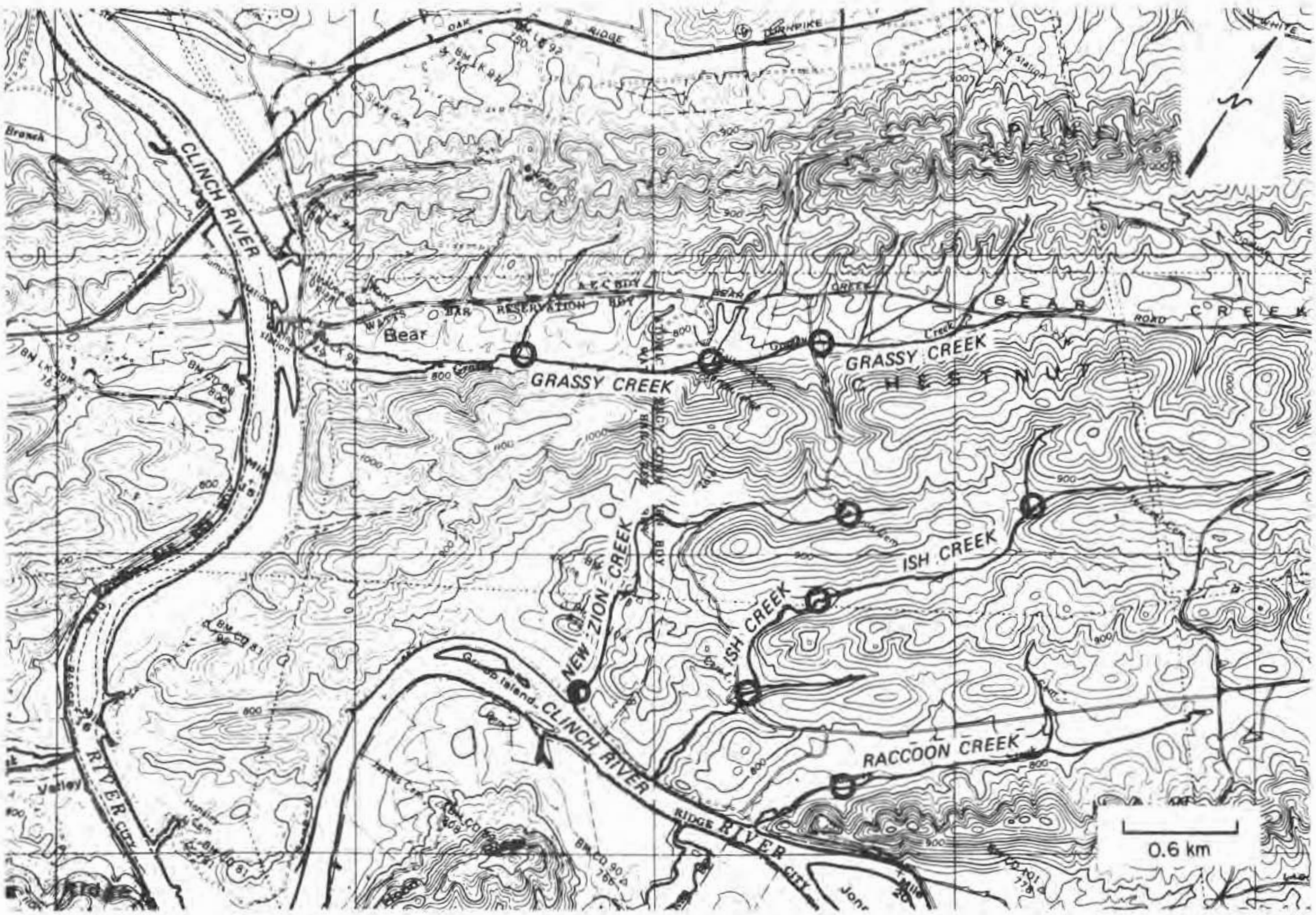


Figure 3.14. Fish Sampling Sites on Grassy Creek, New Zion Creek, Ish Creek, and Raccoon Creek. Shown are the upper, middle, and lower reaches on Grassy Creek and Ish Creek, the upper and lower reaches on New Zion Creek, and the lower reach on Raccoon Creek. The pool sampling site on Ish Creek is at the downstream end of the upper reach site.

would undoubtedly contain a moderately diverse invertebrate fauna and a fish fauna predominated by several minnow species. The lower reaches of the creeks would be influenced by their embayments with the Clinch River and would contain a biota similar to that of lower White Oak Creek discussed previously. This has been shown by monitoring in the lower reaches of McCoy Branch and Scarboro Creek (U.S. Energy Res. Dev. Adm. 1975).

The Clinch River will ultimately receive surface water and groundwater discharges from the CWOF site. The river and its biota in the vicinity of the ORR have been detailed (U.S. Nucl. Reg. Comm. 1977; Exxon Nucl. Co. 1977; U.S. Dept. Energy 1979; Boyle et al. 1982). The ecology of the Clinch River near the ORR is largely influenced by releases from Melton Hill Dam (Boyle et al. 1982). Daily discharges can vary from almost zero (slack pond condition) to 283 to 566 m^3/s (10,000 to 20,000 cfs), which may last for several hours. The velocity of this pulse discharge scours the river channel, resulting in a substrate consisting of exposed bedrock (Loar et al. 1981). However, the banks, especially near tributary streams, have substrates consisting of fine clay, silt, gravel, and small rubble. The phytoplankton of the Clinch River is dominated by diatoms in spring, green algae and Cryptomonas in summer, and a return to diatoms with decreasing temperatures in fall. Blue-green algae are only a minor component of the phytoplankton community. The river zooplankton is dominated by rotifers (Loar et al. 1981).

The benthic invertebrate fauna is dominated by midge larvae, Asiatic clams, aquatic oligochaetes, and coelenterates. Siltation stemming from dam development and operation has essentially eliminated the productive commercial mussel population that once occurred in the area (Exxon Nucl. Co. 1977). At least 50 species and two hybirds of fish occur in the Clinch River near the ORR. Threadfin shad is the most numerous species. Other commonly encountered species include: bluegill, gizzard shad, emerald shiner, carp, sauger, and skipjack herring. Forage fish numerically dominate whereas rough fish dominate in terms of biomass (Exxon Nucl. Co. 1977).

Commercial fishing (mainly for catfish, buffalo, carp, drum, and paddlefish) occurs in Watts Bar Lake. However, the commercial catch in the river near the ORR is minimal. The 1972 commercial catch within a 16-km (10-mi) radius of the Exxon site was only about 454 kg (1000 lb) or 1.0% of the commercial catch in the entire reservoir (Project Manage. Corp. and Tenn. Val. Auth. 1975). The reservoir is also used for recreational fishing, with the best fishing occurring in the tailwaters of Melton Hill Dam. Popular sport fish in the lower Clinch River include sauger, bluegill, white bass, striped bass, and yellow bass (Loar et al. 1981).

3.5.3 Endangered Species

Five terrestrial animal species considered endangered by the U.S. Fish and Wildlife Service (1983) have been observed on or around the ORR. Mammal species are limited to the Indiana bat and the gray bat. The Indiana bat inhabits caves and hollow trees, the latter habitat perhaps allowing the species to occur on the ORR although neither species has been reported at the ORR (Project Manage. Corp. and Tenn. Val. Auth. 1975; Exxon Nucl. Co. 1977; U.S. Nucl. Reg. Comm. 1977; Boyle et al. 1982). Federally endangered and threatened bird species observed in the ORR vicinity are the bald eagle (endangered, southern race; threatened, northern race--observed along the

Clinch River), the peregrine falcon (endangered--not observed on ORR, but reported from neighboring Knox County), and the red-cockaded woodpecker (endangered--known to occur in Cumberland County about 80 km [50 mi] from ORR). Additionally, the eastern cougar has been sighted on the ORR and thus should be considered part of the species range. However, the eastern cougar may be extirpated, with sightings actually being individuals of the western cougar race that have been released or escaped from captivity (Boyle et al. 1982).

Thirteen species of terrestrial fauna known or expected to occur on the ORR are classified as endangered or threatened by the state of Tennessee (Hatcher, undated). These include the federally listed species above. Additional species include the Tennesee cave salamander (threatened), Bachman's (pinewoods) sparrow (endangered), sharp-shinned hawk (threatened), osprey (endangered), marsh hawk (threatened), Bewick's wren (threatened), Cooper's hawk (threatened), and the grasshopper sparrow (threatened). Of these, the osprey, Cooper's hawk, and grasshopper sparrow occur regularly on the ORR; the sharp-shinned hawk and Bachman's sparrow have been observed there; and the other bird species are expected to occur on the ORR (Kitchings and Mann 1976; Boyle et al. 1982). Cooper's hawk probably breeds on the WCR site because it has been observed there during two recent breeding seasons.

No federally listed endangered plant species are believed to occur on the ORR. None of the plant species listed as endangered by the state of Tennessee (Comm. Tenn. Rare Plants 1978) have been found on the ORR. Several plant species found on the ORR are rare, threatened, or of special concern, but they are primarily found in the designated natural areas of ORR (Kitchings and Mann 1976). However, *Fothergilla major* has been identified from the CCR (Parr 1984). In addition to these species, Kitchings and Mann (1976) have listed plant species of special interest or of limited distribution within ORR. Only one of these species, the trailing arbutus, occurs on Chestnut Ridge (near New Zion Cemetery). It is rare on the ORR, but is locally abundant in the state.

No federally threatened or endangered aquatic species are known to occur in the Clinch River or in ORR creeks. The mountain redbelly dace, collected from Ish Creek (Oak Ridge Natl. Lab. 1984), is listed by the state of Tennessee as in need of management (Eager and Hatcher 1980). Such a classification means that the species should be managed to the optimum carrying capacity of the habitat, but that it is not threatened or endangered.

3.6 SOCIOECONOMICS AND LAND USE

3.6.1 Demography and Employment

The ORR is located on approximately 15,000 ha (37,000 acres) of federally owned land in Anderson and Roane counties. The city of Oak Ridge is located in both Anderson and Roane counties and is the major population center in Anderson County. Roane County's population is dispersed in several smaller towns. The population in both Anderson and Roane counties increased from 1960 to 1980 (Table 3.8), although Roane County rural population decreased during this period. The population of Oak Ridge increased from 27,169 in 1960 to 28,319 in 1970, then decreased to 27,662 in 1980.

Table 3.B. Populations of Anderson and Roane Counties and Incorporated Municipalities, 1960-1980

County	Population†[1]		
	1960	1970	1980†[2]
Anderson County	60,032	60,300	67,346
Clinton	4,943	4,794	5,245
Oak Ridge†[3]	27,169	28,319	27,662
Oliver Springs†[3]	1,163	3,371	3,600
Rural	27,629	26,469	34,276
Roane County	39,133	38,881	48,425
Harriman	5,931	8,734	8,303
Kingston	2,010	4,142	4,441
Rockwood	5,345	5,259	5,767
Rural	27,812	18,093	26,477

†[1] According to the 1970 Census of Population, urban population comprises all persons living in places of 2,500 or more inhabitants.

†[2] U.S. Bureau of Census, 1980 Census of Population and Housing, Tennessee, PHC80-V-44.

†[3] Parts of Oak Ridge and Oliver Springs are also in Roane County.

Source: 8oyle et al. (1982).

The various facilities located on the ORR have an important influence on area employment. The proximity of Anderson and Roane counties to the ORR and the relatively small population bases of these counties make these counties particularly sensitive to employment changes at the DOE facilities. A combined regular work force of approximately 16,400 is employed at the various facilities on the Reservation. Employment by occupation for Anderson and Roane counties and the state of Tennessee is given in Table 3.9. Anderson County has a high concentration of professional/technical workers when compared to the state as a whole, probably because of the ORR influence in the area. Distribution of employment by occupation for Roane County is similar to the state as a whole and shows minimal influence of the ORR.

Personal income levels reflect the effect of DOE employment in the area. In 1981, the per capita income in Anderson County was $10,439, which was greater than the $8,447 per capita income of the state as a whole (Tenn. Center 8us. Econ. Res., undated). The 1981 per capita income of Roane County ($6,199) was less than that of Anderson County and the state.

Most individuals working at DOE facilities in Oak Ridge reside in communities other than Oak Ridge, particularly in Knoxville (Knox County) (Boyle et al. 1982). In 1971, 62% of the employees at the three DOE facilities lived outside of Oak Ridge. This increased to 64% in 1974 and 73% in April 1981, perhaps largely because of rapid residential development in western Knox County (8oyle et al. 1982).

Table 3.9. Employment in Anderson and Roane Counties and the State of Tennessee, 1978

Occupation	Percent Employment: Anderson County	Roane County	Tennessee
Professional, technical, and related	25.6	11.6	12.0
Nonfarm managers and administrators	6.8	6.2	7.7
Sales workers	5.7	4.4	6.5
Clerical	13.4	10.6	14.8
Craftsmen	18.0	18.0	14.3
Operatives	10.4	27.4	18.6
Transport operatives	2.5	4.4	4.5
Nonfarm laborers	4.6	5.6	5.1
Service workers†[1]	12.2	10.8	12.5
Farm workers	0.8	1.0	3.9
Number employed	27,920	14,050	1,815,000

†[1] Includes household workers.

Source: Data from Tennessee Department of Employment Security (1980).

The distribution of population (1970 Census) within a 16-km (10-mi) radius of ORNL, close to the sites, is shown in Figure 3.15.

3.6.2 Public Services

Public services in Oak Ridge and Anderson County include sewer, water, public utilities, law enforcement, health care, and schools. A study of the quality of public services in Anderson County (Brewer and Slusher 1975) concluded that--in comparison with adjacent Blount, Loudon, and Roane counties--Anderson County provides higher quality educational services with a "strong, balanced" educational program of "urban quality." Likewise, the study concluded that the public welfare services in Anderson County are of a generally high quality and that the "statistical profile" of these services is similar to that of industrialized counties in eastern Tennessee and more favorable than that found in Appalachian counties (Boyle et al. 1982).

3.6.3 Housing

Housing characteristics for Anderson, Roane, and Knox counties (and municipalities) are shown in Table 3.10. The rental vacancy rate for Anderson County is 1.8%, which is low given the fact that some of the existing housing is substandard. Oak Ridge has a slightly higher vacancy rate of 2.0%, and Roane County has a vacancy rate of 2.6%. Knoxville and Knox County both have relatively high rental vacancy rates--7.6% and 8.4%, respectively. This indicates that rental housing is more readily available in Knoxville and the Knox County area than in the area immediately surrounding ORR.

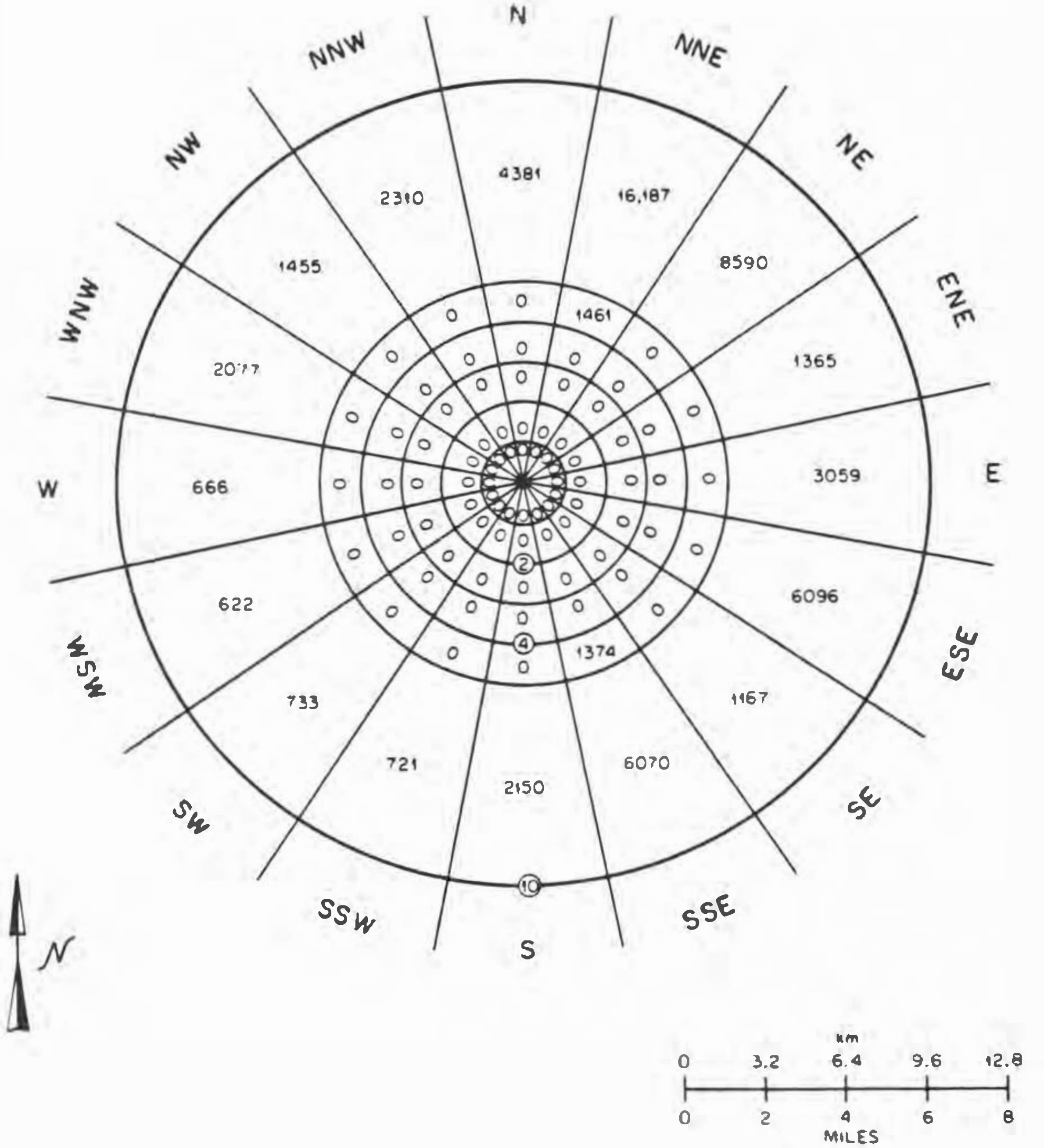


Figure 3.15. Distribution of Population (1970 Census) Within a 16-km (10-mi) Radius of Oak Ridge National Laboratory. Source: Fitzpatrick (1982).

Table 3.10. Housing Characteristics for the Oak Ridge Reservation Area, 1980

	Total Number of Units†[1]	% Owner-Occupied	Vacancy Rate: Owner-Occupied†[2]	Vacancy Rate: Rental	Median Rent/Month	Median Value†[3]
Oak Ridge	11,487	61.7	0.9	2.0	$164	$42,100
Anderson County	25,829	68.4	0.8	1.8	$151	$36,200
Roane County	18,526	71.4	1.3	2.6	$106	$33,100
Knoxville	73,233	47.9	1.6	7.6	$156	$32,600
Knox County	125,777	59.3	1.8	8.4	$159	$39,900

†[1] Total number of year-round housing units.

†[2] Units for sale.

†[3] Median value is for owner-occupied units. Excludes residences on 4 ha (10 acres) or more, mobile homes, condos, homes with medical or commercial offices.

Source: U.S. Bureau of the Census (1980).

Oak Ridge has the highest median value for residential homes in the area. Rent in the Oak Ridge area is also higher than in Anderson County as a whole, Roane County, Knox County, and Knoxville. Oak Ridge also has high property tax rates, which has contributed to an inadequate supply of quality housing, at affordable prices, to meet the housing needs of local citizens and people who want to both work and live in the city (Folz 1984).

3.6.4 Transportation

Roads in the vicinity of the preferred and alternative sites are shown in Figure 3.16. The main public road in the immediate vicinity is State Highway 95, which intersects two major interstate highways, I-40 and I-75, 8 km (5 mi) and 24 km (15 mi) to the south, respectively. The WCR site is located just to the southwest of Highway 95, which is an important commuting route for employees working at ORNL and ORGDP. The closest access to the WCR site is via Bear Creek Road (which intersects Highway 95) to New Zion Patrol Road to Lou Cagle Road. New Zion Patrol and Lou Cagle are nonpublic gravel roads used for security patrol and forest management. Bear Creek Road is a two-lane paved road running east and west of State Highway 95; the eastern segment is also a nonpublic road and is maintained for the Y-12 weapons facility. Average daily traffic on State Highway 95 just southeast of the 95/58 intersection was 4190 vehicles in 1982.

The CCR alternative site is accessible via unimproved roads from Bear Creek Road and Bethel Valley Road. By this route the site is approximately 10 km (6 mi) from ORGDP, 3.2 km (2 mi) from ORNL, and 3.2 km (2 mi) from Y-12. The ECR alternative site is accessible via unimproved roads from Bethel Valley Road, Scarboro Road, Oak Ridge Road, and from roads within Y-12. By these

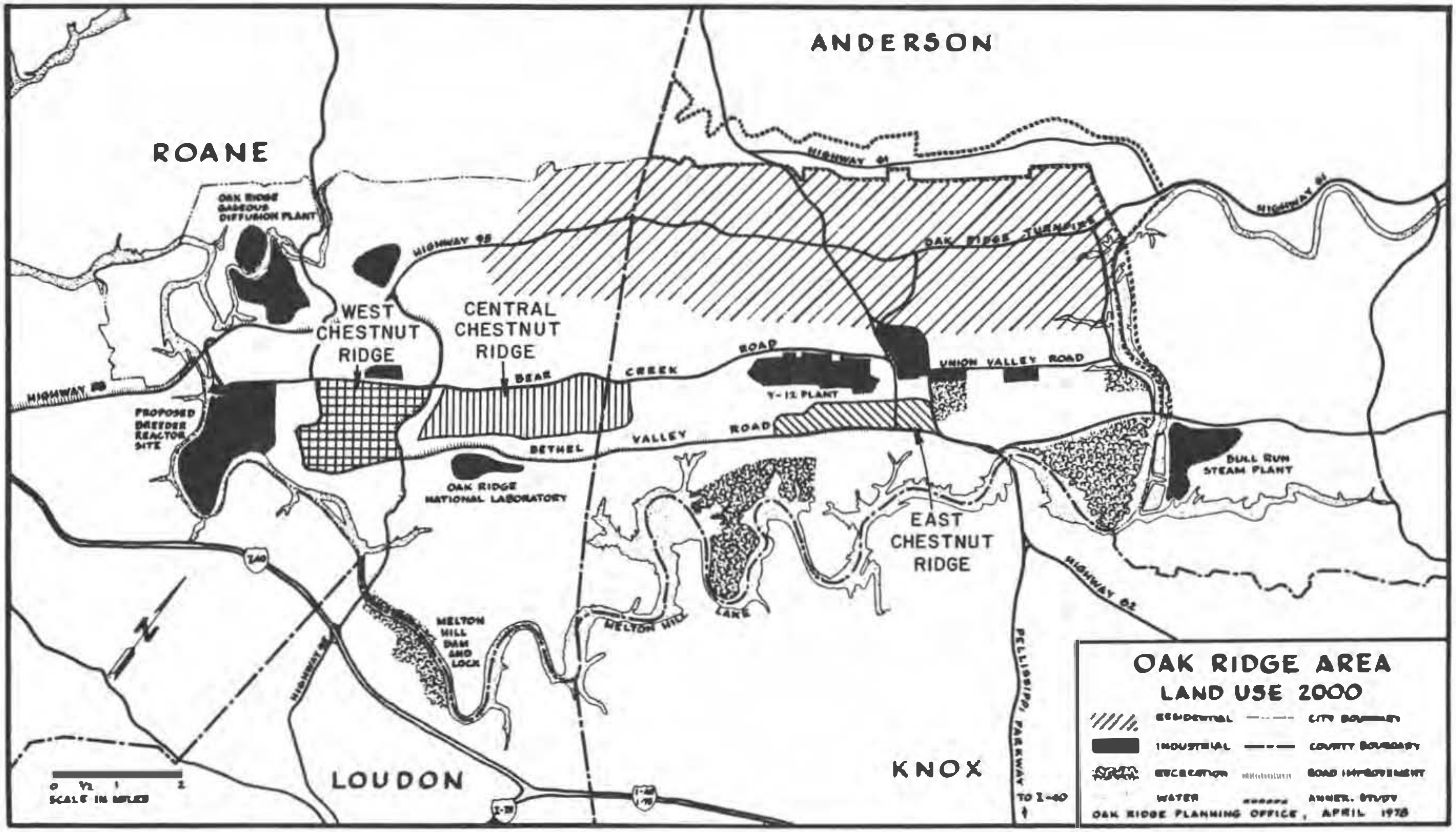


Figure 3.16. Roads in the Vicinity of the Chestnut Ridge Sites.
Source: Adapted from City of Oak Ridge Planning Department (1978).

routes the site is approximately 8 km (5 mi) from ORNL and 16 km (10 mi) from ORGDP. Most of the ECR lies within 1.6 km (1 mi) from Y-12.

3.6.5 Land Use

The area surrounding the city of Oak Ridge is rural in character, with agricultural, forest, and recreational lands comprising 95% of the 16-county area in 1979 (Boyle et al. 1982). The land-use category breakdown for Anderson and Roane counties is shown in Table 3.11. Forested land accounts for the majority of land in both Anderson and Roane counties--54.0 and 31.1%, respectively--whereas agricultural land accounts for 26.5% in Anderson County and 30% in Roane County. The ORR occupies a relatively small percentage of the land in both counties--7% in Anderson and 9.3% in Roane.

Table 3.11. Land-Use Data for Anderson and Roane Counties, Tennessee†[1]

Land-Use Category	Anderson County		Roane County	
	Hectares	Percentage	Hectares	Percentage
Residential	3,255	3.8	2,097	1.9
Commercial	146	0.2	93	0.1
Industrial	134	0.2	413	0.4
Recreational	4,170	4.8	28,749	25.5
Agricultural	22,834	26.5	33,887	30.0
Public and quasipublic	3,053	3.5	1,968	1.7
Forested	46,567	54.0	35,126	31.1
Oak Ridge Reservation	6,077	7.0	10,453	9.3

†[1] Source: Data from East Tennessee Development District (1979).

Land-use patterns in the immediate vicinity of the sites are controlled by DOE policy, which administers the 15,000 ha (30,000 acres) comprising the ORR. Thus, in the immediate vicinity of the sites, development is restricted to government-controlled activities. The nearest facility to the WCR site is ORNL, approximately 2.5 km (1.5 mi) to the east. ORNL is also the nearest facility to the CCR site, being located approximately 1.6 km (1.0 mi) southeast of the site. The Y-12 plant is the nearest facility to the ECR site, located within 1.6 km (1.0 mi) north of the site. The Clinch River runs approximately 1 km (0.6 mi) to the southwest of the WCR site, approximately 3.6 km (2 mi) to the south of the CCR site, and approximately 2.4 km (1.5 mi) to the south of the ECR site. The majority of land in the vicinity of the sites and throughout most of the undeveloped parts of the ORR is under a forest management plan administered by the ORNL Operations Division. This management plan involves harvesting both hardwood and pine forests and planting of pine. Most of the eastern section of CCR and over half of ECR are contained within the Y-12 security area, while much of the western section and a portion of the central section of CCR are contained within the ORNL security area (Oak Ridge Land-Use Committee 1980).

Twenty-five natural areas within the Reservation have been identified as having scientific value because of species composition or stage of ecological development (U.S. Dept. Energy 1982). Two small natural areas occur within CCR (Dahlman et al. 1977). The Environmental Science Division at ORNL currently is involved in research activities in the National Environmental Research Park located within the ORR. Terrestrial research areas occur extensively over much of Chestnut Ridge, while aquatic research areas are intensified within CCR (Oak Ridge Land-Use Committee 1980). A long-term multidisciplinary research project is being conducted on Walker Branch in the CCR. Various portions of the Oak Ridge Reservation also are used for the storage and disposal of wastes, including: disposal of solid wastes in near-surface landfills; disposal of liquid wastes in underground rock formations (by the hydrofracture method); and disposal of fly ash, cinders, construction wastes, oil, chemical liquid wastes (treated prior to discharge), and combustible and decomposable wastes by various methods (U.S. Dept. Energy 1980). These existing waste disposal activities would have little or no impacts on the usable areas of the WCR, CCR, or ECR sites.

3.6.6 Parks, Recreation, and Historic Sites

The *National Register of Historic Places* lists four sites that occur within about a 16-km (10-mi) radius of Chestnut Ridge (U.S. Dept. Energy 1979). Additionally, there are 45 known sites of archaeological significance on the ORR (Fielder 1974). The American Museum of Science and Energy is located in Oak Ridge, about 14 km (9 mi) northeast of the ORR, and was visited by about 210,000 persons in 1981. The Graphite Reactor, a national historic landmark located at ORNL, attracts 13,000 visitors annually.

A review of the archaeological survey and historical site reconnaissance documents for the Oak Ridge Reservation (Fielder 1974; Fielder et al. 1977) indicates that only one structure is located within the boundary area of the West Chestnut Ridge site. This structure consists of a "foundation only" site and is considered Condition 2, i.e., materials available could be used for restoring another cabin, if required. A number of historical structures occur on Central Chestnut Ridge. Nineteen of these structures are considered Condition 2, ten structures are Condition 3 (partially standing structures), and four structures are Condition 4 (standing structures). The majority of these structures are clustered in the eastern section and the eastern portion of the central section of Central Chestnut Ridge (Fielder et al. 1977). Historical structures were not surveyed to any degree in the ECR site. The archaeological survey of ORR (Fielder 1974) did not extensively survey either the CCR or ECR sites. However, most archaeological sites in the area are centered more along the Clinch River areas than along the ridge areas (Fielder 1974).

Although there are no hunting areas, wildlife preserves, or sanctuaries in the immediate vicinity of Chestnut Ridge, a waterfowl refuge is located on the Tennessee River about 16 km (10 mi) to the west-northwest. About 69 ha (170 acres) of the Chestnut Ridge are also used as a natural study location for ecological observation and experimentation. Information on recreational areas located near the site may be found in other publications (U.S. Dept. Energy 1979; Project Manage. Authority and Tenn. Val. Auth. 1975).

There are no federally maintained wildlife refuges, parks, or forests within the vicinity of the ORR, and there are no federally designated national wetlands in eastern Tennessee. Several swampy areas are located within the ORR, but they are small--the largest being approximately 0.2 ha (0.5 acres) in size.

About 5,550 ha (13,600 acres) of the Reservation were designated by DOE in 1980 as the Oak Ridge National Environmental Research Park (Boyle et al. 1982). This consists of areas that (1) are habitats for regionally unique, rare, or endangered species and (2) are representative of vegetative communities of the southern Appalachian region. A portion of the National Environmental Research Park is contained within the preferred WCR site and the alternative CCR site.

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4. ENVIRONMENTAL IMPACTS OF ALTERNATIVES

This section presents the environmental impacts of the reasonable alternatives, including the proposed action. The analysis in Section 2 of a range of potential alternatives for disposal of waste generated within the Oak Ridge Reservation (ORR) led to identification of three sites for a central waste disposal facility (CWDF) within ORR and two facility designs as the reasonable alternatives. The alternative sites are West Chestnut Ridge (WCR), Central Chestnut Ridge (CCR), and East Chestnut Ridge (ECR) (see Figure 2.2); the alternative designs are below-grade trenches and above-grade tumuli (see Sections 2.1.3.2.1 and 2.1.3.2.2). Reasons for eliminating other potential alternatives are presented in Section 2. West Chestnut Ridge and below-grade trenches were identified as the preferred site and preferred design, respectively.

All reasonable alternatives are rigorously explored and objectively evaluated. A detailed site characterization was carried out for the preferred site. This substantial treatment, which did not reveal any unanticipated impacts for either facility design, provided the baseline for a comparative evaluation of the environmental impacts. The comparative evaluation did not require detailed site characterization studies for the other alternative sites.

The impacts for the preferred site are examined for both facility designs. It was not found necessary to examine in detail all combinations of site and facility designs (which would yield a total of six alternatives). Such a comparison would be needed only if the ranking of the sites could reasonably be expected to be different for a different design and/or vice versa. The only characteristic used for site ranking that is sensitive to differences between the above-grade and below-grade designs is the hydrology--in particular, a water table depth that is insufficient to permit use of trenches. This sensitivity does not occur in the present circumstance because the depth to the water table is sufficient, for all three candidate sites, to allow use of trenches. One may reasonably infer from this fact that the comparative ranking of the candidate designs would be the same for all three candidate sites and that the comparative ranking of the candidate sites would be the same for either candidate design.

Potential impacts to the environment are described in this section in terms of short-term and long-term impacts. Short-term impacts are those related to the construction, operation, and closure of the disposal facility and include maintenance and monitoring activities for a period of 100 years after closure. Long-term impacts are impacts that would occur during time periods extending beyond 100 years and are related to effects of long-term integrity of the waste containment system, possible radionuclide migration from the disposal site, and land commitment.

It is assumed that institutional control would be maintained for a period of at least 100 years, and that the condition of the waste-disposal site and potential for future impacts would be reviewed prior to release from institutional control. The long-term impacts are estimated for the case in which institutional controls are lost after 100 years or are removed and the waste-disposal site is released for unrestricted use at the end of a 100-year period. The assumptions on which the estimates of radiological impacts for this case are based are very conservative and may overestimate, by an order of magnitude or more, the rate at which radionuclides migrate from the trenches or tumuli and the radiological impacts. Monitoring data accumulated during the period of institutional control, during which time the release of radionuclides and radiological impacts could be controlled and would be very small, would enable a more accurate estimate of the long-term impacts to be made at the time of review. DOE intends that institutional control would be continued beyond the 100-year period if the review indicated that removal of institutional controls might lead to radiological impacts that did not comply with standards for protection of public health and safety.

The no-action alternative, described in Section 2.1.1, is defined as that alternative which corresponds to no change from current LLW management procedures for as long as possible and management procedures that involve the least change in action thereafter. The no-action alternative is actually a delayed-action alternative because LLW would continue to accumulate, current disposal sites would become filled to capacity, and safe disposal of this waste would ultimately be necessary. Thus, apart from the additional impacts from the delay in disposal of the waste, the impacts would be the same as for the other alternatives. The only impacts involved in a comparison of the no-action alternative with the other alternatives are, therefore, the additional impacts that would result from the delay in disposal.

4.1 SHORT-TERM IMPACTS

Most of the short-term impacts would take place during the development and construction of the CWDF. The CWDF is expected to be developed in two phases. Phase I would extend through the emplacement of the first two years volume of waste. Phase II would extend through the balance of the facility's lifetime. A full description of the activities during the two phases is given in Appendix D.

4.1.1 Site Preparation and Construction

4.1.1.1 Hydrology

4.1.1.1.1 Surface Water

Construction of either below-grade trenches or above-grade tumuli would result in some temporary adverse impacts on surface water. Disturbed areas would be subject to wind and water erosion, with subsequent increases in turbidity, sedimentation, and dissolved solids in surface waters. The potential for such temporary impacts would occur in late winter and early spring during periods of high potential runoff and in the summer months during the thunderstorm season (Table 3.4). The magnitude of potential erosion impacts would depend on the steepness of slope, timing of construction, and amount of material exposed. Impacts to water quality could occur from release of oils, greases, and fuels during operation and maintenance of construction equipment and from improper management of domestic wastes generated by construction workers. These contaminants would cause a short-term reduction in water quality.

Surface runoff at the disposal site would be slightly increased due to the loss of vegetation and ground cover, resulting in reduced evapotranspiration and interception and increased imperviousness of the ground surface. The mean annual evaporation in the site area is about 122 cm (48 in.) (U.S. Geol. Surv. 1970). Alterations in streamflow regimes and drainage patterns in the creeks could also be expected. Local surface drainages might be temporarily or permanently altered by access roads and construction activities. Most impacts would be short-term, but even permanent alterations would cause only minor impacts locally. During the initial phase of construction, the volume of excavation for the construction of below-grade trenches is expected to be larger than that for the above-grade tumuli. The potential adverse impacts associated with trench construction are expected to be greater than impacts for the above-grade disposal alternative.

Impacts would be comparable between either the WCR or CCR sites because habitats, stream types, and number of streams are similar. Potentially, impacts at ECR would be slightly less because past activities, such as clearing and agriculture, have delineated small stream drainages and springs that are often covered with litter in the present areas of WCR and CCR. Also, stream drainage systems are not as extensive within ECR as compared with WCR and CCR (Figure 3.13). Additionally, the upper reaches of the streams within the ECR site are not truly perennial in nature, and usually only flow during moister spring months.

4.1.1.1.2 Mitigation (Surface Water)

Erosion and sedimentation associated with the construction of disposal facilities would be controlled through measures such as: minimizing the disturbance of vegetative cover; limiting clearing and grading; minimizing the time that excavated areas are exposed; minimizing creek crossing and fording; limiting the operation of construction vehicles and other equipment during unfavorable weather conditions; minimizing the time that the construction areas are exposed; using swales and berms in the excavation areas; using interceptor ditches, water bars, seeding, gravel, crushed stone, or mats to control erosion and runoff; and using straw bales downslope from the excavation. Appropriate measures would be incorporated into the design.

Efforts would be made to restrict refueling of construction vehicles, storage of construction materials, disposal of waste materials, and handling of any potentially contaminating material near surface waters in order to prevent contamination of these creeks. Fuels, chemicals, oils, greases, solid wastes, and materials needed at construction sites would be stored and handled in a manner to prevent accidental spills. Self-contained sanitation toilets would be provided where required to ensure protection of surface water quality.

4.1.1.2 Ecology

4.1.1.2.1 Terrestrial

The disposal areas would require about 64 ha (160 acres) of land to be committed for the life of the project. Construction of the CWDF at WCR would result in the long-term loss of a mixture of upland hardwoods (32.2 ha [80 acres]), pine plantations (21.5 ha [53 acres]), natural pine stands (3 ha [8 acres]), clearcut and abandoned fields (2.2 ha [5.4 acres]), and rights-of-way (5 ha [13 acres]) (Table 3.7). Similar habitats would be lost if construction occurs in the CCR or ECR. However, the percentage of each type of habitat affected cannot be determined with certainty because definitive disposal areas within CCR and ECR have not been identified, and habitat composition varies among the sites. For example, more than 50% of ECR consists of pastures and fields, while most areas of WCR and CCR are forested (Section 3.5.1). The habitats to be lost to construction are common on the ORR and comprise only about 12.6% of the land area occurring within the WCR boundary, less than 4% of the land occurring within the CCR boundary, and approximately 25% of the land area occurring within the ECR boundary.

The sites provide breeding habitat for many bird species due to the variety of forest types present. Forest clearing for site development would reduce breeding habitat and cause adjustments in population distributions in general. Common to abundant bird species of the site whose breeding habitat would be affected by clearing include red-tailed hawk, yellow-billed cuckoo, eastern screech-owl, great horned owl, woodpecker (red-bellied, downy, hairy, and pileated), great crested flycatcher, Carolina chickadee, white-breasted nuthatch, Carolina wren, wood thrush, pine warbler, ovenbird, yellow-breasted chat, summer tanager, and scarlet tanager. Affected species would be forced into unaffected areas where, depending on existing carrying capacity, they might be subject to greater intra- and interspecific competition for nesting habitat and food resources. If a given species is at its carrying capacity, then the total number of individuals would likely be reduced (Dvorak et al. 1978). It is anticipated that the ORR could support displaced individuals. Although tree clearing might cause adjustments in population distributions, generally the total population for any given species within Reservation would not be affected. Forest fragmentation within the CWDF buffer zone, due to loss of patches of forest habitat, might result in locally reduced populations of those species indigenous to such habitat.

The cleared areas would not initially provide habitat for bird species that inhabit fields and open areas due to the presence of construction and subsequent disposal operations. However, the creation of forest edge should enhance habitat for bird species such as cardinal, field sparrow, American goldfinch, indigo bunting, blue grosbeak, rufous-sided towhee, whip-poor-will, common crow, prairie warbler, white-eyed vireo, and common yellowthroat. The creation of edge habitat might be somewhat detrimental to wildlife species that are more restricted to forest habitat. This would occur either through competitive interactions with edge-inhabiting species or through habitat reduction. Such occurrences are somewhat commonplace (or widespread) on the Reservation due to timber-management operations.

Construction of the disposal areas would similarly affect the forest-dwelling mammals. Commonly occurring hardwood and/or pine forest mammals include: opossum, short-tailed shrew, southern flying squirrel, golden mouse, white-footed mouse, gray squirrel, and eastern chipmunk. The more common large mammals such as red fox, gray fox, white-tailed deer, and striped skunk would be less likely to be affected due to their wide-ranging habitats and variety of preferred habitats. This similarly would apply to the common bat species of the ORR.

Several of the small mammal species--including the white-footed mouse, cotton rat, least shrew, pine mouse, eastern cottontail rabbit, and woodchuck--might reoccupy portions of the disposal area after the area was capped and revegetated. The presence of woodchuck and other burrowing species might be of concern relative to trench cover integrity (see Section 4.2.1.4). However, other species such as the short-tailed shrew, golden mouse, and gray squirrel might be displaced from the disturbed areas until forest habitat were reestablished. White-tailed deer would initially leave the area of construction, but would probably acclimate to the activities associated with waste delivery and disposal. Other wide-ranging mammals such as opposum, skunk, and racoon would behave similarly. Although a localized displacement of mammals is expected, the overall effect on mammal populations within Chestnut Ridge is expected to be minimal.

Reptiles and amphibians from the construction areas would be displaced or destroyed. Most species that occur in upland or mixed hardwood and pine forests also occur in other habitats--e.g., ruderal areas, old fields, and floodplain forests. Therefore, habitats to be disturbed by construction would represent only a very small portion of habitat available to the herpetofauna. Some reptiles such as the black racer, corn snake, and rat snake might increase in the area after the capped disposal area was revegetated. This would be particularly likely to occur if white-footed mice and other small mammals increased on the site. American and Fowler's toads might also increase on the site after enclosure of each disposal area.

Fauna inhabiting areas adjacent to active site construction areas might also be disturbed if within auditory or visual detection of construction activities. This could cause animals to leave or avoid such areas, thereby impacting areas that were not physically disturbed by construction. Those animals that remained in these areas might have their feeding or reproductive activities affected, although actual prediction of such effects is difficult (Soholt and Bynoe 1982).

Based upon habitat types contained within WCR, CCR, and ECR, it could be anticipated that construction impacts to terrestrial fauna and flora would be less for the ECR alternative. This is based partly on the fact that ECR has been extensively disturbed in the past (e.g. used for hay production) and is now largely in an old-field condition. The ECR also is not contained within the boundaries of the U.S. Department of Energy Environmental Research Park. Overall construction activities would be less if extensive removal of trees is not required.

4.1.1.2.2 Aquatic

Aquatic ecosystems in the vicinity of the preferred WCR site or alternative CCR and ECR sites would be affected by construction of the three disposal areas, access roads, and ancillary facilities. Description of the disposal areas, access roads, and ancillary facilities are given in Appendix D. The potential impacts associated with construction would primarily involve (1) increased erosion and subsequent siltation of receiving streams, (2) disturbance or destruction of smaller tributaries or springs that feed the major vicinity creeks, and (3) water chemistry changes and increased flows in streams receiving groundwater or surface water from trench dewatering and site rainfall runoff. Streams that would be potentially impacted by construction activities at the WCR site are Grassy Creek (by Area A and ancillary facilities), New Zion Creek (by Areas A and C), and Ish Creek (by Areas B and C) (see Figure 4.1 in Section 4.2.2). The streams that could be impacted by construction activities at the CCR site are White Oak Creek, Bearden Creek, Walker Branch, and Bear Creek. Exactly which streams would be impacted and the extent to which they would be impacted would depend upon disposal area siting within the CCR. Streams that could be impacted by construction at the ECR site are McCoy Branch, Kerr Hollow Branch, and Scarboro Creek. Again, actual siting of waste disposal facilities within the ECR would determine the extent of impact to any specific stream. The disposal areas would be surrounded by water diversion ditches, with temporary settling ponds for collection of surface water runoff as needed.

Most adverse impacts associated with increased suspended solids and siltation--even under conditions of direct instream disturbance (e.g., highway crossing construction)--are temporary, and biota usually recolonize affected areas within a year after disturbance has ceased (Barton et al. 1972; Barton 1977; Reed 1977). Therefore, negative impacts to affected creeks are expected to be minor, temporary, and reversible. Construction impacts would be negligible to the Clinch River because any introduced solids would be within concentration ranges that currently exist in the river.

Although small feeder streams and springs might be destroyed by construction activities, it is not expected that any fish inhabit these areas. However, these systems often contain a diverse assemblage of invertebrate species as well as many of the ORR salamander and frog species. Construction activities would locally destroy some of these habitats and associated biota, but the overall impact to the site would be minimal because (1) springs and spring seeps are numerous within the ORR ridge areas, and (2) the disposal areas would be sited so as to avoid the moister areas of Chestnut Ridge where most of the seeps and springs are located.

Chemical effects to receiving streams related to construction should be negligible. The streams in the vicinity of these sites are groundwater-fed via the springs and seeps on Chestnut Ridge. Therefore, chemical constituents contained in site dewatering discharges would be similar to the constituents of the springs and seeps that feed into the streams.

Based upon the amount of aquatic habitat contained within the WCR, CCR, and ECR sites, it can be anticipated that construction impacts to aquatic biota would be less dramatic for the ECR alternative. This is because fewer streams are present within the ECR site than within either the WCR and CCR sites, and because many stream reaches on the ECR are not actually perennial flowing streams. However, the relative degree of impact related to construction activities will be comparable because adequate mitigative measures will be taken to minimize impacts to aquatic systems.

4.1.1.2.3 Mitigation (Ecology)

Measures that would be taken during construction to minimize potential impacts to both aquatic and terrestrial ecosystems are similar to those discussed in Section 4.1.1.1.2 for surface water. After initial site preparation during Phase I (Section D.2.3.1), the areas would be seeded to establish a vegetative cover to minimize erosion. Other site construction practices would include features to minimize erosion and runoff, including: (1) constructing parallel to land contours to minimize exposure of trenches to rain runoff; (2) control of surface flows by interceptor or diversion ditches, checkdams, and/or other similar structures; (3) leveling of rutted areas; (4) maintenance of existing gradients or contours where possible; (5) confining traffic to established roads; and (6) water sprinkling for dust control. Impacts to receiving streams would be minimized because site drainage patterns would be established to lessen onsite erosion. If excessive quantities of solids were being transported in the drainage ditches, a drainage basin would be made to contain most solids onsite.

4.1.2 Facility Operation

4.1.2.1 Radiological Impacts

Implementation of any one of the alternatives would require that operating personnel be exposed to low levels of radioactivity and thus incur radiation doses. These doses would be incurred by workers involved in waste treatment, packaging, loading, transporting, unloading, and disposing of the waste. In addition, workers would be involved in performing various tasks during the maintenance and monitoring period. In this EIS, only the occupational doses for transportation, disposal at the CWOF, and maintenance and monitoring at the site are estimated because these are the activities considered to be directly associated with the operational activities at the CWDF. The other ongoing activities (waste treatment, packaging, and loading) are subject to procedures developed for those activities at other facilities.

4.1.2.1.1 Transportation

Although disposal operations at the CWDF would involve separating the wastes into three categories based on proposed operating procedures, only two categories--based on the physical form of the waste--were used to estimate transportation impacts: (1) semisolid grout, and (2) all other waste forms. A large portion of the grout waste would be transported in a semisolid form that would solidify and cure after it was discharged into the disposal units of the CWDF. The semisolid grout would be transported in cement-mixer trucks that had been modified to permit use for transport of radioactive materials on public highways. Furthermore, the capability of the trucks for carrying out this task would meet U.S. Department of Transportation requirements.

Transporting the waste from Y-12, ORGDP, and ORNL to the disposal site (see Appendix D, Section D.2.1) would produce environmental impacts resulting from both the radiological character of the wastes and the nonradiological aspects of transportation. The radiological impacts of transportation are discussed in this section; the nonradiological impacts are discussed in Section 4.3.4.

Regulations. DOE has directed that the shipments will conform to standards equal to those specified by the regulations of NRC and DOT. The dose-rate limits of 49 CFR Part 173.441 dealing with radiation level limitations would not be exceeded by the wastes because the CWDF waste-acceptance criteria (<200 mrem/h) would be adhered to. The dose-rate limits of 49 CFR Part 177--Carriage by Public Highway--would be followed because part of the routing is on public roads. In particular, Part 177.842 requires that the dose rate must not exceed 2 mrem/h in any position normally occupied in the vehicle. The dose rate in the cabs of trucks transporting wastes to the CWDF is expected to be about 0.1% of this limit for grout waste and less than 0.2% of this limit for other wastes. Part 177.843 requires that the dose rate at each accessible surface of a vehicle be ≦0.5 mrem/h before reuse. Exceeding this limit by buildup of residual waste on surfaces is very unlikely, considering that the dose rate at the lateral surface of a full load of waste is only about 2×10^{-2} mrem/h for grout and about 2 mrem/h for other waste.

Radiological Impacts of Normal Transportation Operations. Radiological impacts for transportation are based on approaches outlined in reports of the U.S. Atomic Energy Commission (1972) and U.S. Nuclear Regulatory Commission (1977b), with particular reference to the methods of Chen et al. (1981). The radiological impacts that were accounted for include (1) the dose to persons surrounding the road (offlink) while the shipment is moving, (2) the dose to persons sharing the road (onlink) traveling in the same or opposite direction as the shipment, and (3) the dose to workers transporting the wastes. These dose estimates are for penetrating radiation only; doses from inhalation and ingestion are assumed to be negligible because the physical forms of the wastes are expected to be such that little or no dispersion would occur.

The dose at the surface of a truckload of waste is based only on the Cs-137 content, the predominant gamma emitter in the wastes. The typical load is assumed to have a cylindrical shape with a volume of 6.9 m^3 (9 yd^3), a radius of 91 cm (3 ft), and a length of 265 cm (8.7 ft). Gamma fluxes and doses are calculated from the geometry described above, assuming 8×10^{-4} Ci Cs-137 per load of grout and 6×10^{-2} Ci Cs-137 per load of other waste and using published graphs of (1) functions of geometry and gamma absorption coefficients (Blizard 1958), and (2) flux equivalents of dose rate (U.S. Dept. Health Educ. Welfare 1970). The estimated dose to transportation workers is based on the effects from gamma flux of a typical load on two cab occupants shielded by a 0.16-cm (1/16-in.) sheet of steel. Estimates of total dose are based on loaded distance only. Doses were calculated for two categories of waste: grout and all other wastes.

The radiological impacts of normal operations in transportation of wastes to the CWDF are summarized in Table 4.1 in terms of unit dose factors for persons participating in the work (occupational, crew) and also for persons not participating in the work (nonoccupational, offlink and onlink). The total dose was obtained by multiplying the unit dose factor by the distance traveled. The transportation dose is the same for both disposal alternatives. The doses listed in Table 4.1 for crew members are ≦0.4% of the dose that would be permitted by the whole-body limit for occupationally related exposure, defined by DOE Order 5480.1A, Chapter XI. Furthermore, the doses in Table 4.1

Table 4.1. Radiological Impacts Associated with Normal Operations in Transportation of Wastes to the West Chestnut Ridge Site

	Unit Dose Factors (person-rem/km)		Total Dose Incurred During CWDF Operating Lifetime (person-rem)	
	Grout Waste	Other Waste	Grout Waste	Other Waste
Occupational				
Crew	1.0×10^{-7}	1.7×10^{-5}	2.6×10^{-2}	8.5†[1]
Nonoccupational				
Offlink†[2]	2.3×10^{-8}	2.8×10^{-6}	6.0×10^{-3}	1.4
Onlink†[3]	6.9×10^{-9}	8.3×10^{-7}	1.8×10^{-3}	4.2×10^{-1}

†[1] This dose is ≦ 0.4% of the dose permitted by the whole-body limit for occupationally related exposure (DOE Order 5480.1A, Chapter XI). Further, assuming a crew of 2 persons per truck, this dose would be divided among at least 12 persons over the lifetime of the CWDF.

†[2] Pertaining to persons occupying positions in a 700-m band along both sides of the road during shipment.

†[3] Pertaining to persons traveling on the roads in the same or opposite direction as the shipment.

for nonoccupational exposures are all ≦0.001% of the dose that the same population would receive from natural background. An individual residing in the ORR area receives an average radiation dose from natural background of about 130 mrem/yr (Boyle et al. 1982).

Radiological Impacts of Transportation Accidents. During transport of the wastes, it is possible for an accident to occur that could result in the release of radioactive materials. If an accident occurred during transportation of wastes to the CWDF, it would be necessary for workers to clean up any materials that spilled. The largest radiological impact resulting from a transportation accident would be the dose incurred by these workers, but this dose is expected to be small. The accident rate for trucks transporting radioactive wastes is assumed to be that suggested by the U.S. Nuclear Regulatory Commission (1977b) for truck travel, i.e., 1.06×10^{-6} accidents per kilometer. The projected numbers of accidents are listed in Table 4.2.

Two accident-recovery scenarios are postulated, and the radiological impacts per occurrence are estimated for both. In the first scenario, 50% of the load is spilled. For grout waste, such a large spill would probably involve solidification of grout at the accident site and require the help of

Table 4.2. Projected Numbers of Transportation Accidents

Material Transported	Number of Shipments	One-Way Distance (km)	Total Distance (km)	Potential Accidents Involving Release of Wastes†[1]	Total Accidents Involving Release of Wastes†[1]
Grout (Y-12)	12×10^3	13	1.6×10^5	8.5×10^{-2}	1.4×10^{-1} (Grout)
Grout (ORNL, ORGDP)	25×10^3	4 (avg.)	1.0×10^5	5.5×10^{-2}	
Non-grout (Y-12)	32×10^3	13	4.1×10^5	2.2×10^{-1}	
Non-grout (ORNL)	16×10^3	3	0.5×10^5	2.6×10^{-2}	2.7×10^{-1} (Non-grout)
Non-grout (ORGDP)	8×10^3	5	0.4×10^5	2.1×10^{-2}	

†[1] Assuming 50% of the accidents involve release of wastes.

heavy equipment to recover it. The recovery is assumed to require six persons and two days. The dose from grout wastes would be 0.0009 person-rem, and the dose from non-grout wastes would be 0.11 person-rem. For comparison, these doses are about 0.1% and 14%, respectively, of the annual dose the workers would receive from natural background. Dispersion of spilled grout by rainfall is expected to add little to the impact of this scenario because the semisolid grout would be capable of absorbing a relatively large volume of water and also because dispersion, if a sufficiently large amount of water were supplied to cause it, would be limited to a relatively small area.

In the second scenario, a mixer truck carrying semisolid grout is involved in an accident and its load solidifies before recovery operations can get underway. The mixer is detached from the truck and buried whole at the CWDF, requiring three persons using heavy equipment to spend three hours recovering it. The dose from the waste would be 2.3×10^{-4} person-rem, which is about 0.1% of the annual dose the three persons would receive from natural background.

These scenarios suggest that radiological impacts from spills in transportation accidents would be small. One potential sequel to any spill of radioactive materials in a transportation accident is the spread of radioactivity to surface streams by runoff from precipitation. The risk of wastes being spilled onto the ground and subsequently spread by surface runoff of precipitation is also expected to be small. The spread of radioactive materials by such an event would be limited not only by the short time required for recovery of spilled materials but also by restricting waste shipment during inclement weather--as specified in the operating criteria.

The waste forms transported to the CWDF would be of limited mobility because of the requirements of the waste-acceptance criteria. Therefore, it is unlikely that the wastes would spread readily in any spills, including those resulting from transportation accidents.

In addition to occupational exposure resulting from a transportation accident, the possibility of radiological impact on nonoccupational personnel must be recognized. Because the population density along the route and the exposure dose rate of the wastes would be small, it is reasonable to expect that the radiological impact of a transportation accident on nonoccupational personnel would be small. The maximum individual dose resulting from loss of contents in a transportation accident is assumed to be incurred by an onlooker at the scene of the accident who is exposed to the penetrating radiation of a full load for 10 minutes at a distance of 6.1 m (20 ft) before being warned to move away. The resulting maximum individual nonoccupational dose would be 9×10^{-8} person-rem for grout and 9×10^{-6} person-rem for non-grout. In comparison, these doses are 0.00007% and 0.007%, respectively, of the annual individual dose from natural background.

A maximum individual dose to nonoccupational personnel has also been estimated for a transportation scenario in which the waste carrier is not directly involved in an accident. For this scenario, it is assumed that one person spends 1 hour at the surface of the load while the flow of traffic is stopped. Under these conditions, the maximum individual nonoccupational dose for each occurrence would be 0.000002 person-rem for grout waste and 0.0003 person-rem for non-grout. In comparison, these doses are 0.001% and 0.2%, respectively, of the annual individual dose from natural background.

It is expected that the transportation impacts would be slightly less if the CWDF were sited at either East Chestnut Ridge or Central Chestnut Ridge rather than at the West Chestnut Ridge site. The reason for this is that the transportation risk (for a given type of waste) depends primarily on the truck-miles transported. Both Central Chestnut Ridge and East Chestnut Ridge are closer to Y-12, which has the largest waste fraction. It should be noted that the transportation analysis for the West Chestnut Ridge shows that the radiological impacts are extremely low and small compared to fluctuations in background dose. Also, the accidents and resulting injuries and fatalities anticipated are extremely small.

4.1.2.1.2 Disposal

Disposal of the low-level waste would be made according to operational procedures developed specifically for the CWDF. These procedures would emphasize--among other things--minimizing contamination, using good housekeeping techniques, and minimizing occupational exposure. Although the ALARA concept would be followed during operation of the CWDF, there would be radiological impacts associated with disposal of the wastes. For this EIS, only disposal activities at the CWOF will be considered. It is recognized, however, that additional radiological impacts would be incurred by workers in the treatment and handling of the wastes prior to shipment and emplacement at the disposal site. These impacts would take place irrespective of the CWOF, and would be subject to procedures developed at the facilities that generate the LLW.

The occupational exposure for disposing of the wastes were estimated from the calculated dose rates at the lateral surface of a load of waste and based on the assumption that two persons would be in close contact with a full load for 0.5 hour during unloading operations. The estimates were made separately for grout waste and all other wastes because of the relatively large differences in their radioactivity content. The occupational exposure incurred during the 40-year operational life of the CWOF for the below-grade alternative would be 0.2 person-rem for the grout waste and 40 person-rem for all other wastes. These doses are 0.05% and 10%, respectively, of the dose that would be permitted by the whole-body limit for occupationally related exposure as defined by DOE Order 5480.1A Chapter XI. It is estimated that the occupational dose would be approximately 30-50% larger for the above-grade alternative because: (1) a trench would offer greater shielding, and (2) above-grade disposal would require longer personnel exposure time for better stacking.

4.1.2.1.3 Potential Impacts to the General Public from Operational Accidents

During operation of the CWDF, potential releases of radioactive material to the environment could occur through onsite accidents, including: (1) the sudden and complete rupturing of a waste package, or (2) an onsite fire that would consume a number of waste packages. Both accidents could result in the subsequent release of a portion of the contained radioactivity.

In the first category, the types and magnitude of accidents potentially occurring at the disposal site are generally similar to those potentially occurring during transportation of the LLW to the disposal site. Impacts from such potential accidents have been addressed in Section 4.1.2.1.1 and would be small.

In the second category, an accidental fire in a trench or tumulus could result in a short-term release of radioactivity to the atmosphere and subsequent radiation exposure to offsite individuals. The maximum amount of LLW uncovered at any time is estimated to be about 1.1×10^4 ft^3. Of this amount, about 50% is conservatively assumed to be combustible. If all of the radionuclides expected to be buried at the CWDF were present in maximum concentrations, the quantities of radionuclides given in Table 4.3 would be released to the atmosphere by a fire.

It is assumed that during the fire, conservative meteorological conditions exist. A D-stability class (neutral wind) and a 1-m/s wind speed were assumed to transport all of the radioactivity to individuals on Highway 95 (at 1024 m, the nearest point at which a member of the public might be exposed and to individuals at the nearest site boundary (2073 m distance). Radiation doses to these maximally exposed individuals are given in Table 4.4. Inhalation would account for about 98% of the dose, with submersion in radioactive air and exposure from contaminated ground surfaces accounting for the remainder of the dose.

Whole-body doses would be due mainly to thorium-232 (60%) and americium-241 (14%). These same radionuclides would dominate the dose to red marrow. The dose to lungs would be mainly from plutonium radionuclides (51%) and thorium-232 (24%), whereas the dose to kidney would be mostly from uranium radionuclides (87%).

All the doses are well below the annual dose limit allowed to an individual in an uncontrolled area by DOE Order 5480.1A.

4.1.2.2 Ecology

4.1.2.2.1 Terrestrial

Impacts to terrestrial ecosystems would be less severe during the operational phase of the CWDF than during the construction phase. Chemical wastes (e.g., grease, oil, and fuel) could arise from equipment washdown, spills, and so forth, but very little, if any, should escape into offsite surroundings because mitigative measures such as drainage diversion ditches would be employed. Thus, no detrimental chemical impacts to terrestrial systems are expected. Atmospheric releases from diesel engines would be small and are not expected to have adverse environmental impacts. Use of gravel or dirt roads within the immediate disposal areas would generate dust along the roadsides.

Site institutional care would continue 100 years past Area C closure (see Appendix D) and would include maintenance of the disposal areas in early successional stages or in a cultivated lawn-like condition. Such habitat would limit wildlife diversity and use of the area relative to that which currently exists. However, a number of early successional plant species could occur on the affected areas, largely dependent on the amount of landscaping and vegetative control conducted during the institutional-care period. Resultant habitat could vary from a landscaped lawn (as exists on some of the other disposal sites on the Reservation) to that resembling an old field. Potential early successional plant species that could occur include: grasses and herbs (broomsedge, milkweed, aster, goldenrod, panic-grass, Kentucky bluegrass, and fescue) and low-growing trees and shrubs (common persimmon,

Table 4.3. Radionuclides Released in a Fire†[1]

Radionuclide	pCi released	Radionuclide	pCi released
H-3	1.0×10^{13}	Sm-151	7.4×10^{10}
C-14	9.0×10^{10}	Eu-152	4.2×10^{7}
Na-22	4.2×10^{4}	Eu-154	2.1×10^{6}
P-32	2.1×10^{4}	Ir-192	2.1×10^{11}
Ca-45	2.1×10^{4}	Po-210	1.1×10^{8}
Mn-54	2.7×10^{7}	Ra-226	1.3×10^{8}
Fe-55	4.2×10^{4}	Pa-231	2.1×10^{2}
Fe-59	6.1×10^{7}	U-232	2.1×10^{4}
Co-60	7.8×10^{10}	Th-232	3.0×10^{10}
Ni-63	4.2×10^{4}	U-233	8.5×10^{8}
Sr-85	1.2×10^{6}	U-234	3.8×10^{9}
Sr-90	1.6×10^{12}	U-235	6.4×10^{9}
Y-90	1.6×10^{12}	Np-235	6.7×10^{5}
Zr-93	6.2×10^{10}	U-236	2.7×10^{10}
Nb-95	2.1×10^{9}	Np-237	1.6×10^{-4}
Tc-99	3.2×10^{12}	U-238	1.9×10^{11}
Sn-121	1.1×10^{10}	Pu-238	1.9×10^{9}
Sn-121m	4.2×10^{10}	Pu-239	6.2×10^{8}
Te-123	1.5×10^{7}	Pu-241	2.1×10^{7}
I-131	1.6×10^{8}	Am-241	3.0×10^{9}
Ce-133	2.1×10^{6}	Pu-242	2.1×10^{8}
Cs-134	8.9×10^{10}	Am-243	1.5×10^{6}
Cs-137	3.8×10^{12}	Cm-244	3.0×10^{9}
Ba-140	2.1×10^{5}	Cf-249	8.5×10^{1}
Ce-144	1.5×10^{10}	Cf-252	1.4×10^{7}
Pm-147	1.1×10^{10}	--	--

†[1] Assumes that 5.6×10^{3} ft^{3} of the waste is combusted.

Table 4.4. Doses to Maximally Exposed Individual from a Fire in a Burial Trench

Location of Individual	Dose (mrem)			
	Whole-Body	Red Marrow	Kidney	Lungs
Highway 95 (1024 m distance)	54	348	49	84
Site boundary (2073 m distance)	17	108	15	26

blackberry, sassafras, sumac, hawthorn, and red mulberry (Galvin 1979). Fauna that could occur in such habitats include: deer mouse, white-footed mouse, eastern cottontail rabbit, woodchuck, least shrew, field sparrow, American goldfinch, common grackle, starling, robin, eastern meadowlark, American toad, and eastern garter snake (Burt 1964; Conant 1975; Robbins et al. 1983). The type of use of the disposal site following the institutional-care period would determine biotic development. Restricted use (allowing no development of the site) would allow secondary succession to occur. In this case, either an upland hardwood or a mixed hardwood and pine forest would likely develop, resulting in the reestablishment of habitat and biota similar to that which currently exists on much of Chestnut Ridge. Unrestricted use would potentially allow for onsite development, e.g., pine plantations, agricultural farming, or housing. Biotic assemblages unique to each type of development would become established, but would be less diverse than that currently existing.

It is anticipated that impacts to terrestrial habitats associated with operation of the CWDF would be relatively the same regardless of which Chestnut Ridge site was used for the CWDF.

4.1.2.2.2 Aquatic

Chemical wastes (see Section 4.1.2.2.1) could also potentially impact aquatic systems. However, because of site drainage control and the low volumes of such wastes, the potential for aquatic systems to be contaminated would be small. Continued erosion would also be possible during operation but it is expected to be less than during construction due to such measures as revegetation and drainage control.

Drought-induced plant dieoff could occur on the disposal covers (especially for the tumuli alternative). This could cause bare areas which in turn could cause accelerated erosion. However, the amount of erosion would be less than during construction when a greater area of unvegetated land would exist. Erosion control would continue to some extent during the 100-year institutional-care period. For erosion potential following the institutional-care period, see Section 4.2.1.1.

No significant difference in the degree of impact to aquatic habitat related to operation of the CWDF on the alternative sites is foreseen because activities will be confined to the immediate disposal area and not near water bodies.

4.1.2.2.3 Mitigation (Ecology)

With proper design and mitigative measures, the maximum potential containment--with minimal environmental disturbance or contamination--can be obtained over the longest time possible. In this regard, the trenches have been designed for: (1) long-term isolation, (2) minimum active maintenance and remedial action, (3) enhancement of natural physical advantage, (4) creation of surface drainage patterns that would minimize trench infiltration, and (5) minimizing of erosion.

The trenches and grounds would be inspected and receive maintenance on a regular schedule to control trench infiltration. Erosional impacts to terrestrial and aquatic habitats would be controlled after site closure due to maintenance, monitoring, and clearing of drainage ditches during the 100-year institutional-care period.

4.1.3 Closure and Institutional Control

4.1.3.1 Site Closure

Site closure generally involves ensuring that the disposal units are securely closed and that the site is capable of containing the wastes over a long-term period with a minimum of maintenance. Site-closure activities would start at the end of the operating lifetime and continue through a 5-year active-maintenance period. These activities would include (1) decontaminating, dismantling, and disposal of all structures that are not required in the following institutional-control period; (2) inspection of trenches and grounds and remedial action wherever necessary; (3) observation of water-runoff patterns and adjustment of surfaces wherever necessary; (4) environmental monitoring and decontamination if required; (5) pumping and, if necessary, treatment of contaminated water collected in trench sumps; and (6) repair or replacement of fencing. The radiological impact of the site-closure period is expected to be even less than the relatively low impact expected for the operating period. Experience at commercial shallow-land burial grounds (Hadlock et al. 1983) has shown that during normal operations at a low-level-waste disposal site, the largest doses are received by persons working in the area of active trenches and by persons involved in offloading of individual containers. In the closure period, these two activities would be carried out only infrequently to dispose of the relatively low volume of wastes that would be generated in decontaminating and dismantling equipment and structures.

Five potential sources of minor radiological exposure in the closure period can be categorized according to the activities involved. One category involves the exposure that would be incurred during the handling of liquids pumped out of sumps. In cases where the radioactivity in these liquids prohibited their discharge to the environment, they would be transported to the liquid-waste-treatment system at ORNL. The average concentration of radioactivity in leachate, however, is expected to be less than the average concentration of radioactivity in buried wastes. A second category involves exposure incurred during the decontamination and dismantling of equipment and structures. The decontamination operations might require such operations as sandblasting, hydrolyzing, and scrubbing with decon solutions. These activities would involve minimal quantities of radioactivity because operating criteria would limit the accumulation of radioactivity on surfaces during the operating lifetime of the CWOF. A third category of exposure would occur during disposal of the materials from decontaminating and dismantling the last disposal unit. The dose rate from such activities should be small because of the small quantities of radioactivity. A fourth category of exposure would result from monitoring activities; this source also is expected to contribute only a small dose. The fifth category of exposure would result from closed disposal units in such operations as (a) final grading and seeding, (b) final surveying, (c) final inspection of all trenches, and (d) repair of trench caps. The exposure from closed trenches is expected to be less than that experienced at commercial LLW disposal sites because the average concentration of radioactivity would be lower.

The major radiological impact of the closure period is expected to consist of the external dose to the work force. This impact can be estimated by assuming that the exposure dose rate for the closure work force would be about equal to the exposure dose rate for the maintenance work force during the operational period (0.05 person-rem/yr). Thus, if the closure period is the planned 5-year active-maintenance period, the total radiological impact would be expected to be about 0.25 person-rem. In comparison, if a crew of five persons is involved, this dose is about 8% of the dose that this group of workers would receive during the 5-year period from natural background.

4.1.3.2 Institutional Control

Just as the radiological impacts of the site-closure period are expected to be less than those of the operating period because of reduced operational activity, the radiological impacts of the institutional-control period are also expected to be less than those of the site-closure period because of further reduction in activities. If the institutional-control period proceeds as expected, there would be no handling of radioactive materials during this time. The main activities would consist of (1) routine inspections, (2) maintenance of fences, (3) repair of any caps that develop subsidence, (4) maintenance of vegetative cover, and (5) post-closure environmental monitoring. The main type of exposure expected from such activities would be minimal radiation from covered disposal units. As described above, the dose rate from a covered disposal unit at the CWDF is expected to be less than the 0.01 mR/h experienced in operation of the Barnwell low-level-waste disposal sites (Chem-Nuclear 1980). If the institutional-control period required exposure of two persons to covered disposal units for 2 hours per day for 200 days per year at 0.01 mrem/h, the total dose over a 100-year institutional-control period would be less than 0.8 person-rem. For comparison, this dose is about 3% of the dose that two persons would received in 100 years from natural background.

4.2 LONG-TERM IMPACTS

Assessments of long-term environmental impacts must take into account the large uncertainties in the estimates of those impacts. There are three major sources of these uncertainties. One is the inherent limitations in the models used: even the most sophisticated models are very simplified representations of the complicated phenomena that determine the impacts. A second source of uncertainty is lack of specific data for parameters needed for the model. For example, the rate at which radionuclides are leached from the waste by infiltrating water is a critical parameter that is not known (in part because it depends on a number of other unknown parameters, such as the chemical and physical properties of the waste at the time that the leaching occurs). A third source of uncertainty is lack of specific knowledge about factors controlling "scenarios", i.e., of conditions, events, and human activities, that might occur 100 years or more in the future. The greatest uncertainty in impact prediction is from the second and third sources.

The general approach taken to solve the problem of lack of data or inability to foresee future scenarios is to use parameter values based on extrapolations from past or current experience, related data, or expert opinion. Two strategies are commonly adopted for taking into account the unavoidably large uncertainties in these judgmental estimates. One--the "best estimate" strategy--is to attempt to make realistic estimates of the data and scenario parameters. The uncertainty in the estimates is tempered by introducing a conservative bias into each estimate, but otherwise attempting to be as realistic as possible. The other--the "worst case" strategy--is to introduce a upper bounding estimate for each parameter in order to ensure that the final estimate of the impact is bounding.

The optimum choice of strategy depends on the intended application and the circumstances. The overall objective of providing environmental information needed for decision-making leads to two applications: for comparing the environmental consequences of different alternatives and for assessing the need for mitigative action. The best-estimate strategy is marginally advantageous for comparative assessment of alternatives because the errors in the differences between impact predictions for the alternatives are generally less for a best-estimate strategy than for a worst-case strategy. The advantages and disadvantages of the two strategies are approximately balanced for assessing the need for mitigative action if the impacts are not easily quantified or if well-defined standards do not exist. A best-estimate strategy provides a more realistic picture of what is likely to happen; a worst-case strategy provides insight into the worst situation that is likely to occur. In circumstances for which the impacts can be expressed in quantitative terms and standards in the form of quantitative limits have been established, the worst-case strategy is clearly preferable if the bounding estimate of the impact turns out to be less than the established limit. If the bounding estimate of the impact exceeds the established limit, then there is no clear advantage of one strategy over the other. However, for either choice it is then important to have an estimate of the probable error in order to be able to assess the likelihood that long-term impacts might exceed established limits. Credible estimates of the errors are difficult, and sometimes impossible, to obtain.

A best-estimate strategy was adopted in this document for all environmental impacts except estimates of radionuclide concentrations in water and radiological impacts, for which a worst-case strategy was adopted because well-defined quantitative limits have been established for these impacts. The estimated upper bounds for some of the radiological impacts were found to be larger than the limits imposed by current radiation protection standards. A discussion of the implications of these results is, therefore, in order.

The implications depend on the error in the estimates. Data needed to carry through a detailed error analysis that would provide case-specific error estimates are lacking. However, a judgmental estimate can be based on the following considerations. For a best-estimate strategy, it is generally accepted that state-of-the-art models used for evaluating radiation doses received via terrestrial and aquatic pathways overestimate the doses by anywhere from two to six orders of magnitude (Vaughan et al. 1981). Some authorities have estimated that the absolute error band in calculated radiation exposure to a population exposed through aquatic food chains might be a millionfold (Hoffman 1978). Underestimates are considered much less likely because conservative assumptions are made even in the best-estimate approach; however, they cannot be ruled out, and underestimates by a factor of up to 100 are considered possible (U.S. Dept. Energy Undated). These estimates have yet to be proven or disproven, but they represent a cross section of expert judgment.

The quantity of interest for interpreting worst-case estimates is the ratio of the bounding dose estimate obtained by a worst-case strategy to the probable maximum radiological impact (specified as the dose to the maximally exposed individual). This ratio will always be greater than unity if a consistent worst-case strategy is used. If the bounding estimate for a worst-case strategy corresponded to a least upper bound (i.e., a shifting of the estimate from the best-estimate value to a value corresponding to the outer limit of the error band for the best-estimate case), then one could reasonably set the ratio equal to the square root of the total error band for a best-estimate strategy. On the basis of the preceding considerations, one may reasonably infer that the ratio of the worst-case bounding estimate to the probable maximum individual dose is at least 10 and probably closer to 1000. The assumed parameter values used in a worst-case strategy are nearly always more conservative than the values one would obtain by using values at the limits of estimated error bounds. When this added conservatism is taken into account, one can be reasonably assured that the bounding estimates are overestimates by at least a factor of 10 and probably 1000 or more. This overestimate of the hydrological and radiological impacts must be kept in mind in assessing the need for action to mitigate the potential long-term radiological impacts.

Regardless of the reasons one might give in support of the expectation that the actual dose to a maximally exposed individual will be less than the regulatory limit even though the bounding estimate exceeds the regulatory limit, the irremovable uncertainty in the estimates imposes the need to examine possible mitigating measures. These are discussed in connection with the estimates of the various impacts in the following sections. The duration of institutional controls is a key factor in some of the mitigative measures proposed, and merits mention at this point.

An institutional control period of 100 years is assumed for this EIS. Impacts are calculated on the assumption that institutional controls will end after 100 years and that immediate failure of all measures to isolate the radionuclides from the environment will occur at that time. However, in view of the uncertainties in the impact estimates, the option of continued institutional control is included as a possible mitigative measure. This option is not commonly considered for commercial low-level radioactive waste (10 CFR 61); however, it is implicit in the licensing provisions and standards for mill tailings (40 CFR 192). Since the problem arises in the present circumstances as a consequence of the presence of U-238 in the waste, which presents a potential hazard that is more nearly like mill tailings than commercial LLW with respect to its duration, it is considered appropriate to consider extension of institutional control beyond 100 years as a possible option. A control system designed to be effective for at least 200 years and, to the extent reasonably achievable, for up to 1000 years is required for mill tailings (40 CFR 192). It is unlikely to be necessary to invoke this option. The more likely occurrence is that more realistic estimates will become possible before the end of the institutional control period, and that these estimates would provide a credible basis for unrestricted release of the site at the end of a 100-year period. Use of bounding estimates serves to emphasize the uncertainty in long-term estimates and the importance of monitoring activities to provide data that can be used to reduce the uncertainty in the estimates before the end of the institutional control period.

4.2.1 Site Integrity

After closure of the below-grade trenches or above-grade tumuli, physical and biological processes can affect site integrity over the long term. Following is a general discussion of these processes and their potential impact on site integrity. The resultant radiological impacts associated with site-integrity failures caused by such mechanisms as erosion, human intrusion, subsidence due to karst formation, and biologic and seismic effects are evaluated in Section 4.2.2. Because these failures are likely to be interrelated, the analysis of radiological impacts in Section 4.2.2 addresses a possible worst-case scenario bounding all such failure mechanisms.

4.2.1.1 Erosion

4.2.1.1.1 Sheet and Rill Erosion

Soil erosion, by the action of water, could prove to be an important factor in the long-term integrity of the site. The soil erosion process can degrade the stability of the protective cap, and the gradual loss and degradation of the barriers placed over the wastes would eventually allow penetration of the wastes by plant roots. The subsequent uptake, translocation, and accumulation of waste constituents by plants could serve to transport these materials into food chains and the surrounding environment. With complete erosion of the cap (or portions thereof), contaminated wastes could also be eroded and transported into the surrounding environment. To evaluate the effects of soil erosion on the integrity of the waste-containment design, potential soil loss is estimated for each alternative design.

The U.S. Department of Agriculture's Universal Soil Loss Equation (USLE) has been used to evaluate the erosion potential of cover at disposal facilities and to demonstrate the longevity of such covers. Although initially developed for evaluating average annual soil loss on cropland due to water erosion, the equation has been found to yield good estimates of long-term average sheet and rill erosion rates on uniform slopes such as those at waste-burial sites in the eastern United States (Foster 1979). The USLE has been used by the U.S. Nuclear Regulatory Commission (1980), the U.S. Environmental Protection Agency (1982), and the U.S. Department of Energy (1983b).

In this analysis, the average annual or long-term average seasonal erosion rate for the West Chestnut Ridge site is estimated using the USLE (Wischmeier and Smith 1978) according to the assumptions detailed by Knight (1983a). Soil loss (per unit area per year) due to water erosion is computed as the product of five major factors:

$$\text{Soil Loss} = (R)\ (K)\ (LS)\ (C)\ (P)$$

where R = rainfall and runoff factor, K = soil erodibility factor, LS = topographic or slope-length factor, C = vegetative cover/management factor, and P = erosion control practice factor.

Damage of the covers caused by water erosion are evaluated only for the long-term period (100 to 1000 years, or a total of 900 years). During the initial 100-year period, it is assumed that there will be no net loss of soil from the caps because site maintenance activities will include addition of soil material to the caps to replace any eroded soils.

The dominant surface soil at the Chestnut Ridge sites is the Fullerton cherty silt loam (Luxmoore et al. 1981). It is assumed that Fullerton loam will be used as the 1.8-m (6-ft) topsoil cover on the disposal site.

During construction of the cap, the cover soils will be compacted to varying extents by trucks and heavy earth-moving equipment. Such compaction will drastically alter the physical characteristics of the soil such as bulk density, thereby altering the soil erodibility factor (K). With time, however, the physical characteristics of the cover soils will return to a state similar to that of undisturbed native soils of the same soil classification due to such processes as the action of plant roots penetrating the cap surface, frost heave, and soil desiccation. For the long-term period, therefore, the bulk density of undisturbed Fullerton loam soils will be used to estimate the K factor.

Long-term vegetation management (i.e., land use) is the single most important determinant of the rate of water erosion at a waste-burial site (Knight 1983a). The range of soil loss that can be expected at the West Chestnut Ridge site for the long-term period (200 to 1000 years) is estimated by assuming that erosive and nonerosive land uses (agriculture and natural succession to forest, respectively) represent the extreme bounds of possible uses affecting long-term erosion rates. The erosive land use assumes that the West Chestnut Ridge site is used for 4-year crop rotation of wheat, meadow, and corn (grown in two successive years) using good soil management practices (e.g., contour plantings) (Wischmeier and Smith 1978). This land-use pattern is evaluated as a worst-case erosion scenario only and is not expected to occur. The nonerosive land use is assumed to be a mature oak-hickory forest, the local climax vegetation for the West Chestnut Ridge site (Whittaker 1975). The values of the vegetative cover factor (C) for each of the various successional stages involved in the development of mature forests of the sites have been determined using information presented in Wischmeier and Smith (1978) and are presented in Table 4.5.

The erosion calculations do not allow for variations of the soil erodibility factor (K) for the various cover layers. It is possible that the rate of erosion may be reduced by the cobble-gravel layer. Agriculture may not be possible in such layers but, similarly, plant development may be reduced on these layers, thereby reducing vegetative cover and increasing erosion losses. Natural succession rates would also be slowed by these layers.

Table 4.5. Land Use, Stage of Succession, and Universal Soil Loss Equation (USLE) Factors Used in Estimating Water Erosion from the CWDF

Disposal Facility Design	Land Use	Stage of Succession†[1]	Length of Stage (yr)	USLE Factors†[2]				
				R	K†[3]	LS†[4]	C	P
Tumulus	Agriculture†[5] (4-yr crop rotation)	-	900	470	0.28	6.0, 0.3, 5.0	0.35	0.5
	Natural succession (oak-hickory forest)	Old field/meadow	50	470	0.28	6.0, 0.3, 5.0	0.011	1.0
		Shrub	250	470	0.28	6.0, 0.3, 5.0	0.04	1.0
		Early forest	200	470	0.28	6.0, 0.3, 5.0	0.011	1.0
		Mature forest	400	470	0.28	6.0, 0.3, 5.0	0.001	1.0
Trench	Agriculture†[5] (4-yr crop rotation)	-	900	470	0.28	0.5	0.35	0.5
	Natural succession (oak-hickory forest)	Old field/meadow	50	470	0.28	0.5	0.011	1.0
		Shrub	250	470	0.28	0.5	0.04	1.0
		Early forest	200	470	0.28	0.5	0.011	1.0
		Mature forest	400	470	0.28	0.5	0.001	1.0

†[1] General successional patterns developed from information in Daubenmire (1968), Whittaker (1975), and VanKat (1979).

†[2] R = rainfall and runoff factor; K = soil erodibility factor; LS = topographic or slope/length factor; C = vegetative cover/management factor; P = erosion control practice factor. All data from Wischmeier and Smith (1978), except K factors obtained from state soil conservation services for the Fullerton silt loam and LS factors estimated using Wischmeier and Smith (1978) and burial site dimensions and structural details.

†[3] No account has been taken of the effectiveness of the cobble/gravel layer in reducing the erosion rate. The weathering rate of such a layer is dependent upon the rock type used.

†[4] Three LS factors given for the tumulus design represent the LS factor for the steep outer slope of the mound, the top slope of the mound, and the average tumulus slope, respectively.

†[5] Agricultural erosion rates are considered here to represent a worst case for sheet and rill erosion. Such land use is not expected to occur at the Chestnut Ridge sites.

The average annual soil losses are calculated using the values presented in Table 4.5. The long-term soil losses, which are derived by extrapolation of the average annual soil loss estimates, are presented in Table 4.6. Such estimates are used solely to compare the relative potential for loss of containment under the trench and tumulus scenarios and are not intended to predict the actual longevity of containment.

It should be noted that the USLE can be used to estimate an idealized average rate of soil loss from a sloping surface. In actuality, however, localized variations in soil texture, vegetative cover, drainage, etc., along a given slope could increase or decrease soil erosion rates at specific locations along the slope. Erosion rates along a given slope may also be smaller downslope as the material eroded from upslope areas is redeposited.

Because the USLE cannot be used with any validity to analyze erosion rates for slopes in excess of 18% and because of the change of the slope parameter (LS) with time,* an averaged slope for the tumulus piles was also evaluated. This averaged slope estimate reflects an underestimation of the erosion rates for the steep side slopes of the tumulus and an overestimation of the erosion rates for the more gentle top slopes. Such averaged slopes, however, may more closely approximate the ultimate shape of the tumulus in the long-term period.

Changes in environmental factors such as climate and topographic relief that could occur during the long-term period would subsequently alter the composition and structure of plant communities on the Chestnut Ridge sites. Changes in these factors would, in turn, alter the rate of soil erosion. Unfortunately, current state-of-the-art modeling is not capable of predicting such changes.

Although the constraints of the USLE (Foster 1979) limit the accuracy of the soil erosion estimate for the Chestnut Ridge sites, a number of general conclusions can be made. Neither erosive nor nonerosive land-use patterns (agricultural or natural succession) would result in the complete erosion of the protective earthen cover over the wastes in the trench design. Only under the unlikely erosive land-use pattern would complete erosion of the protective cover of the tumulus occur prior to 1,000 years. Sheet and rill erosion losses would be greatest for the tumulus design under an agricultural land-use regime and would be minimal for the trench design under both agricultural or natural succession regimes.

4.2.1.1.2 Gully Erosion

Although the USLE can be used to approximate long-term soil erosion loss from the cover systems by sheet and rill erosion, it cannot be used to estimate the potentially severe losses due to gully erosion. There are two forms of gully erosion: (1) "headcutting" or erosion of gullies from adjacent drainage areas and subsequent intrusion into the disposal area, and (2) "direct

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*Upslope erosion and subsequent downslope deposition would result in increases in slope length and decreases in slope height.

Table 4.6. Estimates of Annual and Long-Term Erosion of the Earthen Cover Systems for the Tumulus and Trench and Cover Thickness at 500 and 1,000 Years for the Trench and Tumulus Alternatives at the Chestnut Ridge Sites

	Annual Erosion Rate (cm/yr) Relative to Land Use (Vegetation)			
	Tumulus		Trench	
Parameter	Agriculture†[2]	Natural Succession†[3]	Agriculture†[2]	Natural Succession†[3]
Steep outer slope of tumulus (4:1)	1.0 - 0.3	0.2 - 0.006	-	-
Top slope of tumulus	0.09	0.09 - 0.0003	-	-
Averaged slope of tumulus or trench	1.0 - 0.3	0.2 - 0.005	0.09	0.04

	Total Erosion (m) Relative to Land Use (Vegetation)							
	Tumulus				Trench			
	Agriculture†[2]		Natural Succession†[3]		Agriculture†[2]		Natural Succession†[3]	
Parameter	500 yr	1000 yr	500 yr	1000 yr	500 yr	1000 yr	500 yr	1000 yr
Steep outer slope of tumulus (4:1)	2.1	3.5	0.7	0.8	-	-	-	-
Top slope of tumulus	0.4	0.75	0.04	0.04	-	-	-	-
Averaged slope of tumulus or trench	2.0	3.4	0.6	0.6	0.2	0.7	0.03	0.04

	Estimated Cover Thickness (m)							
	Tumulus				Trench			
	Agriculture†[2]		Natural Succession†[3]		Agriculture†[2]		Natural Succession†[3]	
Parameter	500 yr	1000 yr	500 yr	1000 yr	500 yr	1000 yr	500 yr	1000 yr
Steep outer slope of tumulus (4:1)	0.9	-0.5	2.3	2.2	-	-	-	-
Top slope of tumulus	2.6	2.25	2.96	2.96	-	-	-	-
Averaged slope of tumulus or trench	1.0	-0.4	2.4	2.4	2.8	2.3	2.97	2.96

†[1] Estimates are intended for purposes of comparing the relative potential for the loss of containment resulting from sheet and rill erosion only, not for predicting the actual longevity of containment. These estimates do not evaluate the effectiveness of the cobble/gravel layer in slowing the rates of erosion for either the tumulus or trench design.

†[2] Four-year crop rotation. This land-use pattern is evaluated as a worst-case erosion scenario and is not expected to occur at the Chestnut Ridge sites.

†[3] Oak-hickory forest.

gully erosion" or the formation of gullies directly on the disposal facility cover. At present, there are no models that can predict the possibility or extent of erosion losses by gully erosion.

Because of the topographic relief and drainage networks at the Chestnut Ridge sites. "Headcutting" gullying is possible and could affect both the trench and tumulus cover designs. However, because there is mature climax vegetation cover in the areas surrounding the site, there is less possibility that such gully erosion would develop. Removal of this vegetation by fire or changes in land use could trigger "headcutting" gullying of drainage systems adjacent to the waste-disposal facilities.

The potential for "direct" gully erosion to occur at the Chestnut Ridge sites would be dependent upon the stability of the vegetative cover of both the trench and tumulus designs and on the slope stability of the tumulus design. Loss or reduction of the vegetative cover as a result of drought, fire, land-use changes, etc., as well as seasonally heavy rains could trigger "direct" gully development in either the trench or tumulus facilities although the losses would be potentially more severe for the tumulus design because of the greater topographic relief. The steep outer slopes of the tumulus pile would be especially vulnerable to gully erosion. Failure of the tumulus side slopes as a result of saturation or seismic events could also initiate gully erosion.

The magnitude of gully erosion possible at the Chestnut Ridge sites cannot be estimated at this time. If a site is not under active routine surveillance, gully erosion losses may be substantial, and such losses could jeopardize the containment systems. The probability of gully erosion after controls are lifted is considerably greater for the above-grade alternative than for the below-grade alternative.

4.2.1.2 Geologic Effects Applicable to the Trench and Tumulus Designs

Although detailed geologic investigations conducted in the disposal area have failed to locate any solution features in the immediate vicinity of the West Chestnut disposal facility (Woodward-Clyde 1984; Ketelle and Huff 1984), such solution features are known to occur in the Knox Formation (see Section 3.2.2). Any karst features, if present under the disposal area, could pose a potential threat to the integrity of either the tumulus or trench disposal facility designs. Enlargement and collapse of any such karst features under the disposal facilities could result in the partial or possibly total subsidence of either the trench or tumulus type facility over the solution feature. Depending on the extent of such subsidence, the cover systems of either type of disposal facility could be disrupted--allowing increased infiltration of surface waters to the wastes. Such incidents, however, are considered unlikely for the proposed trench or tumulus designs because of the physical properties of residuum soils and the mitigative measures considered in the selection and design of the disposal facility.

The range of age of soil formation on the Chestnut Ridge sites is believed to have extended from late Tertiary or early Pleistocence (1 million years) to Holocene or Recent (post European settlement) (Lee et al. 1984). The residuum soils are composed of the insoluble residue resulting from weathering of the carbonate rock over a certain time period. A conservative estimate of the rate of bedrock weathering and soil formation indicates that several tens of thousands of years were required to form the existing soil mass (Ketelle and Huff 1984). This time span suggests that the soils at West Chestnut Ridge site have remained in place for their formations for periods of time far exceeding the performance period of a LLW-disposal facility. In addition, measures have been taken to avoid locating potential disposal areas in proximity of known karst features. The site has also been designed to exclude the mapped karst features from the areas usable for trench or tumulus layout. The exclusions extend from the center of the karst feature to the perimeter of the area of topographic influence of the karst features. With these considerations, it is expected that the occurrence of karst features on the site and the potential consequence of a karst soil collapse would be alleviated. Nevertheless, the pathway analyses as presented in Section 4.2.2 considers a worst-case analysis applicable to failure of all disposal design features including occurrence of karst subsidence.

The potential for moderate damage from earthquakes in eastern Tennessee (see Section 3.2.3) suggests the possibility of failure of the steep outer slopes of the tumulus disposal unit during the long-term period. Seismically triggered failure of the tumulus would be most likely to occur if the tumulus became saturated following failure of the internal drainage system of this design (see Section 4.2.1.3). Seismic activity might also trigger settling of the sand layers in the cover systems of both the trench and tumulus designs, resulting in disturbance of the drainage systems of the disposal facility.

4.2.1.3 Potential Design Failures

4.2.1.3.1 Tumulus

The existence of ceremonial mounds found throughout the world demonstrates the survivability of man-made earthen structures for periods exceeding 1,000 years. Thousands of such mounds have been found in the eastern United States and available evidence indicates a high survival rate for these mounds (Lindsey et al. 1983). Excavation of some of these U.S. mounds has revealed structures similar to those considered for the West Chestnut Ridge tumulus facility (e.g., layering or manteling of soils in compacted layers a few feet thick, clay caps, vegetative cover).

Despite the historic evidence to substantiate the possible survivability of such mound features, it is necessary to analyze the potential failure mechanisms that may affect the long-term integrity of the tumulus-type facility at West Chestnut Ridge. With time, eluviation of fine soil particles from one layer to the next would result in the eventual clogging of the tumulus internal drainage systems. Beyond the initial maintenance period, maintenance of the external drainage systems would also stop and these drainage systems would eventually fill. Failure of these drainage systems would alter the surface and groundwater flow regime in and around the tumulus and might eventually result in ponding of surface water, poor drainage in the tumulus, and saturation of the wastes. Failure of the drainage system underlying the mound that drains the sand layer might result in a blowout failure of the toe of the mound. The rate at which such failures might occur is uncertain.

Some seismically related tumulus failures might also be expected to occur over the life of the disposal facility. Liquefaction failure of the sand layer might be possible, especially if the layer were saturated at the time of the seismic event, causing possible outer slope failure. Cracking of the concrete pad or disturbance of the peripheral or interior walls could also occur. Such damage would, if severe, jeopardize the cover system integrity by disrupting the drainage systems.

Settlement of the bulk or containerized wastes might also lead to the development of cracks or depressions in the cover system that could disrupt the internal drainage systems of the tumulus and increase water infiltration into the wastes. Settlement of the sand or cobble/gravel layers would be expected to be small.

4.2.1.3.2 Trench

As with the tumulus design, eluviation of fine soil particles would eventually result in clogging of the internal drainage systems of the trenches. Past the initial maintenance period, maintenance of external drainage systems would be stopped and external drainage systems would also fail. Failure of these drainage systems would alter the surface water and groundwater regimes around the waste trenches and could eventually result in increased saturation of the wastes.

The seismic activity expected for this region for the long-term period might trigger settling of wastes or the sand or cobble/gravel layer in the cover systems. Settling of the cover would result in disturbance of the cover system integrity and might result in ponding of water on the trench cover and increased infiltration into the trench. Compaction of the bulk wastes during emplacement and grouting of the interstitial spaces between the waste containers would minimize such settling of wastes.

It should be noted that the radiological pathway analysis bounds design failures as a result of seismic activity for both the trench and tumulus alternatives.

4.2.1.4 Biotic Effects

Biota can either beneficially or adversely affect the long-term integrity of the proposed containment systems by physically and chemically altering the cover layers. Beneficial aspects include: increased soil stability, decreased erosional losses, and improved tilth which allows for potential productive land use of the cover surface. On the other hand, plant and animal intrusion through the cover system could result in the development of physical and biological pathways for the mobilization and dispersion of contaminants from the system.

Disturbance of the cap by burrowing animals, the creation of channels by plant roots, and the formation of soil aggregates by microorganisms all would have the effect of decreasing soil bulk density and producing interconnected voids of various sizes. Increased water infiltration into the tumulus cap could increase the likelihood of slippage or slumping of the cap materials along the clay/sand interface, especially in the steeper perimeter slopes of the tumulus disposal design.

Increased infiltration might also result in more water moving through the cover layers into the stored wastes where accelerated leaching and contamination of groundwater could occur. These effects could be balanced by the enhanced water storage capacity of soils due to modification by biological activity, as well as by the ability of vegetation to absorb and transpire large amounts of soil moisture back to the atmosphere.

Numerous examples of plant root intrusion into buried radioactive wastes have been reported (Cline and Uresk 1979; Fitzner et al. 1979; Breedlow et al. 1982; Yamamoto 1982). If the riprap and other layers of the containment covers over the wastes were breached by deep-rooted plant species, uptake of radioactive and other waste constituents might take place, with transport of some fraction of these constituents to above-ground or near-surface plant organs (Knight 1983b). Waste constituents could then be dispersed either directly to the atmosphere (as in the case of tritium) or to food webs via a variety of conventional herbivores (mammals, reptiles, insects, etc.). Physical dispersal of contaminated plant parts by wind and water could also occur.

Burrowing rodents, carnivores, ants, and termites have been reported as intruding into buried radioactive wastes (Fitzner et al. 1979) and, as such, are a potential problem with regard to isolating such wastes for extended periods of time (Oak Ridge Natl. Lab. 1979). Tunneling activities of animals cause soil pulverization, transfer of materials between layers of the containment structure, and creation of voids as tunnels and nest chambers. Loose soil and/or waste materials brought to the surface by burrowing activity will be subject to accelerated erosion and dispersal in the environment compared to undisturbed, vegetated soil surfaces (Hakonson et al. 1983). Small mammals have been reported to excavate anywhere from 4 to 55,000 kg soil/ha/yr (3.56 to 49,090 lb/acre/yr) (Ellison 1946; Abaturov 1972). Contaminated animal biomass entering food webs is another route of waste constituent dissemination.

Both the trench and tumulus caps would be invaded by plant roots and animals. The effective rooting zone would be only about 0.9 m, which would preclude the development of most mature native trees (Spurr and Barnes 1973) and would be limiting to many other plants except grasses, forbs, and some shallow-rooted shrubs and small trees. Shrubs and trees would germinate and become established in this soil depth but their growth would slow when the roots encountered the topsoil and cobble-gravel interface. Local species that are adapted to heavy soils would continue to grow on the compacted topsoil layer. As the initial intruding roots died and left channels through the topsoil layer, other plant roots could follow. Eventually, soil settling and rock fragmentation would fill the interstices within the cobble-gravel layer and provide a soil pathway for plant roots (Hakonson et al. 1983).

The early plant communities on the disposal unit areas would be slightly more susceptible to erosion and would provide poorer wildlife habitat than the surrounding area. The initial plant community, and the later mature communities that developed on either type of cap, would be particularly susceptible to drought because of the shallow depth and drainage of the caps. Following long periods without precipitation, large areas of bare ground might be produced that would be subject to accelerated erosion. The stressed plant communities on the caps would also be more susceptible to the adverse effects of herbivores (grazing animals and insects), disease, and fire than the surrounding plant communities growing on normal soils of the area.

The plant communities on the covers would undergo plant succession following the cessation of active site maintenance. However, the successional patterns would likely be different than those in the surrounding plant communities on normal soils. During the maintenance period, this succession would be regularly interrupted by activities aimed at precluding or destroying large, deep-rooted plants. During the long-term period after maintenance ceased, cover communities might initially "stagnate" in a grass/forb/small-shrub/small-tree stage, with a few individuals of larger tree species usually present. These young trees might not reach maturity because of their susceptibility to drought. When adequate moisture was restored, the cycle would begin again with new seedlings replacing the plants that died. During the first 300 years of the long-term period, biological modification of the cover layers would continue and adapted plant species would colonize the cover. Eventually, deep-rooted mature trees would develop. Continued soil modification, development, and settling combined with vegetation succession might result in the establishment of a climax forest. However, this community would continue to be more susceptible to drought than a similar one on normal soils of the area.

The cobble-gravel layer in the tumulus and trench covers would initially deter burrowing animals from intruding into the wastes and residues. However, as root growth modified and disrupted these layers, mammals, ants, and other insects would intrude into the contaminated materials because the materials would be within the known tunneling depths of these organisms (Cline et al. 1982). As the thicknesses of the covers became appreciably reduced by erosion, the likelihood of animal intrusion would increase.

4.2.1.5 Mitigation (Site Integrity)

Maintenance and mitigative measures would ensure against adverse physical and biotic effects until the end of the institutional-care period. Maintaining the physical integrity of the disposal trenches or tumuli is important because the covers would be designed to lessen the potential of biointrusion. Such measures to be initiated at site closure include: compaction of trenches, remedial action for any observed threats to trench integrity (e.g., ponding, subsidence, and inadequate vegetation cover), observation of drainage patterns to ensure avoidance of infiltration and erosion, and leaving earthen checkdams upstream of each trench to divert surface runoff. The following mitigative measures could be considered to control biointrusion: (1) removal of large, deep-rooted plants, (2) herbicide treatment to prevent regrowth of such plants, (3) trapping and/or poisoning of burrowing animals, (4) insecticide treatment to control burrowing insects, and (5) addition to and recompaction of the soil layers.

4.2.2 Groundwater Impacts

Contamination of area groundwater and/or surface water as a result of the transport of radionuclides from the CWDF site could result in exposure of an individual and the general public. Exposure of an individual may occur after institutional controls have ceased. The individual could inhabit the CWDF site and consume contaminated water from a site surface water body or from an onsite well. The general public could consume contaminated water from a public water supply source that receives contaminated groundwater and/or surface water discharges. The nearest potential public water supply source is the Clinch River.

In this section, the potential impacts of waste leachate from the Chestnut Ridge sites on groundwater and surface water are analyzed for two disposal alternatives--below-grade burial in trenches and above-grade disposal in tumuli are considered in the analysis. The analysis considers that the site would be under institutional control for at least 100 years following closure of the disposal site. During this period, it is expected that site integrity would be properly maintained and the disposal units would operate satisfactorily. Any leachate from the waste would be minimal and would be collected and pumped out of the burial ground, resulting in insignificant contaminant migration. Therefore, the analysis of groundwater impacts assumes that the leachate migration occurs after the first 100 years of the institutional-control period.

The estimates of released quantities of material and the scenarios leading to such releases depend on many factors, some of which are not precisely known at this time--such as the exact inventory of the LLW, leach rates, retardation factors, etc. Therefore, assumptions are required when the data are lacking. These assumptions were made based on engineering judgment and available data and are considered conservative--that is, the values overstate rather than understate the quantities of a radiological release. However, because of the assumptions that had to be made, the quantities of radiological release given in this section must be regarded as estimated maxima rather than confident predictions of expected values.

4.2.2.1 Waste Streams - Source Term

The wastes to be disposed at the site would be low-level radioactive wastes generated from Y-12, ORGDP, and ORNL. An analysis of radionuclide migration (Pin and Witherspoon 1984) has been based on a representative portion of the waste. The volume of wastes received on a routine schedule is expected to eventually reach 11,000 m^3/yr (380,000 ft^3/yr). In addition, the volume of wastes received on a nonroutine schedule may reach a level of 20,000 m^3/yr (700,000 ft^3/yr). A portion of these totals would consist of sludges fixed in grout to be received on a routine schedule at a rate of 6,000 m^3/yr (200,000 ft^3/yr). An additional volume of grout may be received on a non-routine schedule at a rate of about 10,000 m^3/yr (40,000 ft^3/yr) for a limited period of 3.5 years. The remaining waste mass is expected to be disposed in bulk or baled form with little or no containment. This latter type of waste is unstabilized and is considered most likely to experience slumping, subsidence, and degradation--thus potentially generating higher percolation and leaching rates than grouted wastes. Therefore, the wastes in bulk and baled form are used to produce conservative source terms for the groundwater impact analysis.

The waste acceptance criteria for the CWDF will limit the waste streams to those that are equivalent to Class A waste in the NRC waste classification scheme, with the exception of the limit on the allowed concentration of transuranic (TRU) elements. This limit would be 100 nCi/g rather than 10 nCi/g, which is the limit allowed for NRC Class 8 waste. Waste corresponding to NRC Class C waste would not be allowed.

Analysis of waste streams indicates that the wastes expected to be buried at the site include an assortment of radionuclides. These radionuclides and their average concentration in the unstabilized waste form 100, 500, and 1,000 years after closure of the CWDF are given in Table 4.7. A complete

Table 4.7. Average Concentration of Selected Radionuclides for CWDF Groundwater Impact Analysis

Radionuclide	Yearly Expected Activity, Delivered (Ci/yr)	Average Concentration (pCi/mL)	Half-Life (yr)	Average Concentration (pCi/mL)		
				100 yr	500 yr	1000 yr
H-3	210	3.0×10^{4}	1.23×10^{1}	1.1×10^{2}	1.7×10^{-8}	1×10^{-20}
C-14	2	2.8×10^{2}	5.73×10^{3}	2.8×10^{2}	2.6×10^{2}	2.5×10^{2}
Co-60	2	2.8×10^{2}	5.30	5.8×10^{-4}	1.1×10^{-26}	4.5×10^{-55}
C-137	82	1.2×10^{4}	3.02×10^{1}	1.2×10^{3}	1.2×10^{-1}	1.3×10^{-6}
Sn-121m	1	1.4×10^{2}	5.5×10^{1}	3.9×10^{1}	2.6×10^{-1}	4.7×10^{-4}
Sr-90	34	4.8×10^{3}	2.86×10^{1}	4.2×10^{2}	2.6×10^{-2}	1.4×10^{-7}
Tc-99	2	2.8×10^{2}	2.13×10^{5}	2.8×10^{2}	2.8×10^{2}	2.8×10^{2}
Zr-93	2	2.8×10^{2}	1.53×10^{6}	2.8×10^{2}	2.8×10^{2}	2.8×10^{2}
Pu-238	0.03	4.3	8.78×10^{1}	1.9	8.3×10^{-2}	1.6×10^{-3}
Pu-239	0.11	1.6×10^{1}	2.41×10^{4}	1.6×10^{1}	1.5×10^{1}	1.5×10^{1}
Am-241	0.05	7.1	4.32×10^{2}	6.1	3.2	1.4
Cm-244	0.05	7.1	1.81×10^{1}	1.5×10^{-1}	3.4×10^{-8}	1.7×10^{-16}
U-234	0.01	1.4	2.47×10^{5}	1.4	1.4	1.4
U-235	0.23	3.2×10^{1}	7.00×10^{8}	3.2×10^{1}	3.2×10^{1}	3.2×10^{1}
U-238	2.73	3.8×10^{2}	4.4×10^{9}	3.8×10^{2}	3.8×10^{2}	3.8×10^{2}

Source: Pin and Witherspoon (1984).

description of waste streams that would be emplaced in the CWDF is given in Appendix C.

4.2.2.2 General Model Description

4.2.2.2.1 Hydrogeological Conditions at the West Chestnut Ridge Site

As discussed in Section 3.3.2, shallow unconfined aquifers occur below the preferred CWDF site. These aquifers are localized with recharge occuring in the higher elevations and are most susceptible to contamination resulting from the vertical migration of waste leachate from the burial trenches or tumuli. Any contamination that may occur in the unconfined aquifers can potentially reach the alluvium of three nearby creeks: Grassy Creek, New Zion Creek, and Ish Creek. These creeks drain the site and, in turn, discharge into the Clinch River. The locations of these creeks, relative to the WCR site and the Clinch River, are shown in Figure 3.8.

The interconnecting pathway through groundwater and then surface water appears to be the most critical pathway for contaminating the water system in the area. Therefore, this pathway was considered in the analysis of the transport of radionuclides from the trenches or tumuli located within the proposed site. A direct subsurface hydraulic connection between the shallow aquifers and the Clinch River has not been established, although one may exist (Pin and Witherspoon 1984). Also, any radionuclides that may be transported from the shallow aquifers to a deeper regional bedrock aquifer and then to the Clinch River are likely to be diluted to a large extent by the deeper aquifer and, therefore, would not create significant contamination.

A plot plan showing the proposed locations for the trenches (or tumuli) in the WCR site is shown in Figure 4.1. Three separate disposal areas have been identified: Area A consists of 29 ha (71 acres), Area B is 16 ha (40 acres), and Area C is 19 ha (46 acres). Examination of the plot plan indicates that the trenches (or tumuli) would be located in two distinct ridge areas with trenches extending from the ridgetop down one side of each hill only. Because the localized shallow aquifers are a subdued image of the surface topography (Ketelle and Huff 1984), it is anticipated that most of the radionuclides reaching the shallow aquifer from the trenches (or tumuli) in Area A would be discharged to the alluvium of New Zion Creek. Similarly, most of the radionuclides reaching the shallow aquifer below Areas B and C would be discharged to the alluvium of Ish Creek (Figure 4.1).

A two-dimensional vertical cross section was selected to study radionuclide migration. The location of this cross section is indicated by the dashed line A-A' in Figure 4.1, and a cross-sectional drawing depicting the major geologic and hydrogeologic features is shown in Figure 4.2. The lateral boundaries of the cross section coincide with area stream channels--Grassy Creek on the right and New Zion Creek on the left. The location and extent of this cross section were selected to represent the site layout and the uniform hydrogeologic characteristics of the WCR site.

4.2.2.2.2 Mathematical Models

Modeling the migration of radionuclides from burial trenches (or tumuli) to the groundwater system at the WCR site involves two principal phases: groundwater hydraulics and solute transport. The hydraulic model, which gives

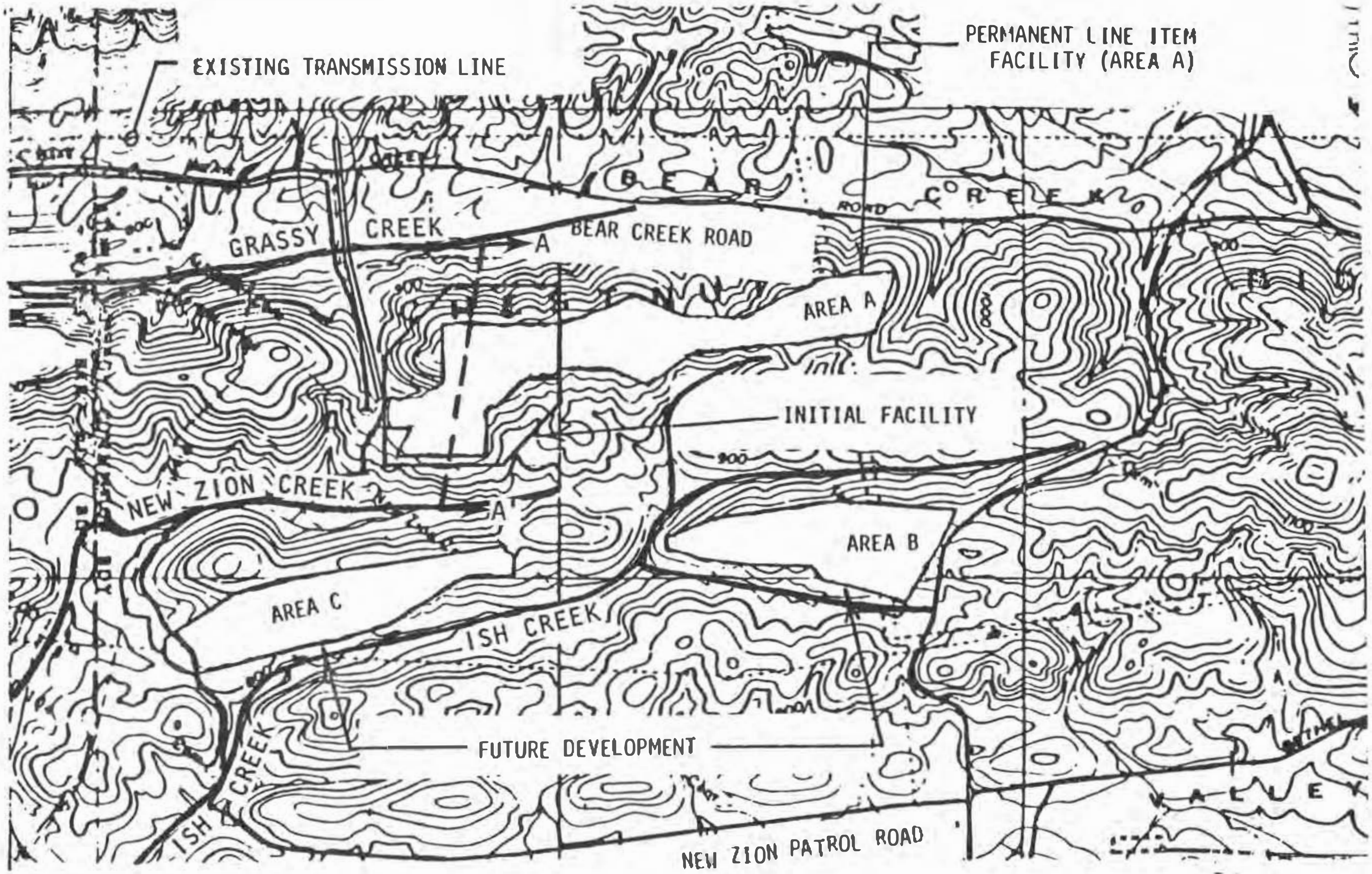


Figure 4.1. Plot Plan for Proposed Waste Disposal Areas at the West Chestnut Ridge Site. Source: Adapted from Ebasco Services Incorporated (1984).

the solution to the two-dimensional (longitudinal and vertical) partial differential equation of groundwater flow, generates groundwater flow velocities at various times and locations in the subsurface system. These flow rates and directions are then used in the solute transport model to simulate the migration of radionuclides in time and two-dimensional space. The solute transport model includes the effects of convective transport, hydrodynamic dispersion, radioactive decay, and chemical sorption. The flow and solute transport equations have been described in detail by Yeh and Ward (1980, 1981), Bear (1979), and Robertson (1974). For the current study, solutions of the flow and solute transport equations were obtained by using the finite-element models FEMWATER and FEMWASTE developed at Oak Ridge National Laboratory (Yeh and Ward 1980, 1981).

The FEMWATER and FEMWASTE models are designed to simulate contaminant transport in a saturated or unsaturated porous medium subject to variable initial or boundary conditions. These two codes have been verified and are generally considered to be good models for simulating contaminant transport in aquifer systems, especially in the unsaturated zone (Thomas et al. 1982; Oster 1982).

For the finite-element computation, the schematic cross section shown in Figure 4.2 was subdivided into an assemblage of small elements of various sizes. Constant head conditions are assumed at Grassy Creek and New Zion Creek based on the observed water levels in these streams. The upper boundary corresponds to site surface topography. Slope-dependent infiltration rates are imposed on this boundary. The lower boundary is assumed to lie within sound bedrock below which water movement and flow rates are negligible.

The source term that defines the boundary conditions at the bottom of the burial trenches (or tumuli) is a major factor in determining the radionuclide concentrations in the aquifer system. For model simulation, the disposal facility is assumed to be under institutional control for a period of at least 100 years. During this time period, the integrity of trench (or tumulus) caps and drain systems are maintained, and hence, no leachate is generated and no radionuclides will migrate from the burial site. However, the radionuclides in the trench (or tumulus) will undergo radioactive decay. For the purpose of establishing a bounding (worst) case, the integrity of trench (or tumulus) caps is assumed to fail after 100 years--allowing water to enter the trenches, saturating the waste, and generating leachate and radionuclide migration.

4.2.2.3 Hydrogeological Parameter Values for the West Chestnut Ridge Site

The values of various hydrogeological parameters were selected to generate conservative estimates of radionuclide concentrations in groundwater. For the model calculation, it is assumed that immediately following the institutional-control period, water in the amount equal to the average annual rainfall rate of 4.4×10^{-6} cm/s (1.7×10^{-6} in./s) will enter the burial waste. The wastes are assumed to be uniformly distributed in the trench (or tumulus) and compacted to a porosity of 0.5. For the assumed infiltration rate and waste porosity, total waste saturation is estimated to occur after 1.6 years (Pin and Witherspoon 1984). The infiltrating water will leach out the radionuclides contained in the wastes. It is assumed that the waste form will not limit the leachability of the radionuclides. The amounts of radionuclides that will be leached from the wastes are conservatively estimated by the solubility limits

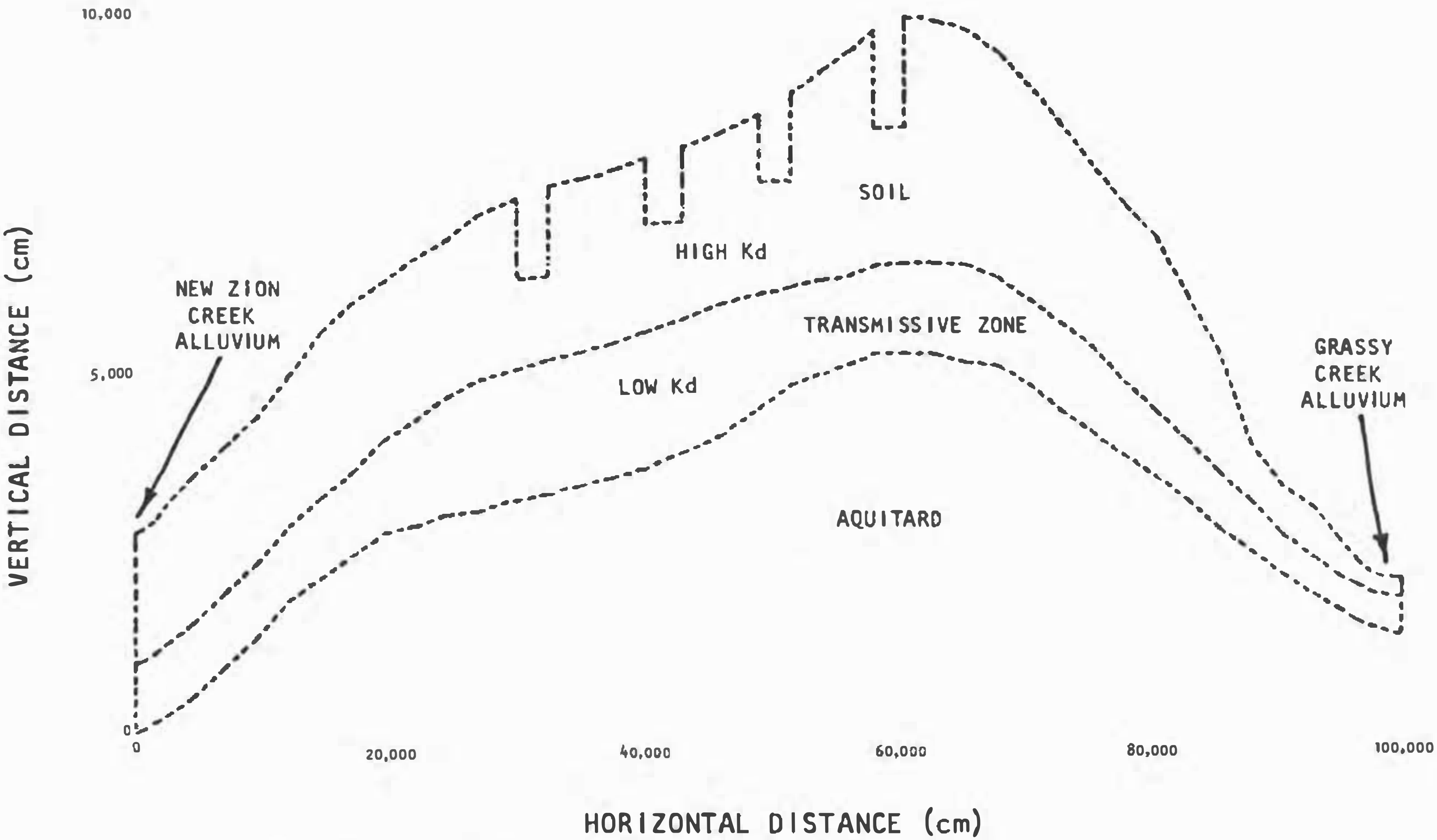


Figure 4.2. Schematic Cross Section for Radionuclide Migration Study at the West Chestnut Ridge Site.

of the radionuclides. Solubility limits in WCR groundwater have been established for some radionuclides (Pin and Witherspoon 1984). For the current study, leaching of radionuclides into the soil below the disposal area is assumed to occur continuously until the total mass of the radionuclide has been removed from the trenches (or tumuli). For those radionuclides with unknown solubility limits, it is assumed that the radionuclide will dissolve completely during the 1.6 years required for waste saturation.

The dispersivities in both longitudinal and vertical directions, which contribute to the dilution of the radionuclides, are conservatively assumed to be zero because site-specific values are unknown. In addition, site characterization studies have shown that the shallow unconfined aquifers below the WCR site occur in weathered bedrock and exhibit high transmissivities (Ketelle and Huff 1984; Woodward-Clyde 1984); therefore, longitudinal advection rather than dispersion appears to be the dominant mechanism in the transport and mixing of radionuclides in the aquifers. Tracer tests (Ketelle and Huff 1984) have shown that the rate of advection within the shallow aquifer can approach 300 m/d (1,000 ft/d). For this reason, it is conservatively assumed in the groundwater analysis that once a radionuclide reaches the shallow aquifer, it is rapidly transported to a nearby stream and to a potential public drinking water supply system located in the Clinch River. The radionuclides, upon entering the river, are assumed to be completely mixed by the river flow. Based on site characterization studies (Ketelle and Huff 1984) and historical Clinch River flow (Boyle et al. 1982), it is estimated that the dilution factor in the Clinch River is about 2,400 (Pin and Witherspoon 1984). This factor was used in determining the radionuclide concentrations in the Clinch River.

Another parameter that is important in determining the radionuclide concentrations in the aquifer and in the Clinch River is the distribution coefficient Kd. This coefficient represents the ratio of the concentration of a radionuclide absorbed on soil particles to the radionuclide concentration of the percolating water in the saturated waste material. The values of Kd for specific sites generally vary depending on the soil properties, chemical content, pH of the water, and nature of the radionuclides. The Kd values for some radionuclides likely to be present in waste to be disposed at the CWDF have been determined by Oak Ridge National Laboratory using batch contact methodology (Seeley and Kelmers 1984). Based on the tests for pH range of 5 to 7, favorably high Kd values of 1,600 to 11,000 L/kg were obtained for strontium, cesium, and cobalt--indicating that good retention could be expected at the site. Very high Kd values of 11,000 to 61,000 L/kg were obtained for uranium, europium, and thorium. However, Kd values of less than 2 L/kg were obtained for technetium and iodine.

For the groundwater impact analysis, the radionuclides listed in Table 4.7 were divided into seven groups (Table 4.8) because the number of radionuclides is too large to be considered on an individual basis. The representative radionuclide in each group was selected based on anticipated waste mass, half-life, solubility, maximum permissible concentration, and mobility in the soil/groundwater system (Pin and Witherspoon 1984). A representative Kd value was selected for each of the first six groups. For the radionuclides included in Group 7, an appropriate Kd value was used for each individual radionuclide and the simulations were performed on an individual basis.

Table 4.8. Distribution Coefficients (Kd) for Representative Radionuclides at the West Chestnut Ridge Site

Group	Representative Radionuclide	Kd (L/kg)
1	H-3	0
2	Tc-99	1
3	C-14	10
4	Sr-90	690
5	Cm-244	1,200
6	Cs-137	11,000
7	U-238	-†[1]

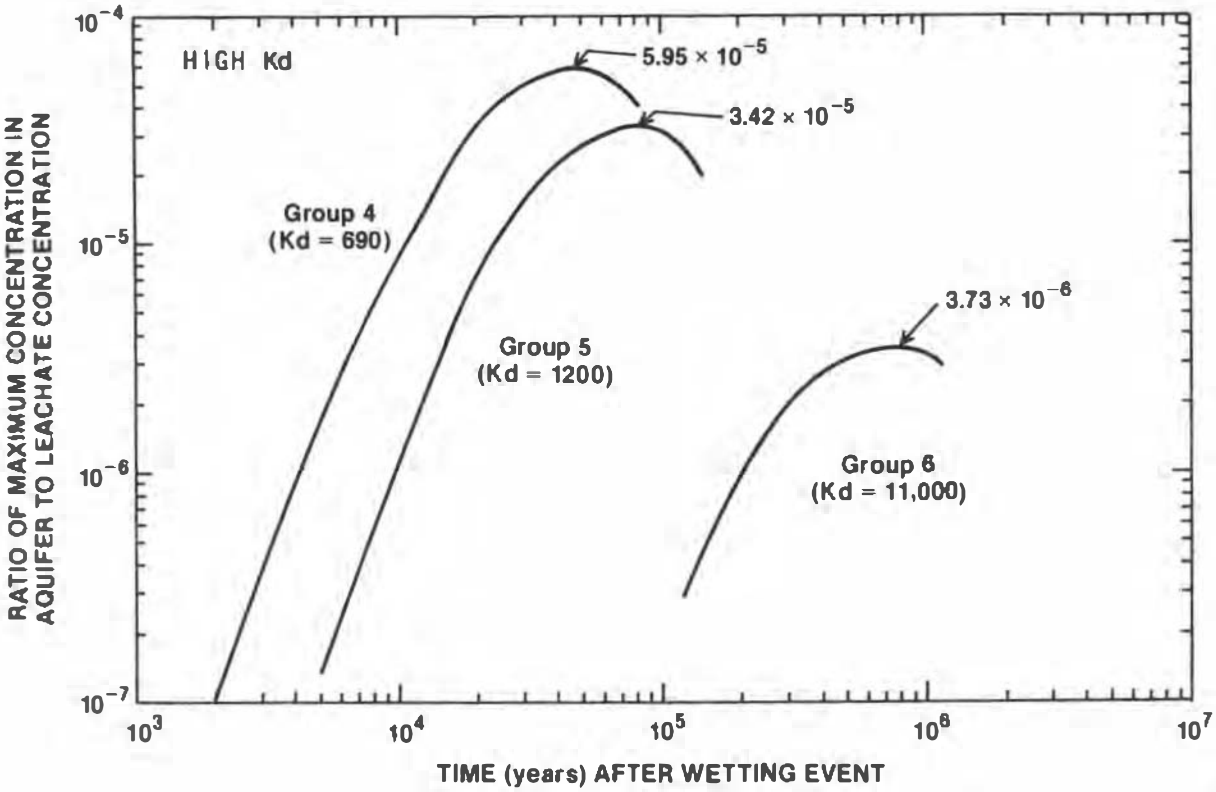
†[1] Appropriate Kd value was used for each individual radionuclide in this group.

4.2.2.4 Discussion of Results

The time variations of radionuclide concentrations in the subsurface aquifer system beneath the burial trenches (or tumuli) and in the nearby surface water were calculated using the modeling procedures and hydrogeologic parameters described above. The numerical simulations start at the lapse of the 100-year institutional-control period. The results of the calculated concentrations are summarized as follows.

4.2.2.4.1 Below-Grade Disposal (Trenches)

The predicted time variations of the ratio of the maximum concentration in the aquifer to the leachate concentration for radionuclides included in Groups 1 through 6 are shown in Figure 4.3. These results were obtained for a constant rate of leaching over a period of 1.6 years and with the assumption that the radionuclides do not decay. The appropriate decay was considered in calculating the maximum concentration. For the uranium isotopes included in Group 7, a longer leaching period was considered because their solubility limits extend the leaching period beyond 1.6 years. The maximum values of the nondecayed dimensionless concentrations are indicated in the figures and are presented in Table 4.9. No values are presented for Sr-90, Cs-137, and Cm-244 because these radionuclides have short half-lives and relatively high retardation rates and would not migrate a significant distance before the radionuclide concentration was reduced to an insignificant level by radioactive decay. For the other radionuclides, the maximum concentrations in the aquifer are shown in Table 4.9. These values were obtained by scaling the dimensionless concentrations with the appropriate leachate concentration and the appropriate decay constant for each radionuclide. The times to reach the maximum concentrations are also presented in Table 4.9.



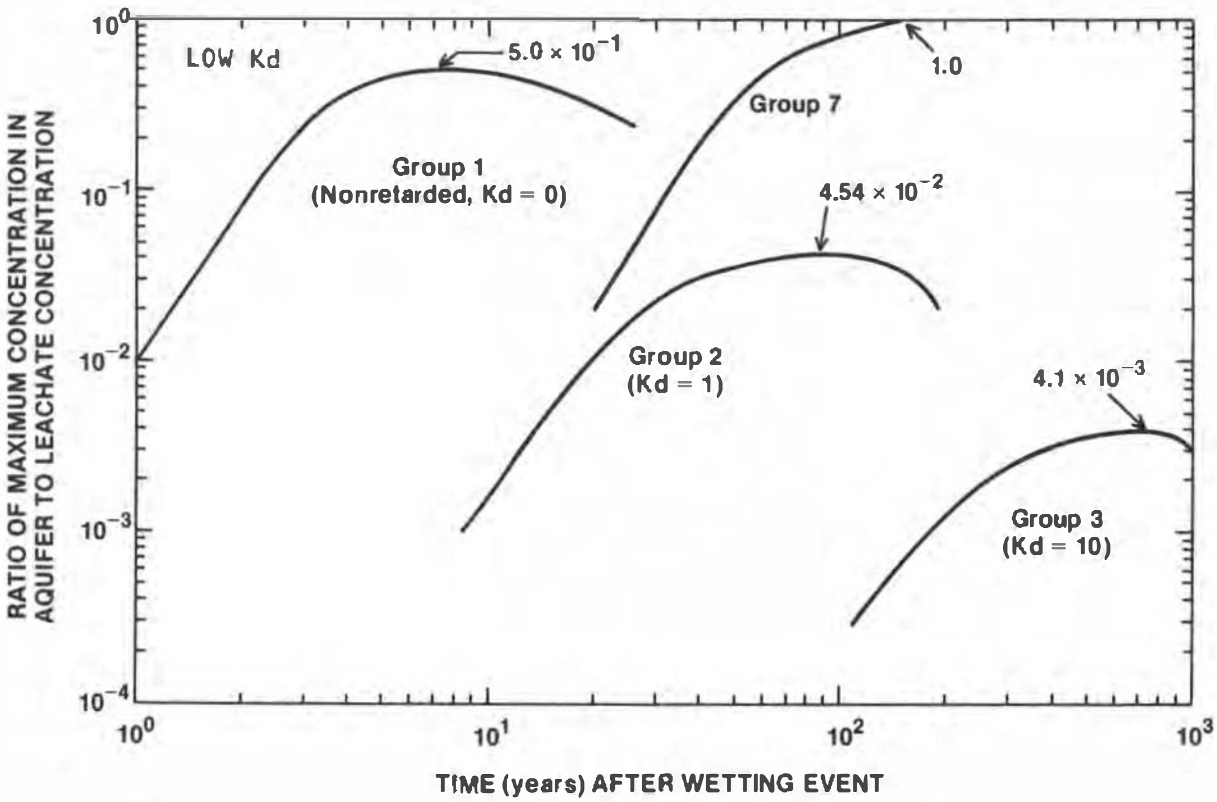


Figure 4.3. Time Variation for Concentrations of Radionuclides with High (top) and Low (bottom) Kd Values for Below-Grade Trench Disposal.

Table 4.9. Predicted Radionuclide Concentrations for Below-Grade Trench Disposal

Radionuclide	Ratio of Maximum Concentration in Aquifer to Leachate Concentration	Maximum Concentration in Aquifer (pCi/L)	Time to Reach Maximum Concentration in Aquifer (yr)	Maximum Concentration in Clinch River (pCi/L)
H-3	5.0×10^{-1}	3.6×10^{4}	7	1.5×10^{1}
Tc-99	4.5×10^{-2}	2.5×10^{4}	96	1.0×10^{-1}
C-14	4.1×10^{-3}	1.0×10^{3}	850	4.2×10^{-1}
U-234	1.0	6.5×10^{1}	150	2.7×10^{-2}
U-235	1.0	1.6×10^{2}	150	6.7×10^{-2}
U-238	1.0	1.6×10^{2}	150	6.7×10^{-2}

The maximum radionuclide concentrations in the Clinch River resulting from groundwater discharge were calculated for a dilution factor of 2,400. This dilution was based on the average annual flow of the Clinch River. (The water flow in the Clinch River is controlled by upstream dams; hence the difference between the low flow and average flow is small.) This dilution factor, as previously discussed, represents the ratio of the Clinch River discharge to the groundwater discharge from the CWDF site. The radionuclide concentrations in Clinch River are well below the MPC limits.

4.2.2.4.2 Above-Grade Disposal (Tumuli)

For above-grade disposal, the waste characterization and pathways from the CWDF to the public water supply system are basically the same as for below-grade disposal. The main difference between these two disposal alternatives is the potential exposure to man as a result of the different performance characteristics of the two alternatives.

The isolation of the waste by tumulus is less likely to be maintained because of the increased potential for water erosion to reduce the overall integrity of the tumulus cap (See Section 4.2.1.1). Exposure of the waste from tumulus to man through all pathways would be possible. Because the tumulus is above grade and has a concrete floor and installed drainage system, the waste is less likely to be inundated by infiltrating water as in the case of the below-grade trench. Consequently, the leaching period would be extended and the leachate would not necessarily be transported solely through the groundwater system. During the institutional-control period, any leachate that was generated would be drained by the internal drainage system of the tumulus. If any contamination was present, the collected leachate would be removed, properly treated, and returned to the tumulus. Following the end of the control period, the drain system is assumed to discharge leachate directly to the nearby surface water system and the surface water is used as a drinking water supply by an onsite resident.

The initial concentration of radionuclides in the leachate generated in the tumulus is assumed to be the same as for the trench. Because the tumulus is analogous to a fixed leach bed, the leachate is further assumed to be leached out exponentially in time, with 90% of the original activity leached 50 years after the lapse of the institutional-control period. Also, the leachate flux is assumed to be only 50% of the annual average rainfall of 139 cm (55 in.) to give credit to the effects of overland runoff, evaporation, and infiltration to groundwater.

For the tumulus, it is assumed that the surface water pathway is more significant than other pathways for transport of radionuclides. Once the leachate has entered the surface water system, the leachate is assumed to be completely mixed and diluted by the noncontaminated surface water. The dilution factors were calculated to be about 30 and 5,900 for Ish Creek and Clinch River, respectively. New Zion Creek is not considered a potential drinking water supply because of its low flow. The dilution factor for the Clinch River is greater for above-grade disposal than for below-grade disposal. This is to be expected because, as discussed above, the amount of leachate discharge to the surface water system is much less for the tumulus disposal alternative.

Based on the above assumptions, the predicted maximum concentration of radionuclides in both Ish Creek and the Clinch River are presented in Table 4.10. Because of the assumed scenario for the leaching process, these maximum concentrations would decrease rapidly as time progressed. Although Sr-90, Cs-137, and Cm-244 have short half-lives, their concentrations are included for the tumulus disposal alternative because the surface water pathway is considered to be the dominant pathway in this alternative and the leachate would be discharged into the surface-water body before these radionuclides incurred any significant decay. The concentration of radionuclides in the Clinch River would be higher during the first 100 years for the above-grade tumulus alternative than for the below-grade trench alternative. After this time period, the radionuclide concentration would decrease rapidly and would be smaller than that for the below-grade alternative. Comparison of the results shown in Tables 4.9 and 4.10 indicates that the predicted maximum concentrations for radionuclides in the Clinch River would be higher for the above-grade tumulus than for the below-grade trench (see Section 4.2.3).

4.2.2.5 Mitigative Measures

In order to validate the modeling results, the wastes to be disposed at the CWDF should be closely monitored, including seasonal evaluation of groundwater characteristics. Effective monitoring of the CWDF will be required to refine model predictions and confirm site integrity.

Measures to mitigate the migration of contaminants would be required only if contaminants were found to be migrating at an unacceptable rate and concentration from the site. Such mitigative measures might include reengineering/reconstruction of the waste-containment system.

Table 4.10. Predicted Maximum Concentration of Radionuclides in Ish Creek and Clinch River for Tumulus Disposal†[1]

Radionuclides	Maximum Concentration in Ish Creek (pCi/L)	Maximum Concentration in Clinch River (pCi/L)
H-3	3.5×10^{3}	1.8×10^{1}
Tc-99	1.9×10^{4}	9.5×10^{2}
C-14	9.3×10^{3}	4.7×10^{1}
Sr-90	1.4×10^{4}	7.2×10^{1}
Cm-244	5.0	2.5×10^{-2}
Cs-137	3.9×10^{4}	2.0×10^{2}
U-234	4.7×10^{1}	2.4×10^{-1}
U-235	1.9×10^{1}	1.0×10^{-1}
U-238	1.2×10^{2}	5.9×10^{-1}

†[1] The maximum concentration is assumed to occur immediately after the end of the institutional-control period. The concentration is further assumed to decrease exponentially with time.

4.2.3 Radiological Impacts

The two potential long-term radiological impacts of principal concern are: (1) the potential radiation dose to individuals using the site after it has been released for unrestricted use, and (2) potential contamination of public drinking water supplies by groundwater or surface water containing radionuclides leached from the waste.

The estimate of risk to individuals using the site after it has been released for unrestricted use is based on an "onsite-resident (OR) scenario" developed from known patterns of human activity and chosen to provide an estimate of the annual radiation dose that would be received by the maximally exposed individual. (Scenarios of this kind are commonly referred to as "intruder" scenarios. This terminology has not been used because it implies a wrongful act, which would not be the case for the postulated circumstance of release for unrestricted use.)

In the OR scenario, an individual--unaware of the presence of the radioactive waste--would construct and live in a house located on top of a trench or tumulus. For the purpose of estimating the dose, it is assumed that the house has a basement projecting 0.9 m (3 ft) into the trench or tumulus and that the residents consume produce from a vegetable garden located in the contaminated area and obtain their drinking water from surface water from a nearby stream (in the case of a tumulus) or from a well located on the edge of the contaminated area in the direction of the groundwater (in the case of a trench) (see Section 4.2.2).

The individual exposure resulting from inhalation of suspended particles of contaminated dust, ingestion of vegetables produced on the contaminated soil, and direct gamma exposure would be similar for both the trench and tumulus disposal designs. However, in the case of the tumulus design, the drinking water supply used by the inadvertent intruder is surface water because this pathway is the most likely transport mechanism for the leachate; in the case of the trench design, the most likely pathway is through the groundwater (see Section 4.2.2). In this case, drinking water is obtained from a well in a shallow aquifer near the disposal area.

Interpretation of the significance of the radiological impact estimates requires consideration of the probable errors in the estimates. Generic estimates were given in the introduction to Section 4; further considerations that apply to the pathway analysis used herein are as follows.

Dose estimates for the water pathways are very conservative and correspond to a consistent application of the worst-case strategy. In addition to the very conservative assumptions of (1) immediate and complete failure of the trench or tumulus cover after 100 years, leaving no barrier to water infiltration, and (2) the unrealistically high leach rate--controlled only by the solubility limits of the infiltrating water, which is assumed to become saturated with the radionuclides as it passes through the waste--the drinking water scenario is, by itself, quite conservative. Use of surface water from a nearby stream or shallow aquifer is an unlikely source of drinking water because much more productive water sources can be found in continguous areas (Pin and Witherspoon 1984). A judgmental estimate of the error (overestimate) in the drinking water contribution to the radiation dose to the onsite resident is that it is at least a factor of 100 (see discussion in the introduction to Section 4).

The estimate of the dose contribution from the other pathways, in particular the ingestion pathway, is less conservative, primarily because of the assumption that the resident individual obtains only 10% of his food from the garden. Contamination of food grown in the garden is from soil that has been contaminated by waste exhumed and distributed during excavation of the basement. The contaminated area would not be sufficient to contaminate all food (which includes meat and milk); however, contamination of 50% of the food might be more appropriate as a bounding estimate. The ingestion pathway estimates are, therefore, judged to be less conservative than the drinking water pathway estimates. Individual food ingestion dose contributions close to the bounding estimates could not be reasonably excluded if the OR scenario were realized immediately following cessation of institutional controls. The critical event that controls this pathway is construction of a house that requires excavation for a basement.

The OR scenario could occur only after institutional controls were removed and would be likely to occur only after records of prior use of the site were lost. It is not possible to predict when the OR scenario would occur nor the probability of occurrence because there are too many uncertainties with respect to cessation of controls and loss of land-use records.

Two different assumptions are used for the elapsed time between release from institutional control (and loss of cover integrity) and the time that the house is built. One assumption is that the OR scenario occurs immediately.

This assumption leads to a very conservative bounding estimate. The second assumption is that the OR scenario occurs 400 years after release from institutional control (500 years after closure of the waste-disposal site). This second assumption does not necessarily give a bounding estimate; it is introduced in order to provide data on the effect of delaying the OR scenario. This delay would reduce the dose to the maximally exposed individual for two reasons. One reason is that the short-lived radionuclides would decay to insignificant concentrations by this time. (This decay would occur whether or not institutional controls were relinquished--i.e., it is unrelated to degradation of the cover and dispersal of the radionuclides. No credit was taken for any decay of the radionuclides prior to closure.) The other reason is that failure of the trench or tumulus cap would lead to dispersal of the radionuclides during the period from 100 to 500 years, which would reduce the source terms and, therefore, the dose. It should be noted that if the OR scenario occurred immediately after release from institutional control, the dose from uranium waste would be nearly independent of the time at which institutional control was relinquished--unless a program of planned and controlled water infiltration and radionuclide release was carried out during the period of institutional control.

The only source of public drinking water that will be affected by release of radionuclides from the CWDF is the Clinch River. The potential collective dose can be estimated by a pathway analysis. It is controlled by the rate at which radionuclides are leached from the CWDF by infiltrating water, the transport and dilution of the leachate by groundwater or surface water that discharge into the Clinch River, and dilution of this discharge by the water flowing in the Clinch River. The contribution to the collective dose from the short-lived radionuclides (those with half-lives of about 30 years or less) will depend on the time that institutional controls are relinquished and release of radionuclides from the CWDF begins. The contribution to the collective dose from the long-lived radionuclides (e.g., U-238) will be independent of the time at which this event occurs.

4.2.3.1 Method Used for Dose Calculations

Radiation effects can occur either by exposure to external radiation from radionuclides in the environment or by exposure to internal radiation from inhaled or ingested radionuclides. The dose-equivalent, in units of rems, is used as a measure of the biological damage from external radiation. The 50-year dose-equivalent commitment, also measured in rems, is used as a measure of the biological damage for internal radiation. The 50-year dose-equivalent commitment is the internal dose received from the time of intake until the radionuclide is eliminated from the body or 50 years has elapsed, whichever comes sooner. The annual 50-year dose-equivalent commitment is the 50-year dose-equivalent commitment from one year's intake of radionuclides. Internal and external doses are considered equivalent and are summed for the purpose of risk estimation. For reasons of brevity, the term "dose" is used in the following discussion for both the external dose-equivalent and the internal 50-year dose-equivalent commitment.

The methodology used for making estimates of radiation dose following the release of radionuclides to the environment was that given in reports by Adams and Rogers (1978) and Killough and McKay (1976). The dose conversion factors used for estimating doses from the intake of radionuclides through inhalation and ingestion are those given by Dunning et al. (1981); the factor for estimating dose from external radiation is that given by Kocher (1981).

The environmental parameters used in estimating doses are given in Regulatory Guide 1.109 (U.S. Nucl. Reg. Comm. 1977c). Many of the basic parameters are conservative--that is, where site-specific information is unknown, the values are chosen to maximize intake or exposure to man. In estimating the dose via ingestion of vegetables and water, an individual is assumed to have obtained 10% of his food and all of his drinking water at the location of contamination.

In estimating the dose from inhalation of resuspended contaminated soil, it is assumed that the individual lives on the land. Resuspension factors used for living on land (normal activity) are $1 \times 10^{-9}\ m^{-1}$ (U.S. At. Energy Comm. 1974) and for mechanically disturbing the land (plowing) $1 \times 10^{-7}\ m^{-1}$ (Healey 1977).

The methodology for determining direct gamma exposure to an individual residing in a house built directly into the disposal units is based on information given in a report by Adams and Rogers (1978).

The exposure and resulting dose to the resident-intruder or the general public as a result of drinking water from a well or surface water was determined by first calculating the radionuclide concentrations located in the region of maximum radionuclide concentration predicted in the aquifer or surface water. The methodology used to obtain these concentrations is summarized in Section 4.2.2.2.2 and given more completely in a report by Pin and Witherspoon (1984).

4.2.3.2 Doses to Individuals and the General Public

Environmental assessment pathways, methodology, and assumptions are discussed in Section 4.2.2. Additional details can be found in a report by Pin and Witherspoon (1984).

4.2.3.2.1 West Chestnut Ridge

Individual Dose

The dose to the maximally exposed individual for the OR scenario is tabulated for different pathways and organs in Table 4.11. Tabulations for a below-grade trench and an above-grade tumulus are compared for initiation of the OR scenario 100 years after closure (immediately after assumed release from institutional controls and cover failure) and 500 years after closure (400 years after assumed release of institutional controls and cover failure).

The values listed in Table 4.11 are the maximum annual dose to different organs of an onsite resident for different pathways and scenario-initiation times. These maxima occur at different times for different pathways.

The time dependence is determined by three processes: radioactive decay of the radionuclides, the rate of leaching of the radionuclides from the waste by infiltrating water, and the rate of migration of radionuclides from the waste to the drinking water source. There is insufficient data on rates of

Table 4.11. Comparison of Long-Term Radiological Impacts to an Onsite Resident†[1]

	Maximum Annual Dose (mrem/yr)			
Organ Exposed	Ingestion†[2]	Inhalation†[3]	External†[4]	Drinking Water†[5]
	Below-Grade Trench, 100 Years After Closure			
Whole body	210	5.3	160	190
Bone	920	6.2	180	2500
Kidney	230	0.92	150	540
Lung	130	130	150	17
	Above-Grade Tumulus, 100 Years After Closure			
Whole body	210	5.3	160	2300
Bone	920	6.2	180	6400
Kidney	230	0.92	150	3800
Lung	130	130	150	4000
	Below-Grade Trench, 500 Years After Closure			
Whole body	160	5.3	<6	22
Bone	560	6.2	<6	280
Kidney	200	0.92	<6	59
Lung	77	130	<6	20
	Above-Grade Tumulus, 500 Years After Closure			
Whole body	160	5.3	<6	0.00007
Bone	560	6.2	<6	0.001
Kidney	220	0.92	<6	0.0002
Lung	77	130	<6	0.000002

†[1] Based on release from institutional control and failure of trench or tumulus cover at 100 years (with consequent water infiltration and leaching), and initiation of the OR scenario immediately (100 years after closure) or 400 years later (500 years after closure), as indicated.

†[2] Assumes that 10% of the vegetables consumed are grown in contaminated soil.

†[3] Based on a resuspension rate of 1×10^{-9}/m for normal activity and 1×10^{-7}/m for mechanically disturbing the soil.

†[4] Assumes that the individual spends 10% of his/her time out-of-doors and 90% indoors.

†[5] Assumes that the drinking water supply is a nearby well in a shallow aquifer for the below-grade trench and surface water from a nearby stream for the above-grade tumulus.

leaching from the waste to permit a quantitative determination of the times at which the maxima occur. A qualitative characterization of the time dependence may be given as follows.

The time dependence from radioactive decay will depend on the mix of radionuclides at the point of exposure (which may be different for different pathways because of differing leach and transport rates), but will be similar for all pathways and may be approximately characterized as follows. During the first few decades after waste generation, there will be a pronounced decrease from decay of short-lived radionuclides (such as Co-60 with a half-life of 5.3 years and H-3 with a half-life of 12.3 years*). The concentrations of these radionuclides will be negligible by the end of a 100-year institutional control period. The concentrations of radionuclides with moderately short half-lives (such as Sr-90 with a half-life of 28.8 years and Cs-137 with a half-life of 30.2 years) will decrease by a factor of about 10 during a 100-year institutional control period, and will decay to negligible concentrations (to 1/100,000 of the initial concentration) within 500 years. Radioactive decay of the long-lived radionuclides (e.g., C-14 with a half-life of 5730 years, Tc-99 with a half-life of 214,000 years, and U-238 with a half-life of 4,468,000,000 years) will have a negligible effect on the time-dependence. A significant reduction in the concentrations of these radionuclides by radioactive decay will not occur within the time during which credible dose predictions can be made.

The time dependence of the dose from the drinking water pathway will be determined by the concentrations of radionuclides in the aquifer, which are, in turn, determined by the rate of leaching of radionuclides from the waste and the rate of migration through the unsaturated zone to the aquifer. A model in which the concentrations of the radionuclides in the infiltrating water reach saturation before the water leaves the waste (until the radionuclides have been completely leached out) is used to determine the rate of leaching. It is also assumed that cover failure is instantaneous, so that all water from precipitation infiltrates and passes through the waste after the time of cover failure. With this model, all radionuclides except the uranium isotopes are completely leached out of the waste within a time span of 1.6 years. The leaching times are 1.6, 14.7, and 175 years for U-234, U-235 and U-238, respectively. The maximum concentration in the aquifer will occur at a later time, as determined by the rate of migration of the radionuclides through the unsaturated zone and the aquifer. The time dependence of the drinking water dose will be the same as the time dependence of the aquifer concentration, which is shown in Figure 4.3 for the above-described model. The general form will be a sharp rise to a maximum, followed by a sharp drop (except for U-238, for which a plateau extending over about 175 years rather than a sharp maximum will occur). The times at which the maxima occur are given in Table 4.9. An important point is that the maxima are of limited duration; after the maxima have passed, the risk from using drinking water from the aquifer will decrease.

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*The half-life is the time for the concentration to decrease by radioactive decay by a factor of 2. Thus, in 5.3 years the concentration of Co-60 will be 1/2 of the initial value, in 10.6 years it will be 1/4 of the initial value, in 15.9 years 1/8, etc.

In reality, cover failure will be gradual and the concentrations of radionuclides in the infiltrating water as it leaves the waste will be well below the saturation limit. The bounding assumptions of instantaneous failure and saturation concentration were used because data on cover failure rates and leach rates are lacking. The time dependence of the drinking water dose for a more realistic model would have the same form, but the maximum dose would be much less (probably by many factors of 10), and the times to maximum concentration would be much longer.

The contribution from the inhalation pathway will be maximum immediately after construction of the residence on top of a trench or tumulus and will decrease thereafter as the radionuclides are leached from the soil. It is assumed that some of the waste will be excavated and distributed on the surface as a consequence of construction of the basement; inhalation exposure would occur as a consequence of dust resuspension from disturbance of the surface layer of this soil. The radionuclides will be leached from the surface layer of the soil before they are leached from the remainder of the waste; hence, the inhalation contribution will decrease to a negligible value well before the dose due to drinking water from a shallow well has reached a maximum. The inhalation dose contributions are considered to be very conservative bounding estimates.

The external exposure will come from exposure in the basement of the house, which is assumed to project into the waste, and exposure to gamma radiation from the contaminated soil that was dispersed during construction of the basement. (A simplified model of a house constructed on the contaminated layer was used to estimate the dose from both of these sources.) This exposure will also be maximum immediately after construction. Radionuclides in the soil under the house will be protected from further leaching. However, most of the exposure (97%) is from Cs-137; hence, this contribution will decrease by an order of magnitude during an additional 100-year period following the end of the assumed 100-year institutional control period.

If the time delay between construction of the residence and harvesting crops from the garden is neglected, then the time dependence of the ingestion and inhalation pathways will follow the same curve, which will be maximum at the time of initiation of the DR scenario and decrease steadily thereafter as the radionuclides are leached from the soil.

It may be seen from the foregoing considerations that the maxima for the first three pathways in Table 4.11 (ingestion, inhalation, and external) for a below-grade trench can reasonably be added together for estimating the maximum dose, but that this contribution should not be added to the maximum drinking water contribution. By the time the contribution from the drinking water pathway becomes significant, the contribution from the other pathways will be insignificant.

The maxima for the different pathways will not be as widely separated for an above-grade tumulus because the drinking-water contamination is assumed to be from surface water contamination. The retardation delay, which accounts for most of the separation of the maxima in the trench case, will not occur. However, the likelihood that a resident would obtain drinking water by impounding the water from Ish Creek is considered to be so low that this scenario can be discounted as not being credible for predicting a future dose to the maximally exposed individual.

The most significant comparison of alternatives in Table 4.11 is for the dose to the critical organ, i.e., the organ receiving the largest dose. The critical organ for all pathways except the inhalation pathway is the bone. The largest dose for the inhalation pathway is to the lung; however, this comparison is not significant because it does not discriminate between the alternatives.

The drinking water dose for the 100-year case is estimated to be much greater for the tumulus than for the trench. The reason for this is that radionuclides leached from the trench would be transported to the drinking water supply (a well) by the groundwater, which is a slower process and subject to greater dilution than the radionuclides leached from the tumulus, which would be transported to the drinking water supply (surface water) more rapidly with less dilution. The comparison is not considered significant in view of the low probability that a stream would be used as a drinking water supply. If it were assumed that a well in the shallow aquifer were used for both alternatives, then the dose for the tumulus would be much less than the dose for the trench. For the 500-year case, the dose for the tumulus would be much less than for the trench regardless of the supply source for drinking water. This is because the radionuclides would leach out of the tumulus during the 400-year period, and any residue in the stream bed would be insufficient to cause appreciable contamination. Migration of the radionuclides through the aquifer would be retarded by adsorption on the pore and particle surfaces in the aquifer; hence, the aquifer and well water would still be contaminated after 500 years.

The estimated bounding doses for a maximally exposed individual (the onsite resident) may be compared with radiation protection standards. The applicable radiation protection standards are specified in DOE Order 5480.1A, Chapter XI. These standards specify an annual dose equivalent or committed dose equivalent to an individual at points of maximum probable exposure of 500 mrem to the whole body, gonads, or bone marrow and 1500 mrem to other organs. Comparison of these limits with the sum of the contributions from the ingestion, inhalation, and external pathways shows that the limits would not be exceeded during the period immediately after construction of the residence, before the radionuclides had been leached from the waste or soil.

The long-term predictions for bounding dose contributions from drinking water, which will not attain the maximum values shown in Table 4.11 until after the radionuclides have been leached from the waste and soil,* do not exceed the current DOE radiation protection standards. In assessing this result, the following considerations should be taken into account. First, the assumptions used to obtain bounding "worst case" estimates lead to severe overestimates. This overestimate is judged to be at least a factor of 10, and probably much larger for the drinking water pathway (see introduction to

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*It may be noted that in a model for which leaching occurred over a very extended period of time, there could be an overlap between the contribution from the first three pathways and the last pathway in Table 4.11. However, for such a model the maxima would be much less, and the total would be very unlikely to exceed DOE radiation protection standards.

Section 4). Second, it is improbable that the contaminated shallow aquifer would be used for the drinking water supply, and extremely improbable--to the point that one can consider the scenario as not being credible--that impounded water from a creek would be used as a drinking water supply. If one used the more credible scenario that the water supply for a residence constructed on an above-grade tumulus came from a well rather than from a creek, the contributions to the dose from drinking water for an above-grade tumulus in Table 4.11 would become nil.

The dominant pathway for the dose to the general public is the groundwater pathway or the pathway in which surface water is leached from the waste field by infiltrating water and transported by groundwater through the aquifer or surface water to the Clinch River. The estimated bounds for the maximum individual doses from individuals drinking water from a potential public water supply from the Clinch River are given in Table 4.12. The estimated dose to the general public for the below-grade trench alternative during 100- to 500-year time frame would be well below the 25 mrem/yr whole-body and organ dose limit specified by NRC (10 CFR 61.41c); the estimated bounding dose to the general public for the above-grade tumulus alternative would be marginally above the limit 100 years after institutional controls were lifted but well below these limits 500 years after institutional controls were lifted. As noted earlier, it is judged that a bounding estimate exceeds the actual maximum dose by a factor of 10 or more.

Table 4.12. Maximum Annual Individual Dose from Drinking Water from a Potential Public Water Supply from the Clinch River

	Maximum Annual Individual Dose†[1] (mrem/yr)			
	100 Years After Closure		500 Years After Closure	
Organ Exposed	Below-Grade Trench	Above-Grade Tumulus	Below-Grade Trench	Above-Grade Tumulus
Whole body	0.08	11	0.009	3×10^{-7}
Bone	1.0	29	0.12	5×10^{-6}
Kidney	0.2	17	0.02	1×10^{-6}
Lung	0.008	18	0.0009	1×10^{-8}

†[1] The 50-year dose-equivalent commitment to a maximally exposed individual from radionuclide intake from drinking water for a period of one year.

Population Dose

The population dose is the collective dose received by the general public as a consequence of releases of radionuclides from the waste-disposal facility. The population dose of primary concern will occur after the trenches or tumuli have been closed and operations have ceased; the public exposure that can occur during operation of the facility or as a consequence of accidents (which can lead to significant releases only during the operating period) are discussed in Section 4.1.2.1.

There are three processes by which radionuclides can be released from the waste-disposal facility into the environment and subsequently transported to locations where members of the general public can receive radiation doses: dispersion of eroded surface material (by water or air), biotic transport, and water infiltration. Surface dispersion will not occur until the waste is uncovered by erosion. Assuming that erosion rates are not large enough for this to occur within the time span of concern, surface dispersion can be neglected. Significant releases can occur by biotic transport only if crops are raised on the site. (Biotic transport by natural growth or intrusion of wild animals would be local and much less than that caused by farming.) The West Chestnut Ridge area is not suitable for commercial farming and would not be expected to become so in the foreseeable future. The population that could be affected by home gardening or local sale or exchange of garden produce by an onsite resident would be too small (a few tens or, at most, hundreds of individuals) to be of concern compared to the at-risk population for the population dose (thousands or more). The estimate of the population dose is, therefore, limited to the dose received by the general public as a consequence of release and transport of radionuclides by infiltrating water. The dominant population-dose contribution from this process will result from radionuclides that are transported by water that infiltrates the waste and carries the radionuclides to the Clinch River, either as surface water or groundwater percolating through the local, unconfined aquifer.

Radionuclides that reach the Clinch River lead to exposure by several environmental pathways that can transport the radionuclides from the point of entry into the river to the point of individual exposure by ingestion, inhalation, or external radiation. These include ingestion of fish taken from the river, recreation (fishing, swimming, boating), food from crops watered with water from the river, or drinking water from municipal systems with intakes in the Clinch River (or downstream rivers). The drinking water pathway accounts for 80% of the dose (U.S. Nucl. Reg. Comm. 1977a--Table 5.13). (This distribution is for the mix of radionuclides for a breeder reactor and may be slightly different for the mix for a LLW disposal site, but not sufficiently different to invalidate the conclusion that the dominant pathway for the population dose is the drinking water pathway.) The population dose estimate is, therefore, limited to an estimate of the dose received by means of drinking water from downstream intakes in the Clinch and Tennessee rivers.

The pathway analysis methods for the population dose are the same as those that were used to estimate the expected population dose for the Clinch River Breeder Reactor (U.S. Nucl. Reg. Comm. 1977a). The year 2010 projected population (one million) within 80 km of ORR was used. The maximum annual population dose to the total body for this population was conservatively estimated to be 0.6 person-rem for below-grade trench disposal and 80 person-rem for above-grade tumulus disposal. For comparison, the annual population dose that would be received by the same population from natural environmental radiation (naturally occurring radionuclides and cosmic rays) would be about 10^5 person-rem. Thus, the added population dose from waste in the CWDF would be 0.006% and 0.08% of the dose from natural background sources for the below-grade and above-grade designs, respectively. The variations in natural background dose in different regions of the country due to differences in altitude and in concentrations of naturally occurring radionuclides in the soil is of the order of 50% (U.S. Dept. Energy 1980).

4.2.3.2.2 Central and East Chestnut Ridge

The ingestion, inhalation, and external exposure pathways are the same for a trench or tumulus located anywhere on Chestnut Ridge; hence, the dose estimates for these pathways, as given in Table 4.11, are equally applicable to all of the reasonable alternative sites identified in this EIS. The dose contribution from drinking water, both for the maximally exposed individual (an onsite resident) and for the general population will depend on the hydrological conditions at a site. There are no significant differences in the soil characteristics between the different sites on Chestnut Ridge; the same geological strata and soil types extend for the entire length of the ridge. The only differences that could lead to different estimates by the models used for the hydrogeological calculations would be differences in the geological cross section (see Figure 4.2). Reconnaissance-level data and preliminary seismic studies indicated that the thickness of the soil layer and the geological cross sections for the three different sites were comparable, so that one could reasonably expect the input for model calculations, for all three sites, and, hence, the dose contributions from drinking water, to be approximately the same. The results given in Section 4.2.3.2.1 are, therefore, applicable to all three alternative sites on Chestnut Ridge.

4.2.3.3 Health Effects

The health effects of primary concern are those due to radiation doses received by individuals as a consequence of exposure to ionizing radiation from radionuclides in the waste. These health effects are cancer and genetic effects. About half of all cancer cases are nonfatal (Am. Cancer Soc. 1978); the health risk estimates given below are based on statistics for the fatal cancers. The number of genetic effects (gene mutations and chromosome aberrations that can cause disease and abnormalities in progeny) for a given low-level radiation dose is approximately twice the number of cancer fatalities (Natl. Acad. Sci. 1980). Hence, an assessment of genetic health effects can be inferred directly from an assessment of the cancer fatalities. The following discussion of health effects is, therefore, limited to consideration of cancer fatalities. The number of cancer fatalities due to low-level ionizing radiation is approximately proportional to the radiation dose-equivalent.*

*A radiation dose is defined in terms of the energy absorbed by bone or tissue from ionizing radiation, and is commonly expressed in units of "rads" or "Grays (Gy)", where 1 Gy = 100 rad. A radiation dose-equivalent is obtained by multiplying the radiation dose by a "quality factor", which is used to take into account differences in the biological damage from different kinds of ionizing radiation and is commonly expressed in units of "rems" or "Sieverts (Sv)", where 1 Sv = 100 rem. The quality factor for gamma radiation is 1; a quality factor of 20 is used for alpha particles emitted inside the body by inhaled or ingested radionuclides. Thus, for radionuclides inside the body, a dose of 1 rad from gamma radiation and 0.05 rad from alpha particle emission both give a dose-equivalent of 1 rem and cause approximately the same biological damage.

This relation is expressed as a quantity called a "risk estimator" or "risk factor", which gives the estimated number of cancer fatalities for a given dose. The current recommended value for the risk factor is 10^{-4}/rem (Int. Comm. Radiol. Prot. 1977).*

The interpretation of this risk factor is that if one individual receives a dose-equivalent of 10,000 rem of low-level radiation, that person is almost certain to develop a fatal cancer. (It should be noted, however, that there is a latent period, i.e., a delay between the time the dose is received and the time at which the cancer appears; hence, the consequences are more serious for a young person than for an elderly person because the latter might die from natural causes before the cancer developed.) If a person received a dose of only 100 mrem, then the probability that this individual would develop a fatal cancer as a consequence of the radiation dose would be 10^{-5} (one chance in 100,000). Equivalently, if 100,000 individuals were each exposed to an individual dose-equivalent of 100 mrem, then one of these individuals could be expected to develop a fatal cancer as a consequence of this exposure.**

The short-term radiological impacts are almost entirely occupational. The health effects (fatal cancers) associated with these short-term radiological impacts may be obtained directly from the dose estimates. The dose estimates are 40.2 person-rem from disposal operations (Section 4.1.2.1.2) and 8.5 person-rem from waste transport (Table 4.1) over a 40-year period; 0.25 person-rem over a 5-year period for closure operations, and 0.8 person-rem over a 100-year period for subsequent monitoring and surveillance, for a total occupational dose of 50 person-rem. This would result in a probability of 5×10^{-3} that a single worker from the total work force involved would suffer a fatal cancer.

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*Bounding risk factors for low-level, low-energy transfer (LET) ionizing radiation (i.e., low-level gamma radiation)--obtained by two different linear-quadratic models--have been estimated to be 7.7×10^{-5}/rad and 2.3×10^{-4}/rad (Natl. Acad. Sci. 1980--Table V-1). The geometric mean of these values is 1.3×10^{-4}/rad. Because of the uncertainty in the value, as indicated by the range, it may be rounded to one significant digit. Since the quality factor for LET radiation is 1, this leads to a risk factor of 10^{-4}/rem.

**It should be noted that estimates of health effects at low doses (below about 10 rem) are based on prudent extrapolations from observed effects at high doses; health effects in humans at such low dose rates have never been observed. There is some scientific evidence that very low radiation doses are not harmful (Luckey 1982). It may also be noted that the annual effective dose equivalent that everyone receives as a consequence of natural background radiation is about 100 mrem/yr.

Using the risk factor, the health effects for the maximally exposed individual may be inferred directly from the individual doses in Table 4.11.* For a maximally exposed individual the risk of fatal cancer during the year of maximum exposure is 2×10^{-4}/yr for a below-grade trench and 1×10^{-3}/yr for an above-grade tumulus if the OR scenario occurs 100 years after closure and 9×10^{-5}/yr for either if the scenario occurs 500 years after closure. These bounding values are somewhat higher than the risk levels of 10^{-6}/yr to 10^{-5}/yr that are considered acceptable for involuntary risk (Int. Comm. Radiol. Prot. 1977). As noted earlier, this is considered to be a consequence of the very conservative "worst case" assumptions used to ensure that the estimates would be bounding.

The lifetime risk for continuous exposure may be estimated by multiplying the annual risks by a life expectancy of 70 years. This leads to bounding estimates of the probability that the maximally exposed individual would die of cancer as a consequence of exposure to ionizing radiation from radionuclides in the waste of 0.005 for below-grade trenches and 0.03 for above-grade tumuli. These estimates assume that the maximum dose would be maintained for 70 years. If the worst-case assumptions used to estimate the dose were applicable, the duration of the maxima would be less (except for U-238 in the well water). These estimates may be compared with the probability of 0.16 that an individual will die of cancer from other causes (Natl. Acad. Sci. 1980).

The number of overall health effects (fatal cancers) in the general population that are attributable to the CWDF are obtained by multiplying the annual population dose by the duration of the risk (to obtain the total population dose, integrated over time) and the risk factor. The duration of the risk is not accurately known. For below-grade trenches it will be a few hundred years--somewhat longer than the 175 years required for the U-238 to leach out of the trench because migration through the aquifer will increase the time (but decrease the maximum dose). The only radionuclides that reach the Clinch River will be the very long-lived radionuclides (primarily U-238) because the other radionuclides will decay to insignificant concentrations before reaching the Clinch River. For the above-grade tumuli, radionuclides leached from the waste will be transported by stream to the Clinch River; hence, the delay will be small and the time during which contamination of the

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*The risk factor of 10^{-4}/rem is applicable to the effective dose-equivalent calculated by means of the dosimetry models recommended by the International Commission on Radiological Protection (ICRP) in ICRP 26 and ICRP 30 (1977, 1978). The dose-equivalent in Table 4.11 has been calculated using the older dosimetry models recommended in ICRP 2 (1960) because DOE radiation protection standards are currently based on this model (DOE Order 5480.1A). The effective dose-equivalent calculated using the new dosimetry models usually lies between the whole-body and bone dose-equivalents calculated with the older dosimetry models. For ingestion of U-238, the effective dose-equivalent is about five times as large as the ICRP-2 whole-body dose equivalent and one-third as large as the ICRP-2 bone dose equivalent. For the purpose of obtaining risk estimates, the effective dose equivalent has been assumed to be five times the whole-body dose, i.e., a risk factor of 5×10^{-4}/rem has been applied to the whole-body dose.

river occurs will correspond closely to the leachout time. Contributions from the short-lived radionuclides can occur. There will be a sharp peak of short duration (a few years) in the river concentration due to the short-lived radionuclides, then a broad maximum of about 200 years due to U-238. (It should be recalled that these time estimates are based on a model that greatly overestimates peak concentrations, with a corresponding underestimate of the durations.)

The duration of the elevated radionuclide concentrations have not been estimated with sufficient accuracy to permit quantitative estimation of the overall health effects. The population health effects for the tumuli will be greater than for the trenches because of the contribution from the short-lived radionuclides, but not by a factor as large as the ratio of the maximum population dose rates (80/0.6 = 130) because the duration of the contribution from the short-lived radionuclides will be much less. The contribution to the dose from U-238 will be the same for both design alternatives because the total amount of U-238 released into the Clinch River will be the same; only the duration and peak concentrations will be different. The duration of the hazard will be finite because it will disappear when the U-238 has been diluted to concentrations comparable to the concentration of naturally occurring U-238 in freshwater sources (0.1 pCi/L).

An indication of the magnitude of the population health effects may be obtained by considering the number of fatal cancers attributable to the CWDF that would occur in the at-risk population (1 million persons) over a lifetime (70 years). This risk is estimated to be 0.02 for the below-grade trenches; i.e., there would be a probability of 0.02 that a single individual in the at-risk population would die from cancer attributable to exposure to radionuclides from the CWDF rather than from some other cause. Thus, the lifetime risk for each individual in the at-risk population would be 2×10^{-8}. These risk estimates may be compared with the 160,000 fatal cancers that will develop in this same population from all other causes, or the lifetime risk of 0.16 for a single individual.

The release of U-238 would continue for several hundred years; hence, the total risk might be as much as a factor of 10 greater. The population health effects from the tumuli will be greater by the contribution from short-lived radionuclides. The peak population dose from the tumuli (80 person-rem/yr) will last only for about two years. Using this duration, the added health effects from the short-lived radionuclides is estimated to be 0.08 cancer fatalities. Thus, the overall population risk for the tumuli is only slightly greater than for the trenches; a factor of about 2 or less would be a reasonable estimate.

4.2.3.4 Mitigation

During the long-term period, the most effective mitigative measure would be to continue maintenance, monitoring, and corrective actions--such as compaction of trenches or tumuli, repair of caps, and possible reengineering of waste-containing systems--and to minimize the potential for human intrusion into the wastes. The potential long-term need for mitigation is primarily a consequence of the U-238, which has a half-life of 4.5 billion years. It is obviously impossible to provide effective containment of such long-lived radionuclides until they decay to innocuous concentrations. In fact, complete isolation represents a worst case in the sense that the risk at the time of failure of isolation, which will inevitably occur, will be greater for this case. The only feasible mitigation measure is to limit dispersal into the environment to a rate such that the concentration at a point of potential human exposure remains below the level that presents a hazard to human health.

Dispersal of U-238 into the environment at concentrations comparable to the concentrations of naturally occurring U-238 would eliminate the hazard without creating a new hazard. The normal range of naturally occurring U-238 in the soil is 0.2 to 3 pCi/g, with a median of 0.7 pCi/g, and the mean concentration in freshwater sources is about 0.1 pCi/L (Bowen 1979). The rate of release would have to be controlled to prevent a local buildup of radionuclide concentrations that exceeded safe limits. One applicable limit is on the concentration of U-238 in liquid effluent that may be discharged into a sanitary sewer system in an uncontrolled area; this limit is 600 pCi/L (DOE Order 5480.1A, Chapter XI). The discharge would have to be monitored so that the safe limits for the concentration in any drinking water supply was not exceeded. A safe drinking water limit for U-238 has not yet been established.*

Actual experience on the leach rate of radionuclides from the emplaced waste prior to removal of institutional controls will enable more realistic estimates of the radiological impacts. It is expected that the more realistic estimates will be much lower than the bounding estimates given in this EIS, and will, therefore, eliminate the need for mitigative measures.

4.3 SOCIOECONOMICS AND LANO USE

A waste-disposal facility of the size of the CWDF requires few workers for initial construction or operation, so there will be no significant impacts caused by in-migration of workers. Additionally, the unique historical development of the Oak Ridge area has raised public awareness of waste management. Thus, the socioeconomic impacts of this project are not demographic, but institutional and economic, and related to the residents' quality of life.

4.3.1 Population and Employment

The initial construction phase is expected to last one year. During this phase, the first trench would be excavated and the necessary buildings erected.

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*A drinking water concentration limit for U-238 may be estimated from the EPA dose limit of 4 mrem/yr to a critical organ for man-made radionuclides ingested in drinking water (40 CFR 141.16(b)); the estimated value is 20 pCi/L. This estimate is based on a consumption of 2 L/day of water and a dose conversion factor of 2.55×10^{-4} mrem/pCi for U-238. The dose-conversion factor is based on dosimetry models recommended by the International Commission on Radiological Protection (ICRP 1977, 1978); hence, it requires a reinterpretation of the EPA dose limit of 4 mrem/yr to a critical organ as an effective dose equivalent limit of 4 mrem/yr. The EPA limit, which may differ from this estimate, will be applicable as soon as it is established.

Additional trenches would be excavated as the need arises on an annual basis. The peak construction work force for the proposed action is expected to be 60 workers, and local contractors would be used as much as possible. Thus, negligible effects on the local population are expected because of the relatively small size of the construction work force, short duration of the construction activities, and predominately local work force.

The operational work force required for the CWDF would be about 35 persons. It is expected that about 15 workers would be drawn from other ongoing waste-management activities at ORR. The 20 new additional workers expected to be drawn from the local work force represent only 0.05% of the Anderson and Roane county work force. Thus, no effect on the area population is anticipated from operation of the CWDF. Because the number of workers would be approximately the same for each alternative, the socioeconomic impacts of the alternatives would be similar.

4.3.2 Public Services

No effect on public services in the surrounding areas is anticipated from construction or operation because no increase in the area population is expected.

4.3.3 Land Use

The major effect of the proposed and alternative actions (both construction and operation phases) would be to preempt the land from future alternative uses. Because of the kind of waste to be disposed, the land on which the CWDF is built must be considered to be dedicated to waste management for the foreseeable future. In order to contain the CWDF wastes, the land above, under, and surrounding the containment area must remain undisturbed. Improper onsite surface or subsurface development could stress engineered barriers and allow for migration of the wastes offsite. Therefore, certain onsite human activities (e.g., excavation or agricultural activities) must be prevented during the period of potential radiological impact (see Section 4.1.2.1).

Commitment of a site that has potential industrial or public use may be a significant impact because of growth and financial opportunities foregone. Anderson County requested land on the ORR for a landfill site but was turned down for lack of available land (Bolling 1984). Local citizens and governments have objected to commitment of potential industrial land during the EIS scoping process on the Niagara Falls Storage Site EIS (U.S. Dept. Energy 1984) and the CWDF (U.S. Dept. Energy 1983a). The Tennessee Technical Corridor Foundation hired an architectural and engineering firm (Adams Craft Herz Walker) to locate potential industrial sites along the technical corridor (which ends in Oak Ridge). One of the principal partners in the firm is on the Roane-Anderson Economic Council and has identified two potential industrial areas within the boundaries of the CWDF buffer zone at WCR (Adams 1984). The potential industrial areas account for approximately 61 ha (150 acres). The trench areas where the waste would be buried have not been cited as a potential industrial development site but do have the potential for a commercial waste facility (Williams 1984).

There are three important caveats related to potential industrial/commercial uses of the West Chestnut Ridge site. First, industry must be interested in locating in the Oak Ridge area before potential industrial land is important. Second, although developable land is limited in the Oak Ridge area, the city of Oak Ridge has enough available land in its industrial park and other holdings to meet needs for the next few years (Faust 1984). Also, Martin Marietta Corporation (1983) has proposed the development of an industrial park with the city of Oak Ridge. Third, although the site may be a good location for a commercial waste facility, it is uncertain whether area residents would want a commercial facility that would accept radioactive waste from outside the area. It should be pointed out that DOE does not expect the entire 508-ha (1,253-acre) site to be excluded from other possible uses in the future. If it can be demonstrated that other proposed facilities can safely coexist with the CWDF and not disrupt routine operations, such facilities might be allowed within the buffer zone.

Visual resources of the Chestnut Ridge area would be adversely affected by construction activities. The ridge is visible from Bear Creek Road (west of Highway 95) and the initial CWDF would cover part of the top of West Chestnut Ridge. Trees and vegetation would be removed from the affected portion of the ridge during the construction phase of the project. This initial development of the CWDF would be visible from Bear Creek Road and would distract from the undeveloped wooded, hilly terrain. The major portion of the CWDF would not be visible from the road.

Siting of the CWDF at the CCR or ECR sites could conflict with security areas for the ORNL or Y-12 Plant (Section 3.6.5).

4.3.4 Transportation

In the preferred site, the CWDF would be located on the far west end of the ORR away from downtown Oak Ridge. Transportation routes for construction and operation can easily avoid the downtown area.

Construction of the CWDF at any one of the three sites might result in increased traffic congestion and road deterioration in the area of the CWDF. A number of large pieces of equipment and vehicles would either be driven in or hauled to the site. This might cause traffic congestion at certain intersections during peak hours. However, if the equipment were brought in during off-peak hours, the impact would be minimal. Transport of fill material needed for trench construction would also result in increased truck traffic.

Potential impacts resulting from transportation during the operational phase of the CWDF are: (1) deaths and injuries resulting from transportation, and (2) air pollution.

Transportation of low-level wastes to the CWDF has the potential to increase the risk of human injury and death because of transportation accidents. Based on accident statistics for the United States (rural and urban areas), the injury rate for truck accidents is 5.1×10^{-7} injuries per kilometer and the fatality rate is 3.0×10^{-8} per kilometer. If it is assumed that the potential for transportation accidents involving shipments of radioactive wastes is comparable to the general truck transportation in the United States, then--based on the above rates--about 0.8 injuries and 0.5 deaths would be associated with the 40-year operation of the CWDF. The actual accident rate and injury rate at ORR has been less than the projected rates.

It is expected that the nonradiological transportation impacts would be slightly less if the CWDF were sited at either East Chestnut Ridge or Central Chestnut Ridge rather than at the West Chestnut Ridge site. The reason for this is that the transportation risk (for a given type of waste) depends primarily on the truck-miles transported. Both Central Chestnut Ridge and East Chestnut Ridge are closer to Y-12, which has the largest waste fraction. From the Y-12 Plant it is about 10.5 km (6.5 mi) to West Chestnut Ridge, 8 km (5 mi) to Central Chestnut Ridge, and 4.8 km (3 mi) to East Chestnut Ridge. It should be noted that the transportation analysis for the West Chestnut Ridge site shows that the projected accidents and resulting injuries and fatalities anticipated are extremely small.

Pollutants--such as carbon monoxide, particulates, nitrogen dioxide, sulfur dioxide, and hydrocarbons--would be generated from combustion of diesel fuel during truck transport. In addition, fugitive dust from roads and from tire abrasion would be generated. All these pollutants have the potential to cause air pollution. However, taking into consideration the low frequency of shipments of waste (two trucks per hour per 8-hour shift for the first four years), the current traffic patterns over the proposed routes, and the rural nature of the area, no adverse air pollution impacts or violations of air-quality standards are expected.

4.3.5 Parks, Recreation, and Historical Sites

The proposed construction and operation of the CWDF at the preferred site is not expected to impact currently existing public access parks, recreation, or historic sites. Future park and recreational development opportunities at the West Chestnut Ridge site would be foregone for the foreseeable future. An archaeological survey was conducted along the transmission line corridor that crosses the preferred site, and no archaeological site was discovered in the area of the proposed CWDF (Fielder 1974).

In view of the fact that historic structures are located within the WCR and CCR sites (see Section 3.6.6), necessary precautions would be taken to protect them from possible damage during the construction and operational phases of the CWDF (Brown 1984).

Implementation of the proposed action at either WCR or CCR would impact a portion (1.2%) of the Oak Ridge National Environmental Research Park (see Section 3.6.6). Although loss of any portion of a national environmental research park may be viewed as important, the permanence of these parks is not ensured by DOE (Boyle et al. 1982). As discussed in Section 4.1.1.2.1, following the institutional-care period, the affected areas may be allowed to return to the types of habitat currently existing at the proposed site through natural succession. Construction and operation of the proposed CWDF would afford potential research opportunities for scientists within the Oak Ridge National Environmental Research Park (e.g., revegetation, faunal distributions). Implementation of the proposed action on CCR could adversely affect research in progress on Walker Branch.

4.4 IMPACTS FROM THE NO-ACTION ALTERNATIVE

The incremental impacts from the no-action alternative--which is, in fact, a delayed-action alternative--are primarily the additional impacts that would result from storage of the waste. Storage for an extended period can reduce the inventory of short-lived radionuclides placed in the disposal site by radioactive decay; however, this does not reduce the overall impact when the potential impacts due to migration of these radionuclides from facilities in current use or from a storage site are taken into account. No new methods for disposal of LLW, other than those considered in identifying the range of potential alternatives for this EIS, can be anticipated in the foreseeable future; hence, the impacts for immediate disposal and delayed disposal are otherwise comparable. The net difference is the increased cost and risk of the additional step of placing the waste at the storage location, from which it must be removed for final disposal, and the increased cost and risk of monitoring and maintenance of the waste at a location that is less suitable than a permanent disposal site for long-term retention of the radioactivity.

At the present time, separate disposal facilities are maintained for the disposal of waste from the three plants within ORR. One facility is maintained for waste from ORNL. A separate shared facility is maintained for waste from Y-12 and ORGDP. The incremental impacts from continued use of these facilities, and the changes in operation and incremental impacts that occur as they become unavailable or filled to capacity, are presented below.

4.4.1 Impacts Prior to Filling of Current Disposal Facilities to Capacity

4.4.1.1 X-10 Facilities (Oak Ridge National Laboratory)

Currently, six burial grounds and several waste pits and trenches are located in Melton and Bethel valleys within ORR (Figure 4.4). The earliest burial facilities--Solid Waste Storage Areas No. 1, No. 2, and No. 3 (SWSA-1, -2, -3)--were located in Bethel Valley near the source of the wastes. Because convenience was the primary consideration, preoperational geological investigations were not undertaken. SWSA-3, the last to be operated in Bethel Valley, was closed in 1951 when geologic considerations prompted development of burial grounds in the more favorable Conasauga shales in Melton Valley. Waste disposal in Melton Valley began in 1951 with the operation of an 11-ha (28-acre) tract called SWSA-4. This area was closed in 1960. Subsequently, SWSA-5 (15 ha [37 acres]) and SWSA-6 (28 ha [68 acres]) were developed nearby. Large portions of the area in SWSA-5 are topographically or hydrologically unsuitable for trench disposal and have not been used for burial of waste. SWSA-6 was placed in operation in 1973 and is currently used for routine waste burial. Only about 5.9 ha (14.5 acres) of SWSA-6 is usable due to rough terrain.

The total volume of solid debris LLW generated by ORNL is currently 2,800 m^3/yr (100,000 ft^3/yr). The unused disposal area in SWSA-6 was estimated to be 2.6 ha (6.5 acres) as of May 1983. Based on the estimated area capacity of about 5,000 m^3/ha (70,000 ft^3/acre), SWSA-6 would become filled to capacity in 1987 by LLW from ORNL alone.

4.4.1.2 Y-12 Facilities (Y-12 Plant and Oak Ridge Gaseous Diffusion Plant)

Separate facilities are provided for classified and nonclassified waste generated by Y-12 and ORGDP. Classified waste consists of waste that is classified for security purposes. It is, and will continue to be, disposed of or stored in facilities within the plant security fences. The limited space within these areas and the need to reserve them for classified waste precludes their use for nonclassified waste. Nonclassified waste of potential economic

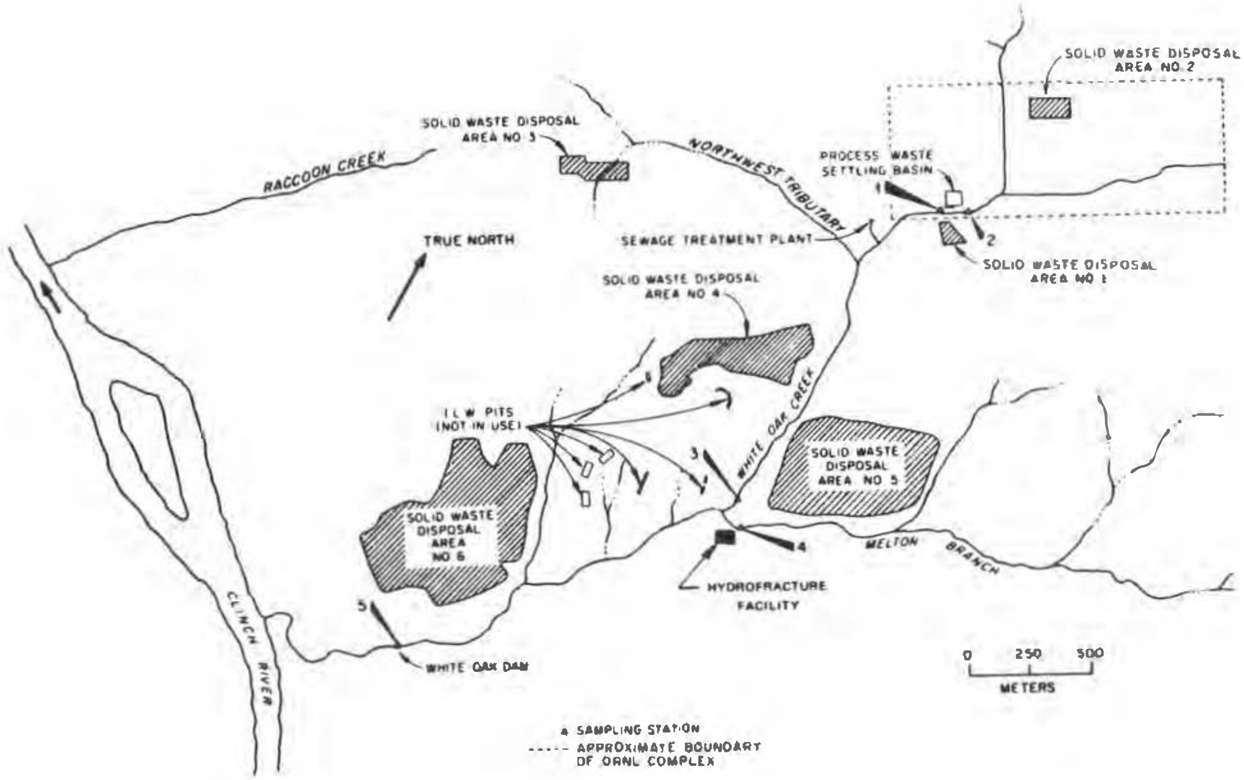

Figure 4.4. Solid Waste Storage (Disposal) Areas at Oak Ridge National Laboratory. Source: Boyle et al. (1982).

value includes uranium waste and uranium chips from Y-12 and contaminated scrap metal from ORGDP. This waste is stored for future recovery operations.

Low-level waste from ORGDP was placed in a burial ground at the ORGDP site prior to 1975. Use of this burial ground was discontinued in 1975, and burial activity was transferred to the Y-12 site. The burial ground for Y-12 radioactive waste, which receives LLW from both Y-12 and ORGDP, is located in the Bear Creek Valley area west of Y-12.

In a recent compliance review by the State of Tennessee Department of Health and Environment, it was determined that the Bear Creek disposal pits were unsuitable for continued use with current operating practice, primarily because of standing groundwater in the pit areas (McKinney 1983). Measurements of groundwater contamination from this condition are not available, but one may reasonably infer that continued use of these pits without corrective action would lead to radiological impacts that are greater than would result from disposal of the same amount of wastes in a new CWDF.

Corrective action to bring the performance of the Bear Creek disposal pits may be possible; however, this option is moot because a Memorandum of Understanding between DOE, the U.S. Environmental Protection Agency, and the

State of Tennessee Department of Health and Environment commits DOE to terminate use of the Y-12 Bear Creek disposal pits by August 1985 (U.S. Dept. Energy et al. 1983). A loss of credibility and strong negative public perception could be expected to occur if there were a delay in implementing the commitments in the Memorandum of Understanding.

It is assumed that under the no-action alternative, nonclassified solid waste from ORGDP and Y-12 would be placed in the SWSA-6 burial ground used by ORNL. This practice would involve very little change from current practice, and could continue until SWSA-6 was filled to capacity. During this period, the impact from waste disposal is assumed to be comparable to the impact that would occur if the same amount of waste were placed in a new CWDF.

The volume of solid LLW from Y-12 and ORGDP, which includes discarded process equipment and materials as well as radioactive trash, is currently about 4,700 m^3/yr (170,000 ft^3/yr) (see Appendix C). If this waste--together with the waste from ORNL--were disposed in SWSA-6 starting in August 1985 (at which time the remaining capacity would be approximately 6,700 m^3 [240,000 ft^3), SWSA-6 would be filled to capacity by the end of June 1986.

The preceding estimate does not include (1) a small volume of waste contaminated with asbestos, for which segregated disposal is desirable to minimize the nonradioactive hazard, nor (2) the large volume of grout waste from the sludge generated by settling and scrubbing operations. Sludge disposal would generate solid waste at an irregular rate depending on the schedule for removing the sludge from holding ponds where it is now stored and for treating it to form a grout mixture suitable for disposal as solid waste. The accumulated volume of sludge in the S-3 holding ponds alone is 34,000 m^3 (1,200,000 ft^3). The projected annual volume of grout waste for which a disposal facility will be needed is 15,000 m^3/yr (525,000 ft^3/yr) starting in August 1986, increasing to 17,000 m^3/yr (585,000 ft^3/yr) in 1988, and then dropping to 6,000 m^3/yr (215,000 ft^3/yr) thereafter.

The no-action alternative does not provide for removal and disposal of the sludge from the holding ponds. These ponds are, at present, leaking into 8ear Creek, thereby resulting in discharges to the waters of the state of Tennessee (McKinney 1983). An additional, and potentially severe, impact is that if a CWDF is not available for disposal of the sludge grout, a delay might occur in implementing the Memorandum of Understanding, which covers the Y-12 holding ponds as well as the Bear Creek disposal pits.

4.4.2 Disposal Options and Impacts When Existing Facilities Are Filled to Capacity

After existing disposal facilities are filled to capacity, continued use of these facilities within ORR is no longer possible. The options available at this point in time for managing radioactive wastes generated by ORNL, Y-12, and ORGDP are to: (1) expand the capacity of existing facilities; (2) provide temporary storage facilities; and (3) develop new disposal facilities. All three of these options necessarily involve some action that differs from current practice. The first two options involve the least action and may, therefore, be considered to be a continuation of the "no-change" policy of the no-action alternative. The third option is outside the scope of the no-action alternative.

4.4.2.1 Expansion of Existing Disposal Facilities

There is no acceptable practice for increasing the below-grade capacity of SWSA-6, the only existing acceptable site, beyond its nominal capacity. The use of unexcavated areas between current trenches for additional capacity has been considered but dismissed as having too high a potential for causing slumping of existing trench walls. Construction of above-grade facilities on top of existing filled trenches is not feasible because the existing trenches were designed according to standard practice that does not include grouting or other measures to provide sufficient support for an above-grade structure. Expansion of the capacities of current ORNL disposal areas in order to permit continued use is, therefore, eliminated from further consideration.

4.4.2.2 Storage of Waste

Storage of radioactive waste introduces an additional step in the sequence of actions between generation and disposal. It does not lead to a reduction in the costs of the remaining steps and can, therefore, be justified only if it leads to a reduction in the overall radiological risks or if unforeseen delays in the development of new disposal facilities make the extra step unavoidable. The radiological risks from LLW are not reduced by storage because the occupational risk for placing the waste in storage is comparable to the occupational risk for disposal, and unless the waste is stored for several hundred years (which is tantamount to converting the storage sites into disposal sites), there will be additional radiological risks when the stored waste is exhumed for disposal. For some of the wastes (e.g., the depleted uranium waste), there will be essentially no reduction in radiological risks during the storage period. The risk of public exposure from stored waste is at least as great as, and usually greater than, the risk from disposed waste because the facilities are not intended, or designed, to provide long-term isolation of the waste.

4.4.2.3 Conclusions Regarding the No-Action Alternative

The foregoing reasons--which may be summarily stated as: (1) waste generated within ORR by ORNL, ORGDP, and the Y-12 Plant will continue to accumulate; (2) existing waste facilities will be filled to capacity within two years; (3) expansion of existing facilities is not feasible; and (4) storage of waste would increase the cost and risk of waste disposal.

In addition to the aforementioned additional impacts for the no-action alternative relative to the proposed action, there is the unquantifiable impact associated with the public perception of the inability of DOE to resolve the problem of providing for waste disposal of LLW generated within ORR. This impact could have an adverse effect on public perception of the ability of DOE to manage the LLW generated by its activites.

4.5 CUMULATIVE IMPACTS

The cumulative impacts of all installations in the vicinity of the CWDF were reviewed for two main concerns: (1) comparison of the total radiological impact at ORR to that of the CWDF and (2) potential for synergism, i.e., the potential for creating a total radiological impact greater than the sum of the impacts of individual installations.

Cumulative radiological impacts can be assessed from the impacts of the individual facilities, including ORNL, ORGDP, and Y-12. The impacts of these three plants have been estimated for gaseous and liquid pathways (Boyle et al. 1982). The radiological impact of the CWDF by gaseous pathways is expected to be negligible compared to these three plants because there will not be any gaseous releases as in the other facilities. Furthermore, the physical properties of the wastes handled by the CWDF are not expected to contribute to the atmospheric dispersion of particulates under normal conditions. Also, the radiological impact of the CWDF by liquid pathways, involving slow processes of seepage through soil, is expected to be negligible during the lifetime of the other plants now operating on the ORR (see Section 4.2.2). For these reasons, the contribution of the CWDF to the cumulative environmental impact at ORR is expected to be inconsequential.

The potential for synergism in environmental impacts can be inferred from the functions of these installations, their relative distances, and their interactions. The functions of the ORNL, ORGDP, and Y-12 facilities are described in Section 1.2.1. Their distances from the WCR site are listed in Table 4.2 and the relative locations are indicated in Figure 3.2. In these descriptions, several facts related to the possibility of synergism are noteworthy: (1) the total impact of the CWDF is small compared to the other three plants, (2) an environmental analysis of ORNL, which included an assessment of cumulative effects of the major facilities in the area (Boyle 1982) concluded that the composite dose to the maximally exposed individual did not exceed the sum of the doses to individuals residing at the boundaries of ORNL, ORGDP, and Y-12, (3) the only interaction of the CWDF with the three plants would be the acceptance of wastes from them, and (4) the three plants would produce waste requiring appropriate treatment and disposal regardless of whether the CWDF were constructed. From these considerations, there is no indication that the operation of the CWDF would cause the total radiological impact to be greater than the sum of those of the separate facilities.

Although not planned, there is a potential for overlap with another project, the disposal of NFSS wastes at the Pine Ridge Knolls site (U.S. Dept. Energy 1984). If the NFSS project is implemented with disposal of the wastes at ORR, one truck hauling radioactive wastes will be brought into ORR every minute during two summers (the CWDF project would involve about 2 trucks per hour per 8-hour shift for the first 4 years. Thus, the cumulative transportation impact would result in increased traffic congestion, increased accidents, and accelerated deterioration of the roads, primarily due to the NFSS project.

4.6 UNAVOIDABLE ADVERSE ENVIRONMENTAL IMPACTS

No matter which of the alternatives is implemented, certain adverse impacts would be unavoidable. The impacts would occur even with the best possible overall program planning, engineering design, quality assurance programs, safety programs, and other mitigative measures. Following is a summary of major unavoidable adverse environmental impacts (details given in Section 4.1 and 4.2).

- Site construction would disturb about 64 ha (160 acres) of existing terrestrial habitat and cause displacement or death of biota within this habitat. Also, small springs and creek tributaries that exist within the designated disposal areas of the CWOF would be modified or destroyed by construction activities (Section 4.1.2.2).

- Workers would be exposed to radiation above the amount they would normally receive from natural background (Section 4.1.2).
- The general public would be exposed to a very small amount of radiation above the amount they would normally receive from natural background (Section 4.2.3).
- Accidents might occur, resulting in release of radioactive materials to the environment (Section 4.1.2).
- Worker injuries could occur, such as those that occur during any industrial project.
- Potential industrial uses would be preempted.
- There would be a need for long-term commitment for maintenance and monitoring.

4.7 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

The types of resources committed for the proposed project and its alternatives can be identified as: (1) material resources--including materials of contruction, renewable resource materials consumed in operation, and nonrenewable resources consumed, and (2) nonmaterial resources, including a range of beneficial uses of the environment. Resources that may be considered irreversibly or irretrievably committed are: (1) biological resources destroyed in the vicinity, (2) construction materials that cannot be recovered or recycled with current technology, (3) materials that are rendered radioactive but cannot be decontaminated, (4) materials consumed or reduced to unrecoverable forms of waste, and (5) land areas rendered unfit for other use.

Waste disposal would restrict use of approximately 64 ha (160 acres) of land. A few springs or portions of small tributary streams would be lost (Section 4.1.2.1). No other irreversible or irretrievable commitment of biotic resources associated with the the any of the sites has been identified. Clean soil that is to be used in the disposal areas as covering and fill for interstices would be irretrievably committed to the site. Similarly, materials (e.g., concrete, sand, and gravel) for the liners and caps would be permanently affixed to the site and not usable for any future purposes. Transport of wastes would require commitments of fuel to run the trucks for a total of about 2 million kilometers (1.2 million miles).

4.8 SHORT-TERM AND LONG-TERM PRODUCTIVITY OF THE ENVIRONMENT

Development of any of the alternative sites would result in short-term and long-term environmental gains and losses. Short-term effects are those that would occur during construction, operation, and the institutional-care period. Long-term effects are those that would extend past the institutional-care period into the indefinite future. Short-term effects are generally considered in terms of trade-offs relative to environmental impacts, land use, and cost. Long-term effects are related to conservation of energy reserves, environmental effects, and land use.

The primary purpose for implementing the CWDF is to place wastes from the Y-12 Plant, ORGDP, and ORNL in an environmentally acceptable, long-term disposal site. The positive short-term and long-term effects of the CWDF are that wastes would be placed in trenches or tumuli that would enhance their isolation from the human environment. Implementation would cause consumption of some depletable resources such as cement and steel; however, these are all common industrial products and consumption for the CWDF would not significantly affect their supply. Also, implementation of the CWDF would require short-term dedication of land during construction, operation, and institutional care of the facility. Disposal of wastes at the CWDF would commit the subsurface area to that purpose indefinitely and would restrict the development at that location of potential mineral resources by drilling or mining.

Use of any of the alternative sites for disposal would result in a less favorable environment and have a localized effect on the biotic community. Creation of the facility would also prevent the use of affected disposal areas for timber management, at least through the institutional-care period.

Following the institutional-care period, the site might be allowed to revert back to habitat currently existing on the site (especially if access were restricted). On the other hand, the area might be used for timber management or agricultural development.

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5. ENVIRONMENTAL PERMITS, REGULATIONS, AND APPROVAL

The permits, certifications, licenses, and other approvals from the federal government or state of Tennessee that may be needed for the CWDF are discussed in this section. Emphasis is on air quality, water quality, disposal of solid and hazardous wastes, protection of critical wildlife habitats, and preservation of cultural resources (Table 5.1).

Many of the regulations and orders discussed herein are internal to DOE, thus resulting in self-regulation in most instances. With regard to the health and safety aspects of handling radioactive materials, DOE's self-regulation derives primarily from Section 110(a) of the Atomic Energy Act (AEA) of 1954 as amended (40 USC 2011 et seq.), wherein DOE-owned, contractor-operated facilities are excluded from licensing and other regulatory functions of the U.S. Nuclear Regulatory Commission (NRC). This exclusion also applies to the NRC "agreement states" that have derived authority from NRC to carry out certain regulatory functions. However, the DOE has followed the general guidelines of 10 CFR Part 61 in the development of the CWDF.

DOE's primary standards for radiation protection are contained in DOE Order 5480.1A, Chapter XI, "Requirements for Radiation Protection," Environmental Protection, Safety and Health Protection for DOE Operations. This order specifies that personnel exposures be kept as-low-as-reasonably-achievable (ALARA) and lists the allowable concentrations of various radionuclides in air and water, both onsite and offsite. The CWDF operations will be designed to meet the radiation standards of the order, and will be no higher than the current practices.

DOE Order 5820.2, Radioactive Waste Management, assigns responsibilities and mandates procedures for various DOE radioactive waste management activities. It addresses waste-acceptance criteria, site selection, site design, site operation, and site-closure/post-closure plans. The CWDF will meet or exceed the requirements of this order. These requirements are in general comparable to the NRC regulation 10 CFR Part 61, which deals with licensing requirements for land disposal of radioactive waste.

DOE Order 5481.1A, Safety Analysis Review System, establishes uniform requirements for the preparation and review of safety analyses of DOE operations. This order will apply to the CWDF.

DOE Order 5482.1A, Environmental, Safety, and Health Appraisal Program (ES&H) applies to all contractors performing work for DOE where DOE has established environmental, safety, and health control under the contractual arrangements for the work to be performed. The ES&H appraisal requirement will apply to the CWDF.

As a federal agency, DOE is required to comply with a number of environmental requirements under various federal laws. These requirements include,

Table 5.1. Required Regulatory Permits and Notifications

Facility/ Activity	Requirement	Agency
CWDF project	EIS required for "major federal action"	Council on Environmental Quality/U.S. Environmental Protection Agency
WCR site	Historic and archaeological site survey	Tennessee State Historic Preservation Officer
	Site use permit	U.S. Department of Energy, Oak Ridge Reservation
	Endangered species consultation	U.S. Fish and Wildlife Service
Construction/ operational activities	Under negotiation	Tennessee Department of Health and Environment/EPA

but are not limited to, those outlined in the six laws and three executive orders described below.

National Environmental Policy Act of 1969, as amended (NEPA) (42 USC 4321 et seq.) requires "all agencies of the federal government" to prepare a detailed statement on the environmental effects of proposed "major federal actions significantly affecting the quality of the human environment." In accordance with the requirements of NEPA, DOE is filing with the U.S. Environmental Protection Agency (EPA) and circulating to the public this environmental impact statement (EIS) on the CWDF. This EIS has been prepared in accordance with the Council on Environmental Quality (CEQ) Regulations on Implementing National Environmental Policy Act Procedures (40 CFR 1500-1508) and DOE Guidelines for Compliance with the National Environmental Policy Act (U.S. Dept. Energy 1980).

Executive Order 12088 (October 13, 1978) requires every federal agency to comply with applicable administrative and procedural pollution control standards established by, but not limited to, the following federal laws:

- Toxic Substances Control Act (15 USC 2601 et seq.)
- Federal Water Pollution Control Act (33 USC 1251 et seq.)
- Public Health Service Act, as amended by the Safe Drinking Water Act [42 USC 300 (f) et seq.]

- Clean Air Act (42 USC 7401 et seq.)
- Noise Control Act (42 USC 4901 et seq.)
- Solid Waste Disposal Act (42 USC 6901 et seq.)

Executive Order 12088 also requires federal compliance with radiation guidance pursuant to Section 2174(h) of the Atomic Energy Act of 1954, as amended [42 USC 2021(h)].

Executive Orders 11988 (Floodplain Management) and 11990 (Protection of Wetlands) (May 24, 1977) require government agencies to avoid to the extent possible any short-term and long-term adverse impacts on floodplains and wetlands wherever there is a practicable alternative.

Clean Air Act (42 USC 7401 et seq.) as amended by the Clean Air Act Amendments of 1977 (Public Law 95-95) provides for the control of air pollution by federal facilities (Section 118). Each federal agency, such as DOE, having jurisdiction over any property or facility that may result in the discharge of air pollutants is required to comply with "all federal, state, interstate, and local requirements" with regard to the control and abatement of air pollution. Authority for regulation of air emissions has been delegated by the EPA to the Tennessee Department of Health and Environmental.

Federal Water Pollution Control Act, as amended by the Clean Water Act of 1977 (33 USC 1251 et seq.) requires all branches of the federal government engaged in any activity that may result in a discharge or runoff of pollutants, excluding materials regulated under the Atomic Energy Act of 1954, to comply with federal, state, interstate, and local requirements. Authority for implementation of these requirements resides with EPA for the DOE facilities at ORR. The U.S. Army Corps of Engineers has been delegated authority over dredge or fill operations.

Resource Conservation and Recovery Act (RCRA) of 1976 (42 USC 3251 et seq.) governs the generation, management, transportation, and disposal of hazardous wastes. It does not apply to source, by-product, or special nuclear material as defined by the Atomic Energy Act of 1954 (42 USC 2011 et seq.). The CWDF will not handle hazardous or hazardous and radioactive mixed waste.

Noise Control Act of 1972 (42 USC 4901 et seq.) directs all federal agencies to carry out programs within their jurisdiction "to the fullest extent within their authority" in a manner that furthers a national policy of promoting an environment free from noise that jeopardizes health or welfare (Section 4). DOE will comply with such requirements to the fullest extent possible.

Endangered Species Act of 1973 (16 USC 1531 et seq.), as amended, is intended to prevent the further decline of endangered and threatened species and to bring about the restoration of these species and their habitats. This Act, which is jointly administered by the Departments of Commerce and Interior, does not require a permit, certification, license, or other formal approval. Section 7 does, however, require a consultation to determine whether endangered and threatened species are known to have critical habitats on or in the vicinity of the site. DOE will comply with this law by undertaking the Section 7 consultation process to ensure that its proposed action will not jeopardize the continued existence of any threatened or endangered species and/or their critical habitats.

Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). DOE will comply with all applicable portions of CERCLA, and plans for compliance are being developed.

REFERENCES (Chapter 5)

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6. LIST OF CONTRIBUTORS

6.1 LIST OF PREPARERS

Name and Affiliation	Education/Expertise	EIS Contribution
TECHNICAL STAFF, ANL		
Thomas L. Gilbert	Ph.D. Theoretical Physics 35 yr experience in analysis of physical systems; 5 yr experience in environmental impact assessment	Alternative site analysis; health effects
Charles Luner	Ph.D. Physical Chemistry 11 yr experience in environmental impact assessment	Project Leader
Anthony J. Policastro	Ph.D. Civil Engineering 9 yr experience in meterological research and development and environmental assessment	Meteorology, air quality assess-assessment
Steve Y.H. Tsai	Ph.D. Civil Engineering 10 yr experience in hydrologic analysis and environmental assessment	Description of existing hydrology and geology; impact analyses
LaVernne E. Trevorrow	Ph.D. Physical Chemistry 30 yr experience in waste management and nuclear fuel cycle	Radiological analysis of transportation and disposal, engineering, waste characterization
William S. Vinikour	M.S. Biology 10 yr experience in environmental assessment and research	Description of existing ecological environment and impacts
Gary Williams	Ph.D. Sociology 8 yr experience in social impact assessment	Description of existing socioeconomic environment and impacts
Margery C.B. Winters	M.S. Physical Geography 4 yr experience in geologic analysis and environmental assessment	Description of existing geology, geological impacts, site integrity analyses
Dimis J. Wyman	M.S. Botany, M.A. Library Science 9 yr experience in technical editing	Technical editing
Jing-Yea Yang	Ph.D. Environmental Engineering 11 yr experience in hydrology and water resources analysis	Description of surface hydrology impacts

6.2 LIST OF REVIEWERS

Name and Affiliation	Area of Expertise
<u>DOE, OAK RIDGE OPERATIONS OFFICE</u>	
Doyle R. Brown	Civil Engineering and Management
Paul B. Dunaway	Environmental Impact Assessment
S.S. Stief	Environmental Engineering and Assessment
<u>OAK RIDGE NATIONAL LABORATORY</u>	
L.D. Bates	Waste Management/Project Management
J.B. Cannon	Environmental Impact Assessment
Roy E. Thoma	Environmental Impact Assessment
<u>DOE, HEADQUARTERS</u>	
Steven Miller Attorney Office of General Counsel	Institutional Issues, Laws, Regulations
Randal S. Scott Division of Defense Programs	Waste Management
Steve Woodbury Office of Environmental Compliance	Environmental Impact Assessment, Environmental Laws and Regulations

APPENDIX A. DISTRIBUTION LIST

Federal Agencies

Mr. Bruce Blanchard, Director (8)
Office of Environmental Project Review
U.S. Department of the Interior
C Street, NW
Washington, DC 20240

Council on Environmental Quality
722 Jackson Place, N.W.
Washington, DC 20006

Federal Emergency Management Administration
1725 I Street, N.W.
Washington, DC 20036

Federal Highway Administration
ATTN: Mr. E.G. Oakley
Division Administrator
Federal Building - U.S. Courthouse
801 Broadway, Room A926
Nashville, TN 37203

Walt Frankhauser, Chief (5)
Department of Energy
DP-123, Germantown
Washington, DC 20585

Mr. David R. Hopkins, Energy Coordinator (5)
Office of Policy and Management
U.S. Environmental Protection Agency
Region IV
345 Courtland Street, N.E.
Atlanta, GA 30365

Materials Transportation Board
ATTN: Mr. James C. Thomas
Director
Southern Region
1568 Willingham Drive
Atlanta, GA 30337

Steve Miller, Attorney
Department of Energy, GC-34
Forrestal Building, Room 6D-032
Washington, DC 20585

National Transportation Safety Board
ATTN: Mr. Jay Golden
Field Office Chief
Suite 921
1720 Peachtree Road, NW
Atlanta, GA 30309

Oak Ridge National Laboratory (150)
ATTN: L. Bates
CWDF Project
P.O. Box X
Oak Ridge, TN 37830

John S. Sieg (10)
National Research Council
Board on Radioactive Waste Management
2101 Constitution Avenue
Washington, DC 2041B

Tennessee Valley Authority
ATTN: Mr. Charles H. Dean, Jr.
Chairman
400 Commerce Building
Knoxville, TN 37902

Tennessee Valley Authority
ATTN: Mr. John R. Thurman
Group Head, NEPA
Environmental Quality Staff
Norris, TN 37828

Tennessee Valley Authority
Director of Land and Forest Resources
Norris, TN 37828

Tennessee Valley Authority
Nuclear Regulation & Safety
ATTN: Mr. Larry M. Mills, Mg.
400 Chestnut Tower No. 2
Chattanooga, TN 37401

U.S. Advisory Council on Historic Preservation
1522 K Street, N.W.
Washington, DC 20005

U.S. Army Corps of Engineers
ATTN: Lt. Gen. John W. Morris
Chief of Engineers
20 Massachusetts Avenue NW
Washington, DC 20545

U.S. Army Corps of Engineers
Lower Mississippi Division
ATTN: Maj. Gen. Robert C. Marshall
Division Engineer
P.O. Box 80
Vicksburg, MS 39180

U.S. Army Corps of Engineers
Nashville District
ATTN: Col. Lee W. Tucker
P.O. Box 1070
Nashville, TN 37202

U.S. Department of Agriculture
ATTN: Director, Office of Environmental Quality
Washington, DC 20250

U.S. Department of Commerce
Deputy Assistant Secretary, Environmental Affairs
Washington, DC 20230

U.S. Department of Commerce
Economic Development Administration
ATTN: Mr. Charles E. Oxley, Director
Southeastern Region
1365 Peachtree Street, NE
Atlanta, GA 30309

U.S. Department of Commerce
Natl. Oceanic & Atmospheric Admin.
ATTN: Mr. Paul Hemman
Suite 300, 1365 Peachtree St., NE
Atlanta, GA 30309

U.S. Department of Energy
Region IV
Office of the Regional Representative
1655 Peachtree Street, NE
Atlanta, GA 30309

U.S. Department of Energy (20)
ATTN: Environmental Protection Branch
Post Office Box E
Oak Ridge, TN 37831

U.S. Department of Health and Human Services
Principal Regional Official
ATTN: Ms. Sara Craig
101 Marietta Tower
Atlanta, GA 30323

U.S. Department of Health and Human Services
ATTN: Director
Office of Environmental Affairs
Washington, DC 20201

U.S. Department of Housing and Urban Development
ATTN: Director
Office of Environmental Quality
Washington, DC 20410

U.S. Department of Housing and Urban Development
ATTN: Mr. Richard W. Lippold
107 Delaware Avenue,
Statler Building
Buffalo, NY 14202

U.S. Department of the Interior
Forest Service
ATTN: Mr. Lawrence M. Whitfield
Suite 800
1720 Peachtree Road, NW
Atlanta, GA 30309

U.S. Department of the Interior
Office of Environ. Project Review
ATTN: Mr. James H. Lee
75 Spring Street, SW
Atlanta, GA 30303

U.S. Department of the Interior
Fish & Wildlife Service
75 Spring Street, SW
Atlanta, GA 30303

U.S. Department of the Interior
ATTN: Director
Fish and Wildlife Service
17 Executive Park Drive, NE
Atlanta, GA 30347

U.S. Department of the Interior
ATTN: Mr. Kenneth E. Black
Regional Director
Fish & Wildlife Service
Room 279, Federal Building
Asheville, NC 28801

U.S. Department of the Interior
Fish and Wildlife Service
Ecological Services
ATTN: Mr. T. Talley
Field Supervisor
Post Office Box 845
Cookeville, TN 37502

U.S. Department of Interior
National Park Service
ATTN: Mr. Paul C. Swartz, Chief
Planning Services Division
Southeast Region
75 Spring Street, SW
Atlanta, GA 30303

U.S. Department of Interior
U.S. Geological Survey
National Center
12002 Sunrise Valley Drive
Reston, VA 22092

U.S. Department of Transportation
ATTN: Director
Office of Environmental Quality
Washington, DC 20690

U.S. Department of Transportation
Office of Environmental Affairs
400 7th Street, SW
Washington, DC 20540

U.S. Department of Transportation
ATTN: Mr. LaMar Baker
Regional Representative
of the Secretary
1720 Peachtree Road NW, Suite 515
Altanta, GA 30309

U.S. Department of Transportation
Regional Director of Railroad Safety
Federal Railroad Administration
ATTN: Charles R. Meyrick
Suite 440 A North Tower
1720 Peachtree Road, NW
Atlanta, GA 30309

U.S. Department of Transportation
Materials Transportation Bureau,
Central Division
ATTN: Mr. Marshall W. Taylor III, Dir.
911 Walnut Street
Kansas City, MO 64106

U.S. Environmental Protection Agency (5)
Federal Activities Office
ATTN: Mr. Allan Hirsch, Director
Rm 2119, Waterside Mall
401 M Street, SW
Washington, DC 20460

U.S. Environmental Protection Agency
ATTN: Dr. W. Alexander Williams
401 M Street, SW
Mail Stop A-104
Washington, DC 20460

U.S. Environmental Protection Agency
Region IV
ATTN: Mr. Charles R. Jeter
Regional Administrator
345 Courtland Street, NE
Atlanta, GA 30365

U.S. Environmental Protection Agency (5)
Region IV
EIS Review Section
ATTN: Mr. Shepard N. Moore
345 Courtland Street NE
Atlanta, GA 30365

U.S. Environmental Protection Agency
Region IV
Federal Activities Coordinator
ATTN: Mr. A.G. Linton, P.E.
345 Courtland Street, NE
Atlanta, GA 30365

U.S. Environmental Protection Agency
Region IV
New Source Permits Coordinator
ATTN: J. Franmathes
345 Courtland Street, NE
Atlanta, GA 30365

U.S. Environmental Protection Agency
Region IV
Toxic Substances Section
ATTN: Mr. Ralph Jennings, Chief
345 Courtland St., NE
Atlanta, GA 30365

U.S. Food and Drug Administration
Bureau of Radiological Health
ATTN: Mr. John C. Villforth
Rockville, MD 20857

U.S. Nuclear Regulatory Commission
ATTN: Mr. John G. Davis, Director
Office of Nuclear Materials Safety
and Safeguards
Washington, DC 20555

U.S. Occup. Safety and Health Admin.
ATTN: Mr. Robert A. Wendell
Regional Administrator
Suite 587
1375 Peachtree Street, NE
Atlanta, GA 30309

U.S. Office of Management and 8udget
ATTN: Mr. Richard 8rozen
Executive Office Building
Washington, DC 20503

Mr. Chester L. Wakamo
Air and Waste Management Division
U.S. Environmental Protection Agency
Region IV
345 Courtland Street, N.E.
Atlanta, GA 30365

Steve Woodbury (5)
Department of Energy, PE-252
Forrestal Building, Room 4G-057
Washington, DC 20585

U.S. Congress

Honorable Howard H. Baker, Jr.
United States Senate
4123 Dirkson 8uilding
Washington, DC 20510

Honorable Tom Bevill
Chairman, Subcommittee on Energy
and Water Development
Committee on Appropriations
House of Representatives
Washington, DC 20515

Honorable William L. Dickinson
Ranking Minority Member
Committee on Armed Services
House of Representatives
Washington, DC 20515

Honorable John J. Duncan
House of Representatives
Washington, DC 20515

Honorable Albert Gore, Jr., Chairman
Subcommittee on Investigations and
Oversight
U.S. House of Representatives
Suite 2321, Rayburn House Office
Building
Washington, DC 20515

Honorable Mark O. Hatfield
Chairman, Subcommittee on Energy
and Water Development
Committee on Appropriations
United States Senate
Washington, DC 20510

Honorable J. Bennett Johnston
Ranking Minority Member
Committee on Appropriations
United States Senate
Washington, DC 20510

Honorable Marilyn Lloyd
Chairman, Sucommittee on Energy
Research and Production
Committee on Science and Technology
House of Representatives
Washington, DC 20515

Honorable John T. Myers
Ranking Minority Member
Committee on Appropriations
House of Representatives
Washington, DC 20515

Honorable Sam Nunn
Ranking Minority Member
Committee on Armed Services
United States Senate
Washington, DC 20510

Honorable Melvin Price
Chairman, Committee on
Armed Services
House of Representatives
Washington, DC 20515

Honorable Jim Sasser
United States Senate
Washington, DC 20510

Honorable John G. Tower
Chairman, Committee on
Armed Services
United States Senate
Washington, DC 20510

Honorable Robert S. Walker
Ranking Minority Member
Committee on Science and Technology
House of Representatives
Washington, DC 20515

All other members of the
Tennessee Congressional
Delegation

National and Local Environmental Groups

Mr. Dave Berick
Environmental Policy Center
317 Pennsylvania Avenue, S.E.
Washington, DC 20003

Environmental Action, Inc.
1346 Connecticut Ave., N.W.
Room 731
Washington, DC 20036

Environmental Defense Fund
1525 18th St. N.W.
Washington, DC 20036

Friends of the Earth
530 7th Street, S.E.
Washington, DC 20003

Mr. H. Paul Friesma, Director (2)
Environmental Policy Program
Center for Urban Affairs and
Policy Research
Northwestern University
2040 Sheridan Road
Evanston, IL 60201

Legal Environmental Assistance
Foundation
602 Gay Street, Suite 507
Knoxville, TN 37902

National Audubon Society
950 Third Avenue
New York, NY 10022

National Resources Defense
Council, Inc.
1725 I St. N.W.
Washington, DC 20006

National Wildlife Federation
1412 16th Street, N.W.
Washington, DC 20036

The Natural Rights Center
ATTN: Mr. Albert Bates, Director
156 Drakes Lane
Summertown, TN 3B483

Mr. Kevin C. Owen, Environmental
Specialist
RECRA Research, Inc.
4248 Ridge Lea Road
Amherst, NY 14226

Mr. W. Paul Robinson
Southwest Research and Information
Center
P.O. 8ox 4524
Albuquerque, NM 87106

Sierra Club Radioactive Waste
Campaign
78 Elmwood Avenue
8uffalo, NY 14201

Mr. Brooks Yeager
Sierra Club
330 Pennsylvania Avenue, S.E.
Washington, DC 20006

State and Local Government

Honorable Lamar Alexander
Governor of Tennessee
Nashville, TN 37219

Mr. Dave Bolling
County Administrator
Anderson County Court House
Room 208
100 N. Main Street
Clinton, TN 37716

City of Oak Ridge
ATTN: Mr. M. Lyle Lacy, III
City Manager
Municipal Building
Oak Ridge, TN 37830

City of Oak Ridge
ATTN: Mr. James D. Harless
Environmental Health Supervisor
P.O. Box 1
Oak Ridge, TN 37830

Mr. Terry K. Cothron,
Environmental Engineer (5)
State of Tennessee
Department of Health and Environment
150 Ninth Avenue, North
Nashville, TN 37203

Charles C. Coutant, Chairman (2)
Env. Quality Advisory Board
120 Miramer Circle
Oak Ridge, Tennessee 37830

East Tennessee Development District
ATTN: Mr. Allen W. Neel
Chairman
Post Office Box 19806
1810 Lake Ave.
Knoxville, TN 37916

The Honorable James E. Elkins
Tennessee Senate
224 North Main Street
Clinton, TN 37716

Mr. Wayne Gregory, Environmental Engineer (2)
Division of Solid Waste Management
State of Tennessee
Department of Health and Environment
7th Floor, TERRA Building
150 Ninth Avenue, North
Nashville, TN 37203

Mr. John L. Leonard (5)
Regional Director
Div. of Solid Waste Mgmt.
Tennessee Department of Health and Environment
1522 Cherokee Trail
Knoxville, Tennessee 37920

Honorable Rubye Luckey
Mayor of Kingston
Cumberland Street
Municipal Building
Kingston, TN 37763

Honorable Mayor and Members of City Council
P.O. Box 1, Municipal Building
Oak Ridge, TN 37920

A. David McKinney (5)
Tennessee Department of Public Health and Environment
1522 Cherokee Trail
Knoxville, Tennessee 37920

Honorable Randy McNally
Tennessee House of Representatives
121 Amanda Drive
Oak Ridge, TN 37830

Honorable Anna Belle Clement O'Brien
Suite 9, Legislative Plaza
Nashville, TN 37219

Roane County
ATTN: Mr. Ken Yager
County Executive
Roane County Courthouse
200 Race Street, P.O. Box 643
Kingston, TN 37763

Tennessee Department of Agriculture
ATTN: Mr. William H. Walker, III
Commissioner
P.O. Box 40627
Melrose Station
Nashville, TN 37204

Tennessee Department of Conservation
ATTN: Mr. Charles A. Howell, III
Commissioner
701 Broadway
Nashville, TN 37203

Tennessee Department of Economic and Community Development
ATTN: Mr. William H. Long
Commissioner
Andrew Jackson State Off. Bldg., Room 1007
Nashville, TN 37219

Tennessee Department of Health and Environment
ATTN: Mr. Robert H. Wolle
TERRA Building
150 Ninth Avenue, North
Nashville, TN 37219

Tennessee Department of Health and Environment
ATTN: Mr. James E. Word
Commissioner
150 Ninth Avenue, North
Nashville, TN 37203

Tennessee Department of Health and Environment
ATTN: Mr. D. Elmo Lunn, Director
Division of Water Management
150 Ninth Avenue, North
Nashville, TN 37203

Tennessee Department of Health and Environment
ATTN: Mr. Norman H. Travis
701 Broadway
Nashville, TN 37203

Tennessee Department of Health and Environment
ATTN: Mr. Harold Hodges
Division of Air Pollution Control
150 Ninth Ave., North
Nashville, TN 37203

Tennessee Department of Labor
ATTN: Mr. Robert Taylor, Director
Occupational Safety
501 Union Building
Nashville, TN 37219

Tennessee Department of Labor
ATTN: Mr. Francis S. Guess
Commissioner
501 Union Building, Second Floor
Nashville, TN 37219

Tennessee Department of Transportation (2)
ATTN: Mr. Robert E. Farris
Commissioner
James K. Polk Building, Suite 700
Nashville, TN 37219

Tennessee Energy Authority
Executive Director
Capitol Boulevard Building
Nashville, TN 37219

Tennessee Wildlife Resources Agency
ATTN: Mr. Gary T. Myers
Executive Director
Post Office Box 40747
Nashville, TN 37204

Public Libraries and Reading Rooms

Clinton Public Library (2)
Clinton, TN 37716

Kingston Public Library (2)
Community Center
Kingston, TN 37763

Oak Ridge Public Library (2)
Civic Center Building
Oak Ridge Turnpike
Oak Ridge, TN 37830

Reading Room
Freedom of Information
Room 1E-190, Forrestal Bldg.
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

U.S. Department of Energy
Public Document Room
Betty G. Camp, Librarian
1655 Peachtree Street, NE
Atlanta, GA 30309

U.S. Department of Energy
Public Document Reading Room
ATTN: Mrs. Brenda Jennings
P.O. Box E
Oak Ridge, TN 37830

Individuals

C.S. Abrams
Manager of Radiological Engineering
Argonne National Laboratory-West
Post Office Box 2528
Idaho Falls, ID 83401

James F. Albaugh
Rockwell Hanford
Post Office Box 800
Richland, WA 99352

Edward L. Albenesius
E.I. DuPont de Nemours and Co.
Savannah River Laboratory
Aiken, SC 29808

Don Barger
113 Jasper Lane
Oak Ridge, TN 37830

Renee P. Bender
114 Monticello Road
Oak Ridge, TN 37830

Randy Birch
Department of Water
Foss Building
Pierre, South Dakota 57501

A.K. Bissell
105 Meadow Road
Oak Ridge, TN 37830

Richard K. Blauvelt
Monsanto Research Corporation
Mound Facility
Post Office Box 32
Miamisburg, OH 45342

Bill Brewer
5501 Newberry Lane
Knoxville, TN 37921

Mr. Ron Canon
1801 El Rancho Trail
Knoxville, TN 37932

Jack G. Couch
Fermi National Accelerator Laboratory
Post Office Box 500
Batavia, IL 60510

Mr. John W.T. Dabbs
106 Osage Rd.
Oak Ridge, TN 37830

Mr. F.W. Dickson
1065 West Outer Dr.
Oak Ridge, TN 37830

Mr. Michael Foster
312 Directors Drive
Knoxville, TN 37923

Harry C. Francke
201 Manhattan Avenue
Oak Ridge, TN 37830

Alma Fulks
105 Kingsley Road
Oak Ridge, TN 37830

Ken Gentry
Bendix Corporation
P.O. Box 1159, D/187, BD59
Kansas City, MO 64141

Mr. B. James George
107 Newport Dr.
Oak Ridge, TN 37830

Mr. Frank A. Guevara
Los Alamos Scientific Laboratory
Group HSE-1, Mail Stop P 229
P.O. Box 1663
Los Alamos, NM 87545

Wayne R. Hansen
Mail Stop K490
Los Alamos National Laboratory
Post Office Box 1663
Los Alamos, NM 87545

R.E. Helms
810 West Outer Drive
Oak Ridge, TN 37830

B. Donnie Helton
Bldg. 703-H
E.I. DuPont de Nemours & Co.
Savannah River Plant
Aiken, SC 29801

The Honorable Jim Henry
Edgewater Estates
Kingston, TN 37763

Industrial Commission of Ohio
Division of Safety and Hygiene
ATTN: Mr. Philip A. Workman
Superintendent
246 N. High Street
Columbus, OH 43215

Mr. Jon Jefferson
Oak Ridge National Laboratory
P.O. Box X
Oak Ridge TN 37831

Harold W. Jernigan
122 Westlook Circle
Oak Ridge, TN 37830

John E. Jones, Jr.
128 Wendover Circle
Oak Ridge, TN 37830

Eugene W. Kendall
Rad Waste Management Project
REECO
Post Office Box 642
Mercury, NV 89023

W.H. Kline
Argonne National Laboratory
9700 South Cass Avenue
Argonne, IL 60439

Mr. Donald W. Lee
Rt. 5, Box 361-C
Lenoir City, TN 37771

Ms. Claudia Lever
President, League of Women Voters
of Oak Ridge
132 Newell Lane
Oak Ridge, TN 37830

Mr. J.F. McBrayer
110 Normandy Rd.
Oak Ridge, TN 37830

John H. McMenamin
Mason and Hanger - Silas Mason Co.
Pantex Plant
Post Office Box 30020
Amarillo, TX 30020

John H. Nelson
Manager of Radioactive Waste
Management Complex
EG&G Idaho, Inc.
Post Office Box 1625
Idaho Falls, ID B3415

Jesamae Noritake
P.O. Box 3472
Oak Ridge, TN 37830

Mr. Robert Peele
130 Oklahoma Ave.
Oak Ridge, TN 37830

P.T. Perdue
103 Oak Lane
Oak Ridge, TN 37B30

R.F. Perkins
113 E. Magnolia Lane
Oak Ridge, TN 37830

Mr. Andy Phelps
P.O. Box 350
Oak Ridge, TN 37830

Mr. Joseph Pidkowicz
135 North Seneca Road
Oak Ridge, TN 37830

Frances Pleasonton
111 Pleasant Road
Oak Ridge, TN 37830

Vicki Quatmann
Route 1, Box 51
Lake City, TN 37769

W.R. Rhyne
140 Windham Road
Oak Ridge, TN 37830

Russ River
223 Villanova Road
Oak Ridge, TN 37830

Mr. Dickinson Roop
107 Redbud Dr.
Clinton, TN 37716

T.H. Row
231 Louisiana Avenue
Oak Ridge, TN 37830

Dr. and Mrs. Henry B. Ruley
344 Louisiana Ave.
Oak Ridge, TN 37830

Roberto J. Salazar
Lawrence Livermore National
Laboratory
Post Office Box 808
Livermore, CA 94550

T. Sander
2615 So. Mission Road
Tucson, Arizona 85713

Ms. Louise Skinner
125 Monticello Rd.
Oak Ridge, TN 37830

Gordon Smith
Sandia Laboratories
P.O. Box 5800
Albuquerque, NM 87185

Ms. Lisa H. Stinton
10929 Sallings Rd.
Knoxville, TN 37922

Stone and Webster Engineering Corp.
ATTN: Ms. Arlene Port
P.O. Box 2325
Boston, Mass. 02107

Ms. Kathryn Tominey
Rockwell Hanford Company
P.O. Box 800, M0021/200E
Richland, WA 99352

John L. Warren
Mail Stop E516
Los Alamos National Laboratory
Post Office Box 1663
Los Alamos, NM 87545

Kenneth S. Warren
105 Evans Lane
Oak Ridge, TN 37830

Joe L. Williams
Paducah Gaseous Diffusion Plant
Post Office Box 1410
Paducah, KY 42001

John D. Williams
813 Montvue
Kingston, TN 37763

Susan Willams
P.O. Box 606
Norris, TN 37828

Ms. Amy Wolfe
Rt. 2, Box 222 FX
Harriman, TN 37748

Robert A. Wynveen
Argonne National Laboratory
9700 South Cass Avenue
Argonne, IL 60439

Donald L. Ziegler
Manager, Solid Waste Operations
Rockwell International, ESG
Rocky Flats Plant
Post Office Box 464
Golden, CO 80401

APPENDIX B. GLOSSARY

Acronyms and Abbreviations

ALARA	As-low-as-reasonably-achievable
CCR	Central Chestnut Ridge
Ci	Curie
CRM	Clinch River Mile
CWDF	Central Waste Disposal Facility
D&D	Decontamination and decommissioning
DOE	Department of Energy
DOT	Department of Transportation
ECR	East Chestnut Ridge
EIS	Environmental impact statement
EPA	Environmental Protection Agency
HC	Hydrocarbons
ICC	Interstate Commerce Commission
LAM	Local air monitoring
LLW	Low-level waste
MM	Modified Mercalli
MPC	Maximum permissible concentration
mrem	Millirem (1/1,000 of a rem)
MSL	Mean sea level
NEPA	National Environmental Policy Act of 1969
NFSS	Niagara Falls Storage Site
NOx	The oxides of nitrogen, primarily NO and NO_2

NRC	Nuclear Regulatory Commission
ORGDP	Oak Ridge Gaseous Diffusion Plant
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
PCBs	Polychlorinated biphenyls
R	Roentgen
rad	Unit of absorbed dose (radiation absorbed dose)
rem	Unit of dose (roentgen equivalent man)
RK	River kilometers
RM	River miles
SO_2	Sulfur dioxide
SWSAs	Solid waste storage (disposal) areas at Oak Ridge National Laboratory
TSP	Total suspended particulates
USLE	Universal Soil Loss Equation of the U.S. Department of Agriculture
WCR	West Chestnut Ridge
X-10	A site designation for the Oak Ridge National Laboratory
Y-12	Site designation of one of the three main plants on the Oak Ridge Reservation

Definitions

ABSORBED DOSE--The amount of energy absorbed in any material from incident radiation. Measured in rads, where 1 rad equals 100 ergs of energy absorbed in 1 gram of matter.

ACCELERATION, HORIZONTAL--A measure of earthquake severity, expressed as surface movement in terms of acceleration due to gravity (g).

ACCLIMATION--The physiological and behavioral adjustments of an organism to changes in its immediate environment.

ACCLIMATIZATION--The acclimation or adaptation of a particular species over several generations to a marked change in the environment.

ACTINIDES--Chemical elements with atomic numbers of 89 (actinium) and above.

ACTIVITY--The emission of alpha particles, beta particles, or gamma radiation as a result of radioactive decay; specific activity is given in terms of the number of nuclear disintegrations occurring in a given quantity of material over a unit of time. The special unit of activity is the curie, 3.7×10^{10} disintegrations per second.

AGREEMENT STATES--Those states that have entered into agreements with the U.S. Nuclear Regulatory Commission regarding transfer of the regulatory authority of nuclear activities from the Commission to the State.

AIR QUALITY--A measure of the levels of pollutants in the air.

AIR QUALITY STANDARDS--The prescribed level of pollutants in the outside air that cannot be exceeded legally during a specified time in a specified area.

ALPHA PARTICLE--A particle emitted from the nucleus in the radioactive decay of certain nuclides. It consists of two protons and two neutrons bound together; identical to the nucleus of a helium-4 atom. It has low penetrating power and short range. The most energetic alpha particle will generally fail to penetrate the skin. Alpha particles are hazardous when an alpha-emitting isotope is introduced into the body.

AQUIFER--A water-bearing layer of permeable rock or soil that will yield water in usable quantities to wells. Confined aquifers are bounded on top and bottom by impermeable materials. Unconfined aquifers are bounded on the bottom by impermeable materials.

AQUITARD--A geologic formation of a rather imperious and semiconfining nature that transmits water at a very slow rate compared to an aquifer.

ASH--Inorganic residue remaining after ignition of combustible substances.

ATMOSPHERE--The layer of air surrounding the earth.

BACKFILL--Material used to refill an excavation.

BACKGROUND RADIATION--Background radiation includes both the natural and man-made (e.g., fallout) radiation in man's environment. It includes cosmic rays and radiation from the naturally radioactive elements that occur (both outside and inside the bodies of humans and animals). For persons living in the Oak Ridge Reservation area, the individual dose from background radiation averages about 130 millirems per year.

BARRIER--Any medium that retards the movement of emplaced radioactive material or reduces the probability of human access to the material. (Examples are engineered features, including waste containers, waste form, or backfill material; a natural geologic medium; or institutional site access and use restrictions.)

BEDROCK--A solid rock formation usually underlying one or more other loose formations.

BENTHIC--Of, relating to, or occurring at the bottom of a body of water. For example, the benthic community consists of the biotic assemblage that dwells within and on the bottom of a water body.

BETA PARTICLE--A particle emitted from the nucleus during radioactive decay. It is negatively charged and identical to an electron. Beta particles are easily stopped by a thin sheet of metal or plastic. Large amounts of beta radiation may cause skin burns, and beta emitters are harmful if they enter the body.

BIOSPHERE--The portion of the earth and its atmosphere capable of supporting life.

BIOTA--The animal and plant life of a region.

BUFFER ZONE--A zone that includes the portion of the site that completely surrounds the burial zone in three dimensions and in which activities are restricted. At the outer boundary, contaminant levels will be below performance objectives applicable to radiation releases to the general environment.

BURIAL GROUND--Tract of land where radioactive wastes are buried in shallow trenches or holes.

CENTRAL CHESTNUT RIDGE--An area within the Oak Ridge Reservation that is an alternative location for the proposed Central Waste Disposal Facility.

COMMERCIAL--Applied in this EIS to wastes and fuels resulting from the production of electric power for public consumption using nuclear reactors, as distinguished from materials produced from the nuclear national defense program.

CONTAINMENT--Confining the radioactive wastes within prescribed boundaries, e.g., within a waste package.

CUMULATIVE IMPACT--Cumulative impact is the impact on the environment that results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions.

CURIE--A measure of the rate of radioactive decay. One curie is equal to 3.7×10^{10} disintegrations per second, which is approximately equal to the rate of decay of one gram of radium.

DECAY, RADIOACTIVE--The spontaneous radioactive transformation of a radionuclide into a different nuclide (inert or radioactive) or into the same nuclide with a different energy level. The process results in the emission of nuclear radiation (alpha, beta, or gamma) and in the steady reduction of radiation and heat generation.

DECOMMISSIONING--The removal of a facility from service and the reduction or stabilization of radioactive contamination.

DECONTAMINATION--The selective removal of radioactive material from a surface, area, object, or person. May be accomplished by: (1) treating the surface with liquids or abrasive materials to remove or decrease the contamination; (2) letting the material stand to that the radioactivity is decreased as a result of radioactive decay; or (3) covering the contamination to shield or attenuate the radiation emitted.

DEMOGRAPHY--Study of human populations with respect to size, density, distribution, and vital statistics (e.g., age, sex, and ethnicity).

DETRITUS--Dead organic tissues and organisms in an ecosystem.

OISCHARGE--In groundwater hydrology, water that issues naturally or is withdrawn from an aquifer.

DISPERSION--Release of particulate or gaseous radioactivity into the atmosphere, followed by mixing and transport.

DISPOSAL, RADIOACTIVE WASTE--The confinement of radioactive waste in a manner considered permanent and for which recovery is not provided.

DISPOSAL SITE--That portion of a land disposal facility that is dedicated to the disposal of waste and related activities. It consists of disposal units and a buffer zone.

DISPOSAL UNIT--A discrete portion of the disposal site into which waste is placed for disposal. For below-grade disposal, the unit is usually a trench; for above-grade disposal, the unit is a tumulus.

DIVERSITY OF SPECIES--An indication of the total number of species in a community as a whole. Also refers to the number of species and the population size for each species.

DOSE--The energy imparted to matter by ionizing radiation. The unit of absorbed dose is the rad, equal to 0.01 joules per kilogram of irradiated material in any medium.

DOSE COMMITMENT--The dose that an organ or tissue would receive during a specified period of time (e.g., 50 or 100 years) as a result of intake (as by ingestion or inhalation) or one or more radionuclides from one-year's release.

DOSE EQUIVALENT--A term used to express the amount of effective radiation when modifying factors have been considered. It is the product of absorbed dose (rads) multiplied by a quality factor and any other modifying factors. It is measured in rems (roentgen equivalent man).

DOSE RATE--The radiation dose delivered per unit time (e.g., rems per year).

EAST CHESTNUT RIDGE--An area within the Oak Ridge Reservation that is an alternative location for the proposed Central Waste Disposal Facility.

ECOLOGY--The science dealing with the relationship of all living things with each other and with the environment.

ECOSYSTEM--The complex of a community of living things and its environment functioning as an ecological unit in nature.

ENDANGERED SPECIES--Plants and animals in an area that are threatened with either extinction or serious depletion of a species.

ENVIRONMENT--The sum of all external conditions and influences affecting the life, development, and, ultimately, the survival of an organism.

ENVIRONMENTAL IMPACT STATEMENT--A document required by the National Environmental Policy Act of 1969 (NEPA), as amended, for all major federal actions that may significantly affect the human environment.

EPICENTER--The point on the surface of the earth above the focus of an earthquake.

EROSION--The process in which uncovered soil materials are carried away by the action of wind or water.

EVAPOTRANSPIRATION--The process by which precipitation is returned to the air through direct evaporation and/or by transpiration of vegetation.

EXPOSURE TO RADIATION--The incidence of radiation on living or inanimate material by accident or intent. Background exposure is the exposure to natural background ionizing radiation. Occupational exposure is that exposure to ionizing radiation which takes place during a person's working hours. Population exposure is the exposure to a number of persons who inhabit an area.

FAULT--A fracture or fracture zone along which there has been displacement of the sides relative to one another parallel to the fracture.

FRACTURE--Breaks in rock formation due to structural stresses. Fractures may occur as faults, shears, joints, or planes of fracture cleavage.

GEOLOGY--The science that deals with the earth: the materials, processes, environments, and history of the planet--especially the lithosphere--including the rocks, their formation, and their structure.

GROUNDWATER--Usually considered to be the water within the zone of saturation below the soil surface.

GROUNDWATER TABLE--The upper limit of the saturated zone, where the hydrostatic pressure equals atmospheric pressure. A water table may exist in either high-permeability or low-permeability material and does not necessarily indicate the presence of an aquifer.

GROUT WASTE--A mortar formed from cement and liquid waste to provide a matrix for isolation of the waste and to seal the waste from the environment.

HALF-LIFE, RADIOLOGICAL--The time in which half the atoms of a radionuclide disintegrate into another nuclear form.

HARDWOODS--Angiosperm trees which yield wood that has a hard consistency.

HEALTH PHYSICS--The science concerned with recognition, evaluation, and control of health hazards from ionizing radiation.

HYDROCARBONS--Organic compounds consisting primarily of hydrogen and carbon. Hydrocarbons are emitted in automotive exhaust and from the incomplete combustion of fossil fuels such as coal.

HYDROGEOLOGY--The study of the character, source, and mode of occurrence of underground water.

HYDROLOGIC--Pertaining to the properties, distribution, and circulation of water.

HYDROLOGIC BUDGET--An accounting of the input to, output from, and storage in, a hydrologic unit that expresses the relationship between precipitation, evapotranspiration, surface runoff, infiltration, groundwater movement, and change in water storage.

HYOROLOGY--The science dealing with the properties, distribution, and circulation of natural water systems.

IMMOBILIZATION OF WASTE--Process of converting waste to a stable solid form that is relatively insoluble.

INFILTRATION RATE, SOIL--The rate at which water enters the surface layer of soil.

INSTITUTIONAL-CONTROL PERIOD--A period following site closure during which onsite activities and site access will continue to be controlled; for this EIS, it is assumed to be a period of 100 years.

INTRUSION--Any action by a person that brings that person in contact with all or part of radioactive wastes so as to produce a radiation dose to that person or to others.

ION EXCHANGE--Replacement of ions adsorbed on a solid, such as a clay particle, or exposed at the surface of a solid by ions from solution, usually in natural water. The phenomena is known to occur when natural water moves through clays, zeolitic rocks, and other materials of the earth's crust.

ISOLATION--Segregating wastes from the accessible environment (biosphere) to the extent required to meet applicable radiological performance objectives.

ISOTOPE--An atom of a chemical element with a specific atomic number and atomic weight. Isotopes of the same element have the same number of protons but different numbers of neutrons.

KARST--A limestone region marked by sinks and interspersed with abrupt ridges, irregular protuberant rocks, caverns, and underground streams.

LEACHATE--Liquid that has percolated through or is derived from waste materials; it contains dissolved, suspended, or emulsified components removed from the waste.

LEACHING--The removal or separation of soluble components from a solid by contact with water or other liquids.

LICENSE--Legal document issued by a government body (e.g., Nuclear Regulatory Commission) indicating compliance, by an applicant, with specified regulations covering the actions proposed by the applicant.

LINER--Any material, in addition to the geologic environment that is emplaced on the surfaces of a disposal excavation and is designed to decrease migration and/or increase attenuation of the radionuclides and/or hazardous components contained in the disposed waste.

LOW-LEVEL WASTE--Radioactive waste not classified as high-level waste, transuranic waste, spent fuel, or uranium mill tailings.

MAN-REM--The radiation dose commitment to a given population; the sum of the individual doses received by a population segment.

MIGRATION--The natural travel of a material through the air, soil, or groundwater.

MOBILITY--The ability of a chemical element or a pollutant to move into and through the environment.

MODIFIED MERCALLI (MM) INTENSITIES--Descriptions of ground effects of an earthquake in the absence of instruments. The MM scale describes a range of observations and bodily sensations characterizing 12 different levels of ground shaking. The MM scale is nonlinear.

MONITORING--Process whereby the level and quality of factors that can affect the environment and/or human health are measured periodically in order to regulate and control potential impacts.

MONOLITH--A massively solid, uniform casting of material (i.e., glass or fused salt).

NATURAL BACKGROUND RADIATION--Ionizing radiation that is present as a result of natural conditions. It is comprised of cosmic radiation and radiation from naturally occurring, terrestrial radioactive material. In the continental United States, this radiation varies from 80 to 200 millirems per year. At the Oak Ridge Reservation, the dose to an individual from natural background radiation is 130 millirems per year.

NIAGARA FALLS STORAGE SITE--A Department of Energy site in Lewiston, New York, where residues from processing of uranium ores are stored. One alternative for disposal of these residues involves transporting them to a site on Pine Ridge Knolls in the Oak Ridge Reservation.

NITROGEN OXIDES--Oxides of nitrogen, primarily NO and NO_2. These are often produced in the combustion of fossil fuels. In high concentrations, they constitute an air pollution problem.

NUCLEAR REGULATORY COMMISSION--The independent federal commission that licenses and regulates nuclear facilities.

NUCLIDE--A species of atom characterized by a mass number, atomic number, and nuclear energy state.

OCCUPATIONAL DOSE--Amount of radiation received by those occupied with the operation of an activity involving the handling of radioactive material.

OPERATIONAL PERIOD--The period over which a waste disposal site is opened for receipt and burial of wastes.

OVERBURDEN--All material (loose soil, sand, gravel, etc.) that lies above bedrock.

OVERPACK--Secondary external containment and shielding for packaged radioactive waste.

PARTICULATES--Solid particles and liquid droplets small enough to become airborne.

PERMEABILITY--The relative ease with which a porous medium can transmit a liquid under a hydraulic gradient. In hydrology, the capacity of rock, soil, or sediment for allowing the passage of water.

PERSON-REM--The sum of the individual radiation dose equivalents received by members of a certain group or population. It may be calculated by multiplying the average dose per person by the number of persons exposed. For example, a thousand people each exposed to one millirem (1/1000 rem) would have a collective dose of 1 person-rem.

PLANT COMMUNITY--Any assemblage of plant populations living in a prescribed area or physical habitat. An organized unit having characteristics additional to its individual and population components.

POLLUTION--The addition of any undesirable agent to an ecosystem in excess of the rate at which it can be degraded, assimilated, or dispersed by natural processes.

PONDING--Isolated areas of accumulated water on a disposal site, usually following rainfall or snowmelt.

POPULATION DOSE--Summation of the doses received by all individuals in a specified population in the vicinity of an activity involving the handling of radioactive material.

POROSITY--That property of a rock or soil that enables the rock or soil to contain water in voids or interstices, usually expressed in percentage or as a decimal fraction of void volume as compared to total volume.

RAO--Unit of absorbed dose (see ABSORBED DOSE).

RADIATION--A very general term that covers many forms of particles and energy, from sunlight and radio waves to the energy that is released from inside an atom. Radiation can be in the form of electromagnetic waves (gamma rays, X-rays) or particles (alpha particles, beta particles, protons, neutrons).

RADIATION MONITORING--Continuous or periodic determination of the amount of radiation present in a given area.

RADIOACTIVITY--The spontaneous decay or disintegration of unstable atomic nuclei, accompanied by the emission of radiation.

RADIOISOTOPE--An unstable isotope of an element that spontaneously loses particles and energy through radioactive decay.

RADIONUCLIDE--An unstable nuclide that undergoes radioactive decay.

RECHARGE--In hydrology, a source or means for replenishment of water withdrawn or discharged from an aquifer.

REGULATION--A regulation has the force of law. A regulation can contain policy statements, goals, and criteria. It can be general or highly specific and can contain administrative or technical requirements, or both.

REM--The unit of dose of any ionizing radiation that produces the same biological effect as a unit absorbed dose of ordinary X-rays.

RESIN--A solid organic polymer used in ion-exchange processes.

RISK--Assuming the factors can be quantified, risk equals the consequences of an event multiplied by the probability of the event's occurrence.

ROENTGEN--Unit of exposure. One roentgen is the amount of gamma rays or X-rays required to produce one electrostatic unit (esu) of charge of one sign (either positive or negative) in one cubic centimeter of dry air under standard conditions.

RUNOFF--All rainfall and snowmelt that does not soak into the ground, does not evaporate immediately, or is not used by vegetation, and hence flows over the land surface.

SATURATED ZONE--A subsurface zone in which all the interstices are filled with water under pressure greater than that of the atmosphere.

SEDIMENTATION--The settling of excess soil and mineral solids of small particle size contained in water.

SEEPAGE--Any water or liquid effluent that flows through a porous medium (e.g., water lost through the bottom of a liquid waste pond).

SEISMIC--Having to do with the geology of earthquakes and extending to prediction of earthquake frequency and severity.

SEISMICITY--The tendency for the occurrence of earthquakes.

SHALLOW-LAND BURIAL--The disposal of solid radioactive waste in excavations, with a minimum cover of 1 m (3 ft).

SHIELDING--A material interposed between a source of radiation and personnel for protection against the danger of radiation.

SLASH--The debris from clearing a tract in a forest.

SLUDGE--Insoluble salts and complex colloidal material in alkaline ("neutralized") aqueous solutions that settle out upon standing in storage.

SOLIDIFICATION--Conversion of radioactive wastes (normally, liquid) to a dry, stable solid.

SOLUTION CAVITIES--Cavities or channels formed in carbonate rocks--such as limestone, dolomite, and marble--caused by chemical dissolution of the rock along fractures, joints, etc.

SPILL--The accidental release of radioactive material.

STORAGE--Retention of radioactive waste in a manner permitting retrieval, as distinguished from disposal which implies no retrieval.

STRATUM--Sedimentary bed or layer, regardless of thickness, of homogeneous or gradational rock material.

SUBSIDENCE--Downward displacement of the earth's surface with little or no horizontal movement.

SUBSURFACE WATER--Water located below the earth's surface, in both the saturated and unsaturated zones.

SULFUR DIOXIDE--A heavy pungent colorless gas formed in the combustion of coal and other sulfur-containing fuel. In high concentration, it is considered a major air pollutant.

SURFACE WATER--All water on the surface, as distinguished from groundwater.

SURVEILLANCE--A monitoring system designed to ensure safe and secure containment of radioactivity at all times and to identify potential sources of escape or release into the environment.

TOPOGRAPHY--The configuration of a land surface area including its relief or relative elevations and the position of its natural and man-made features.

TOTAL SUSPENDED PARTICULATES--Refers to the concentration of particulates in suspension in the air irrespective of the nature, source, or size of the particulates.

TRANSMISSIVITY--Volume of water flowing through a unit width of aquifer of given thickness under a gradient (1 m vertically for each 1 m laterally) and at the viscosity prevailing in the field. Mathematically, it is the product of permeability and aquifer thickness.

TRANSURANIC ELEMENTS--Chemical elements with atomic numbers greater than 92 (uranium).

TRENCH, SHALLOW-LAND BURIAL--A long, narrow excavation with unsupported walls, into which solid radioactive wastes are emplaced and covered with excavated earth.

TRITIUM--A radioactive isotope of hydrogen (H-3); a weak beta emitter with a half-life of 12.5 years.

TUMULUS--An artificial hillock or mound.

UNSATURATED ZONE--The zone above the capillary fringe, in which intersticies and pores in earth materials are only partially filled with water at less than atmospheric pressure. (Note: Some authors include the capillary fringe in the unsaturated zone definition.)

VEGETATIVE SUCCESSION--The progressive changes in vegetation and animal species structure and community processes that follow the abandonment of cropland or pasture.

WASTE, RADIOACTIVE--Materials from nuclear operations that are radioactive or are contaminated with radioactive materials and for which there is no practical use or for which recovery is impractical.

WASTE FORM--The waste package less the container, if any, and the low-level waste either treated or untreated, including any inert fillers, as presented for disposal.

WASTE PACKAGE--The assemblage of low-level waste that is disposed; it normally includes the container plus the contained material.

WEST CHESTNUT RIDGE--An area within the Oak Ridge Reservation that is the preferred location for the proposed Central Waste Disposal Facility.

ZOOPLANKTON--Planktonic (floating) animals that supply food for fish.

APPENDIX C. WASTE CHARACTERISTICS

The wastes that would be emplaced in the CWDF originate from research, development, and production activities at the Y-12 Plant and Oak Ridge Gaseous Difffusion Plant (ORGDP), and also from research and development activities at Oak Ridge National Laboratory (ORNL). These wastes are contaminated with small quantities of radioactive nuclides and occur in a variety of forms such as laboratory trash, sludges or soils fixed in grout, and disintegrated construction materials from the decommissioning of projects and buildings. It is expected that the rate of waste disposal for the first four years would be about 2×10^4 m^3/yr (6×10^5 ft^3/yr) for grout and 8×10^3 m^3/yr (3×10^5 ft^3/yr) for other wastes. After the first four years, the disposal rate would be 6×10^3 m^3/yr (2×10^5 ft^3/yr) for grout and 8×10^3 m^3/yr (3×10^5 ft^3/yr) for other wastes. The waste volumes presented here are the best estimates available at this time from the waste-contributing plants. Changes in these volumes might result from changes in plant programs or in methods of treating some waste forms.

The data on waste characteristics are presented here in three categories corresponding to the categories for emplacement in separate trenches: (1) solid debris low-level waste (LLW), (2) waste contaminated with asbestos, and (3) grout resulting from fixation of sludges and soils. These wastes are inhomogeneous, especially those in the solid debris LLW category. With the division of these wastes into only three categories, the behavior of individual waste forms within each category are indistinguishable. Thus, isotopic radioactivity cannot be associated with individual waste items; average concentrations of radioactive isotopes are associated with groups of waste items as waste generation estimates permit. Whereas the concentrations of radioactivity in the wastes presented here are averages, maximum acceptable concentrations for disposal at the CWDF are given by the waste-acceptance criteria (Pin and Witherspoon 1984). These maximum acceptable concentrations have been chosen to be consistent with the results of a nuclide migration analysis and with concentration guides (DOE Order 5480.1, Chapter XI). The wastes are essentially equivalent to Class A wastes as defined by the Nuclear Regulatory Commission in 10 CFR Part 61. The only significant difference is that the TRU limits will be 100 nanocuries per gram (nCi/g) rather than 10 nCi/g.

Data for the solid debris LLW category are given in Table C.1. This category comprises a large variety of waste forms and materials that may be delivered and emplaced in bulk form; in containers of various sizes; and in plastic-wrapped, compacted bales.

Data for waste contaminated with asbestos are presented in Table C.2. This waste also consists of a variety of waste forms and materials, and has the smallest volume of the three waste categories.

Table C.1. Characteristics of Solid Debris Low-Level Waste

Waste Parameter	ORNL†[1]		Y-12†[1]	ORGOP†[1]	
	Baseline	Nonroutine	Baseline	Baseline	Nonroutine
Volume Rate†[2]	1.7×10^3 m³/yr (5.9×10^4 ft³/yr)	1.1×10^3 m³/yr (4.0×10^4 ft³/yr)	1.8×10^3 m³/yr (6.3×10^4 ft³/yr)	1.0×10^3 m³/yr (3.5×10^4 ft³/yr)	7.6×10^3 m³/yr (2.7×10^5 ft³/yr)
% Combustible	30	-	~30	-	-
Average Isotopic Conc., Ci/m³					
H-3	1×10^{-1}	-	-	-	-
C-14	1×10^{-3}	-	-	-	-
Co-60	1×10^{-3}	-	-	-	-
Sr-90	2×10^{-2}	-	-	-	-
Zr-93	1×10^{-3}	-	-	-	-
Tc-99	-	-	-	3×10^{-3}	2×10^{-2}
Sn-121	6×10^{-4}	-	-	-	-
Cs-134	1×10^{-3}	-	-	-	-
Cs-137	5×10^{-3}	-	-	-	-
Sm-151	1×10^{-3}	-	-	-	-
Ir-192	2×10^{-3}	-	-	-	-
U-234	-	-	-	7×10^{-5}	5×10^{-5}
U-235	-	-	6×10^{-5}	4×10^{-6}	2×10^{-6}
U-238	-	-	2×10^{-3}	5×10^{-5}	4×10^{-5}
Pu-238	-	3×10^{-5}	-	-	-
Pu-239	-	9×10^{-6}	-	-	-
Am-241	-	4×10^{-5}	-	-	-
Cm-244	-	4×10^{-5}	-	-	-
Mixed TRU (mostly Pu-239)	-	9×10^{-5}	-	-	-
Components	Paper, cloth, plastics, rubber, wood, metals, glass, ceramics, concrete, soil, resins	Concrete and other building materials (D&D wastes)	Baled and bulk	Miscellaneous materials plus some incinerator ash	Scrap metal†[3]

†[1] Baseline wastes are received on a regular schedule; nonroutine wastes are received on a campaign schedule.

†[2] The rate of receipt of solid debris LLW from ORNL is expected to begin at about 2×10^3 m³/yr (6×10^4 ft³/yr) and may increase, over a five-year period, to about 3×10^3 m³/yr (9×10^4 ft³/yr).

†[3] ORGOP will produce 10,000 tons of scrap metal during 1985 only.

Table C.2. Characteristics of Asbestos-Contaminated Waste†[1]

Waste Parameter	ORNL	Y-12	ORGDP
Volume Rate	3×10^1 m^3/yr (1×10^3 ft^3/yr)	2×10^2 m^3/yr (7×10^3 ft^3/yr)	1×10^2 m^3/yr (4×10^3 ft^3/yr)
Average Isotopic Conc., Ci/m^3			
U-238	-	6×10^{-4}	4×10^{-6}
U-235	-	5×10^{-3}	3×10^{-7}
U-234	-	5×10^{-5}	6×10^{-6}
Components	Low-level waste contaminated with asbestos	Low-level waste contaminated with asbestos, piping, ductwork	Low-level waste contaminated with asbestos

†[1] This waste is expected to be received on a baseline, or regular, schedule.

Data for grout waste are presented in Table C.3. This waste originates from contaminated sludges and soils from several sources on the ORR. These sludges and soils will be immobilized by converting them to a grout with a water content of about 40% and a density of about 2,400 kg/m^3 (150 lb/ft^3).

This waste will be transported in concrete-mixer trucks either as a wet grout or as blocks of solidified grout that have been previously mixed, cast, and partially cured at the source of the sludge or soil. Sludges from the complex of S-3 ponds at the Y-12 Plant may be shipped to the CWDF as a grout; these would then be one of the major sources of this waste form.

A portion of the grout contributed by the ORGOP would come from incinerator ash. This ash is the residue from incineration of miscellaneous solid and liquid materials (U.S. Dept. Energy 1982), including discarded polychlorinated biphenyls (PCBs) from electrical transformers. The sources of feed to the incinerator would include the ORGDP, the Portsmouth Gaseous Diffusion Plant, the Paducah Gaseous Diffusion Plant, the ORNL Plant, and the Y-12 Plant. The incineration residue would consist of shredded metal, oxidation products, and "dirt" associated with the feed. An estimate of the quantitative composition of this residue suggests that it would be 90% soil, 5% ground steel, and a mixture of metallic oxides. The residue would be tested for PCB contamination before disposal; that portion with an unacceptably high concentration of PCBs would be recycled through the incinerator. The residue would be collected in water and would emerge from the incineration facility as a sludge. On a routine, annual basis, about 8×10^2 m^3 (30,000 ft^3) of this ash would be shipped in bulk form (solid debris waste) and about 2×10^2 m^3 (7,000 ft^3) would be shipped in grout form.

The ORNL Plant is also expected to contribute some grout waste, but the volumes and radioactivities of this waste cannot be defined at this time.

Table C.3. Characteristics of Grout Waste

Waste Parameter	ORNL	Y-12†[1] Baseline	Y-12†[1] Nonroutine	ORGDP†[1] Baseline	ORGDP†[1] Nonroutine
Volume Rate	Volume undefined	5.1×10^3 m^3/yr (1.8×10^5 ft^3/yr)	1.0×10^4 m^3/yr (3.7×10^5 ft^3/yr)	9.6×10^2 m^3/yr (2.7×10^4 ft^3/yr)	4.2×10^2 m^3/yr (1.5×10^4 ft^3/yr)
Average Isotopic Conc., Ci/m^3	Radioactivity undefined				
U-238		-	$\leq 3 \times 10^{-5}$	3×10^{-3}	2×10^{-4}
U-236		-	-	5×10^{-9}	-
U-235		-	$\leq 1 \times 10^{-7}$	2×10^{-5}	2×10^{-6}
U-234		-	-	5×10^{-4}	1×10^{-5}
Np-237		-	$\leq 4 \times 10^{-7}$	-	-
Pu-240		-	$\leq 6 \times 10^{-6}$	-	-
Pu-239		-	$\leq 6 \times 10^{-6}$	-	-
Pu-238		-	$\leq 2 \times 10^{-5}$	-	-
Am-241		-	$\leq 1 \times 10^{-7}$	-	-
Zr, Nb-95		-	$\leq 8 \times 10^{-5}$	-	-
Tc-99		-	$\leq 5 \times 10^{-4}$	5×10^{-3}	-
Ru, Rh-106		-	$\leq 8 \times 10^{-5}$	-	-
Cs-137		-	$\leq 8 \times 10^{-5}$	-	-
Components	Sludges, residues, soils	Sludges	Sediments of S-3 ponds	Sludges plus some incinerator ash	K-1232 sludge

†[1] Baseline wastes are received on a regular schedule; nonroutine wastes are received on a campaign schedule.

REFERENCES (Appendix C)

Pin, F.G., and J.P. Witherspoon. 1984. Oak Ridge Central Waste Disposal Facility Pathways Analysis. ORNL/6082 (Draft). Oak Ridge National Laboratory, Oak Ridge, TN.

U.S. Department of Energy. 1982. Final Environmental Impact Statement, Incineration Facility for Radioactively Contaminated Polychlorinated Biphenyls and Other Wastes, Oak Ridge Gaseous Diffusion Plant, Oak Ridge, Tennessee. DOE/EIS-0084. June 1982.

APPENDIX D. DESCRIPTION OF DESIGN ALTERNATIVES

D.1 INTRODUCTION

The proposed layout, structures, disposal unit designs, and operations for the action alternatives are described in this appendix. In this discussion, "site" refers to the area of interest on West Chestnut Ridge (the preferred site); "facility" refers to the proposed Central Waste Disposal Facility (CWDF); and "disposal unit" is a general term for the cavity or structure into which wastes will be emplaced for disposal. Much of the ancillary structures, layout, and operations would be the same regardless of which design were employed for the disposal unit; but the monitoring programs associated with the two types of disposal unit would differ. If the disposal unit were a below-grade trench, monitoring would emphasize measuring the underground migration of radionuclides through soils. If the disposal unit were an above-grade tumulus, monitoring would emphasize measuring the migration of radionuclides in nearby surface waters.

D.2 FACILITY DESCRIPTION

D.2.1 Site Location and Layout

The preferred site for the CWDF is an area on West Chestnut Ridge within the DOE Oak Ridge Reservation (ORR), Oak Ridge, Tennessee. The site is bounded by Bear Creek Road to the north, Tennessee Highway 95 to the east, and New Zion Patrol Road to the south and west.

The layout of the CWDF--including disposal areas, ancillary facilities, and some access roads--is shown in Figure D.1. The completed facility would consist of an operations area and three major disposal areas. Fixed installations at the CWDF would include a fenced equipment-storage area, an area for survey and decontamination, yard lights, a septic tank and associated drainage field, a diesel storage and pumping station, fencing, a general support building, a heavy-equipment storage building, and a parking lot. Temporary installations might be provided during the initial years of operation as the permanent installations were being constructed.

The CWDF would be served by two-lane roads, 3.6 m (12 ft) in width. The route from ORNL to the CWDF would follow Bethel Valley Road to New Zion Patrol Road to Lou Cagle Road. The route from the Y-12 Plant to the CWDF would follow Bear Creek Road to New Zion Patrol Road to Lou Cagle Road. The route to the CWDF from ORGDP would follow Blair Road to Flannigan Loop Road to Zion Patrol Road to Lou Cagle Road. The waste delivery entrance would be the one gate near the general support building through which all vehicles would enter and leave the facility.

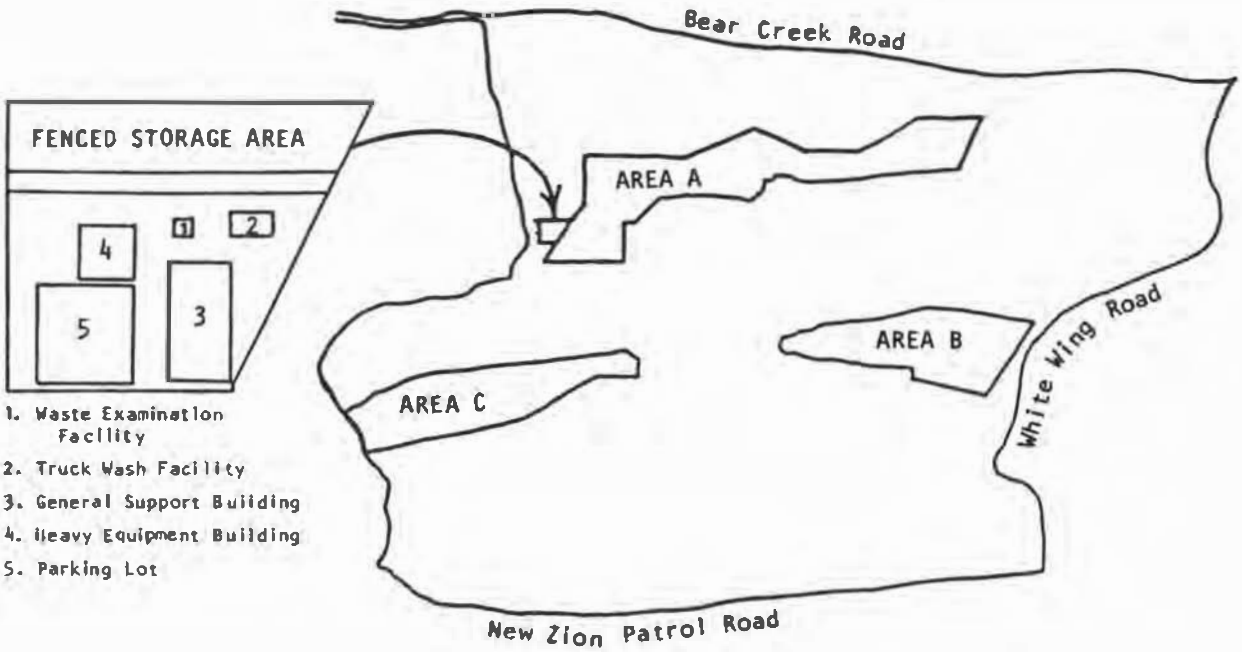


Figure D.1. Layout of the Central Waste Disposal Facility.

Disposal units are expected to be constructed in three separate areas of the CWDF site (labelled A, B, and C on Figure D.1). These three disposal areas would be limited to three geologically and topographically suitable areas lying along the top of West Chestnut Ridge. At the time of closure of the CWDF, a total of about 50 disposal units would have been filled. The total required capacity of the facility would be about 6×10^5 m^3 (2×10^7 ft^3).

D.2.2 Related Ancillary Structures

Two permanent prefabricated metal buildings would be constructed at the site. The general support building--with floor dimensions of approximately 15 m x 31 m (50 ft x 103 ft)--would house offices, change areas, records, equipment, supplies, and a telecommunications system. The heavy-equipment building, with floor dimensions of 15 m x 18 m (50 ft x 60 ft), would house heavy equipment and tools used for site maintenance and firefighting.

Other site facilities would include a waste-receipt and inspection area and a decontamination area (mainly for trucks). Other waste-handling equipment would include front-loaders, trucks, and cranes that can be used for transport and loading/unloading operations. Waste-treatment facilities at the CWDF would be minimal because waste-treatment and packaging operations would have been performed at the waste-generating plants. Any contaminated water removed from trenches or resulting from vehicle and equipment decontamination would be transported to the ORNL liquid waste treatment system. The treatment operations that might be performed at the CWDF include overpacking containers damaged in transport or onsite handling.

Equipment for firefighting and security surveillance would be maintained at the site.

D.2.3 Construction

The CWDF would be developed in two phases. Phase I would extend through the emplacement of the first two year's volume of wastes. Phase II would extend through the balance of the facility's lifetime.

D.2.3.1 Phase I

Phase I construction activities would consist of the following tasks: (1) clearing the site in the northwest corner of Area A; (2) carrying out preliminary grading; (3) upgrading appropriate portions of Lou Cagle Road and New Zion Patrol Road; (4) installing trailers that would house offices, storage areas, change areas, and restrooms; (5) constructing the parking area; (6) constructing a fenced equipment-storage area; (7) constructing the area for monitoring and decontamination of equipment; (8) providing a bottled water supply; (9) supplying fire-suppression equipment: portable extinguishers; (10) installing yard lights; (11) installing an electrical power line; (12) setting up bar gates across access roads; (13) supplying monitoring equipment and beginning the initial monitoring program; (14) setting up a communications system; (15) constructing the waste-inspection area; (16) procuring equipment for maintenance and waste-disposal operations; and (17) installing an onsite well and water-distribution system.

Initial site preparation would consist of clearing and grading the areas for support facilities and the initial disposal units. Topsoil would be removed and stockpiled for future capping of trenches and final site contouring. The initial site-preparation activities would include grading to produce favorable drainage patterns during the lifetime of the CWDF. After initial site preparation was completed, the area would be seeded to minimize erosion. In Phase I, trench construction would begin in the northwest corner of Area A.

D.2.3.2 Phase II

Phase II construction activities would consist of: (1) erecting the general support building and moving the trailers; (2) erecting the heavy-equipment storage building; (3) installing additional security fencing; (4) installing additional lighting; (5) upgrading access roads; and (6) installing in each disposal area as needed surface water gaging stations and flumes equipped with automated proportional flow samplers and flow monitors.

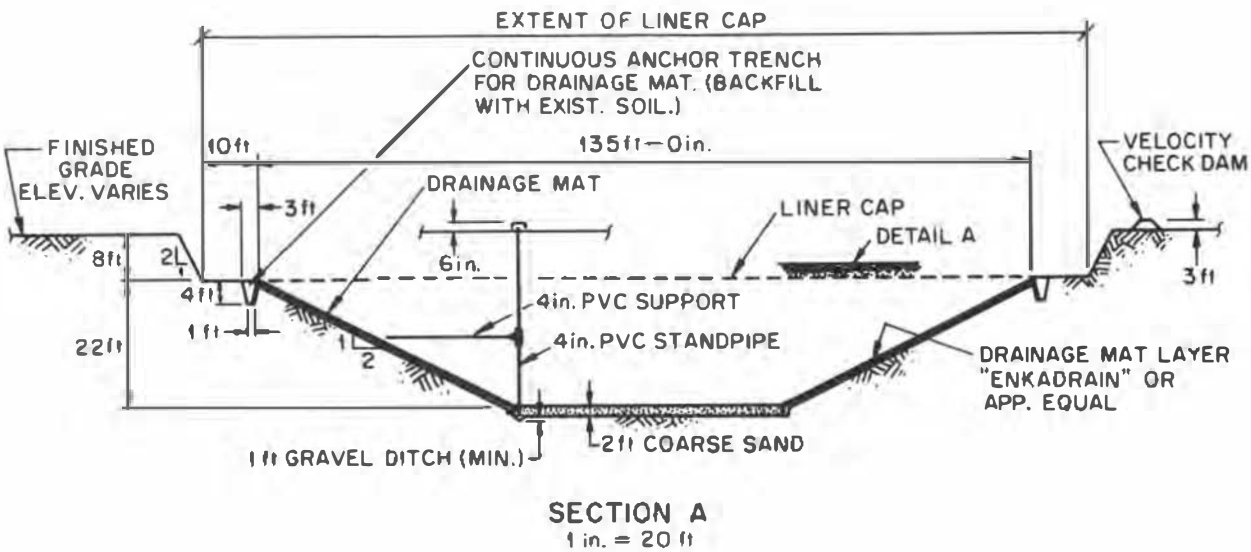
After Area A was filled, disposal units would be developed either in or east of Areas B and C.

D.3 BELOW-GRADE DISPOSAL IN TRENCHES--PREFERRED DESIGN

D.3.1 Trench Design

The trench design has been selected with the aim of accomplishing several objectives: (1) long-term isolation, (2) minimum active maintenance and remedial action, (3) enhancement of natural physical advantages, (4) creation of surface drainage patterns that prevent trench infiltration, and (5) prevention of erosion.

Two basic trench designs would be used at the CWDF. One design (Figure D.2) would be initially 46-m (150-ft) wide at the top, 14-m (45-ft) wide at the bottom, and 9.1-m (30-ft) deep, with a waste layer 6.7-m (22-ft) thick. Its length would be typically 107 m (350 ft), with 91 m (300 ft) available for storage--except where site geometry dictated otherwise. The other trench design, to be used for disposal of the wastes containing asbestos, has smaller dimensions. It would be typically 15-m (50-ft) wide at the top, 3.0-m (10-ft) wide at the bottom, and 5.5-m (18-ft) deep, with a waste layer 3.0-m (10-ft) thick. The length would vary with the geologic situation but would be typically 21 m (70 ft). These sizes are given to characterize a reference trench; in practice, trenches would be constructed with minor variations in any of these



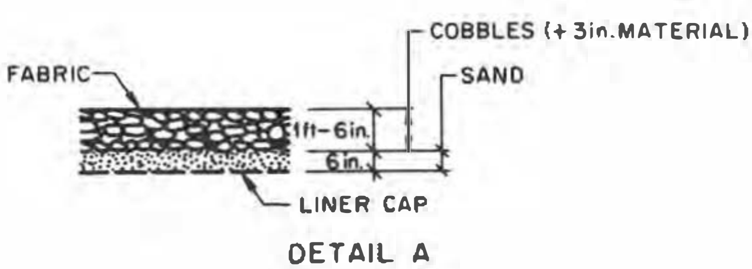


Figure D.2. Schematic Diagram of the Trench Design. Source: Ebasco Services Incorporated (1984).

dimensions, and it is expected that such variations would not significantly affect performance. Trench dimensions might vary in response to operating experience and variation in waste quantities delivered.

During construction of the trenches, dams of excavated material would be set up to prevent rainwater runoff from entering the trenches. In addition to these dams, the surface water runoff at the site would be controlled by water-diversion ditches. No central pond for collection of surface water runoff is planned.

The trench side walls would have a slope of 1:2. The overburden layer would be 2.4-m (8-ft) thick. The side walls of all trenches would be lined with a drain matting. This material is available in sheet form on a roll with filter fabric on both faces. The purpose of this mat is to establish a capillary break between the soil and the waste.

The trench floor would be designed to collect any water that entered the trench during waste emplacement, permit monitoring after closure, and avoid the bathtub effect. A trench drainage system would be designed to direct any water that entered the trench to a French drain and eventually to a corner sump. The French drain--a gravel-filled, V-shaped tunnel running along the lower longitudinal side of the bottom of a trench--would drain to a sump at the lower end of the trench. Polyvinyl standpipes of 10-cm (4-in.) diameter would connect the surface with the French drain, allowing sampling of the drain and monitoring of the movement of isotopes. It would be possible to drain the sump on each trench with a pump.

After backfilling, each trench would be covered with an impermeable membrane. This membrane would be covered with a protective layer and drain. The trench would be topped with a 1.8-m (6-ft) layer of compacted soil. The topsoil layer would have a vegetative cover to control erosion and to reduce loss of soil moisture. This vegetative cover would be chosen from native grasses that flourish in the area.

D.3.2 <u>Waste Emplacement</u>

As discussed earlier, it is currently planned that the wastes would be sorted into three categories for disposal in separate trenches: (1) solid debris LLW, (2) contaminated asbestos waste, and (3) grout. Although placement of wastes in three separate trenches is the initially proposed operating procedure, it might develop that the combination of grout and solid debris LLW in the same trench was not only convenient but also beneficial to performance, especially if solid debris LLW were backfilled with semiliquid grout. Insofar as possible, wastes would be emplaced in the trenches in stacks or in an orderly arrangement to promote trench stability and to optimize the use of space.

It is expected that transport vehicles would usually be driven down into the trenches via a ramp at the end of each trench. The wastes would be unloaded from these vehicles onto the trench floor with cranes, forklifts, or front-loaders. Unwieldy items, however, might be lowered into place from grade level by crane. At times, it might be more suitable to unload any of the waste types from the top edge of the trench. Operating criteria prohibit the unloading of wastes during times of precipitation.

For emplacement of wet grout, a dike of excavated soil would be laid across the trench. The delivery truck would be driven onto the floor of the trench and up to the dike that bounded the area onto which the wet grout was to be poured. The truck would discharge the semiliquid grout into the dike-bounded area by a pivotting chute that would distribute it across the width of the trench. When the dike-bounded area was filled to a depth of 0.61 m (2 ft), another dike would be set up to create another area adjacent to the filled one, and the procedure would be repeated. After the grout had cured sufficiently to support the weight of trucks, a 0.3-m (1-ft) layer of soil would be placed over it, and the process would be repeated to lay down another layer of grout. Thus, the trench would be filled to capacity with alternate layers of grout and soil.

D.3.3 Trench Closure

After emplacement, the waste would be covered with native backfill. This operation would involve pushing the backfill material from any edge of the trench onto the waste and then using a vibratory compactor to force the material between individual waste items. When voids between items would no longer accept backfill material, the overburden would be compacted with a sheepsfoot roller. In the emplacement of solid debris LLW and contaminated waste, each day's receipts would be covered with backfill; thus, a filled trench would consist of alternate layers of waste and backfill. A trench would be surcharged for several months prior to capping. No capping would take place until a trench was completely filled. An impermeable membrane would be laid on, followed by a drainage layer and clay cap. Finally, topsoil, removed and stockpiled in initial site preparations, would be laid on and compacted. After the soil layer was compacted and contoured in accordance with the surface-water management plan, it would be seeded. Survey benchmarks, referenced to USGS benchmarks, would be established. Furthermore, a documentation system, referencing all disposals to these benchmarks, would be maintained.

D.4 ABOVE-GRADE DISPOSAL IN TUMULI

D.4.1 Tumulus Design

An alternative to the below-grade (near-surface) trench is an above-grade tumulus structure.* The design of this disposal concept is adapted from the tumulus design used for disposal of low-level waste by the CEA-ANDRA (Commissariat a l'Energie Atomique-Agence National pour la Gestion des Dechets Radioactifs). A tumulus is an artificial hillock or mound and, as the name implies, each finished disposal unit would be a mound, rising about 9 m (30 ft) above the surrounding land. This concept is suggested as an alternative because (1) the tumulus has been successfully operated for several years at the Centre de la Manche, France; (2) it affords a stratum of dry rock or soil between the

*The "grade" and the "ground" are not necessarily the same; an above-grade structure can be covered with a contoured layer of soil that becomes the ground level and places the waste "below ground"; it would still be "above-grade" because the grade is defined by the elevation of contiguous ground.

wastes and the water table; and (3) it could utilize the relatively large volumes of grout that are to be generated by immobilizing the sludges to provide structure and stability to the disposal unit. Although the tumulus disposal concept described herein is based on the tumulus employed at the Centre de la Manche, several changes have been made to accommodate the characteristics of the CWDF site, the characteristics of the wastes, and the objective of placing the wastes entirely above grade.

The design of the above-grade disposal unit is illustrated in Figure D.3. The unit would have a concrete floor, and the walls would consist of stacked, cylindrical, concrete blocks. These blocks would have been previously cast from mixtures of cement and either pond sludges or uncontaminated aggregate and allowed to cure. The wastes would be piled on the concrete floor and surrounded with gravel. A complete unit would have a layered cap to provide stability and prevent infiltration of water.

The concrete blocks could be isolated, if desired, from underlying gravel and soil. There they would be in contact only with the drained floor and inner components of the cap. The concrete used to form the footings and floor that would be in contact with the underlying gravel and soil would be prepared from commercial cement and noncontaminated aggregate.

Construction of a tumulus unit would begin with excavations for footings, the subfloor drain system, and the concrete floor. Next, reinforcing steel gridwork would be laid into the excavations and the footings poured. After the footings had cured for several days, the gravel and drain tile that underlies the floor would be put into place, and the concrete floor would be poured. After the floor had cured for a suitable period, the network of tile for draining the floor surface would be laid out, and the floor would be coated with a layer of bitumen to provide a noncracking surface that would carry any infiltrated water to the drainage network. Sumps to catch water drained from both the topside and underside of the floor would then be installed. The sumps would permit the drainage from the topside and underside of the floor to be monitored to determine whether it should be treated before discharge.

Next, the concrete blocks would be put into place by cranes, as needed, to form walls. The walls would be formed from three rows of blocks, stepped to give the final shape of the unit a rounded shoulder. Thus, the outermost row would have two-fold stacking of blocks, the middle row three-fold stacking, and the innermost row four-fold stacking.

D.4.2 Waste Emplacement

After the floor and side walls were in place, the trucks delivering wastes from the contributing facilities would enter at one end of the disposal unit, driving onto the floor to unload. For bulk wastes, a truck would dump its load onto the floor of the disposal unit and the wastes would be compacted to the extent possible. For loads of packages, bales, or grout blocks, a crane would lift the items out of the truck and stack them on the floor of the disposal unit. Following emplacement of these waste forms, the discharge of semisolid grout into the disposal unit to cover them and fill the voids between them is expected to enhance the long-term stability of the disposal unit.

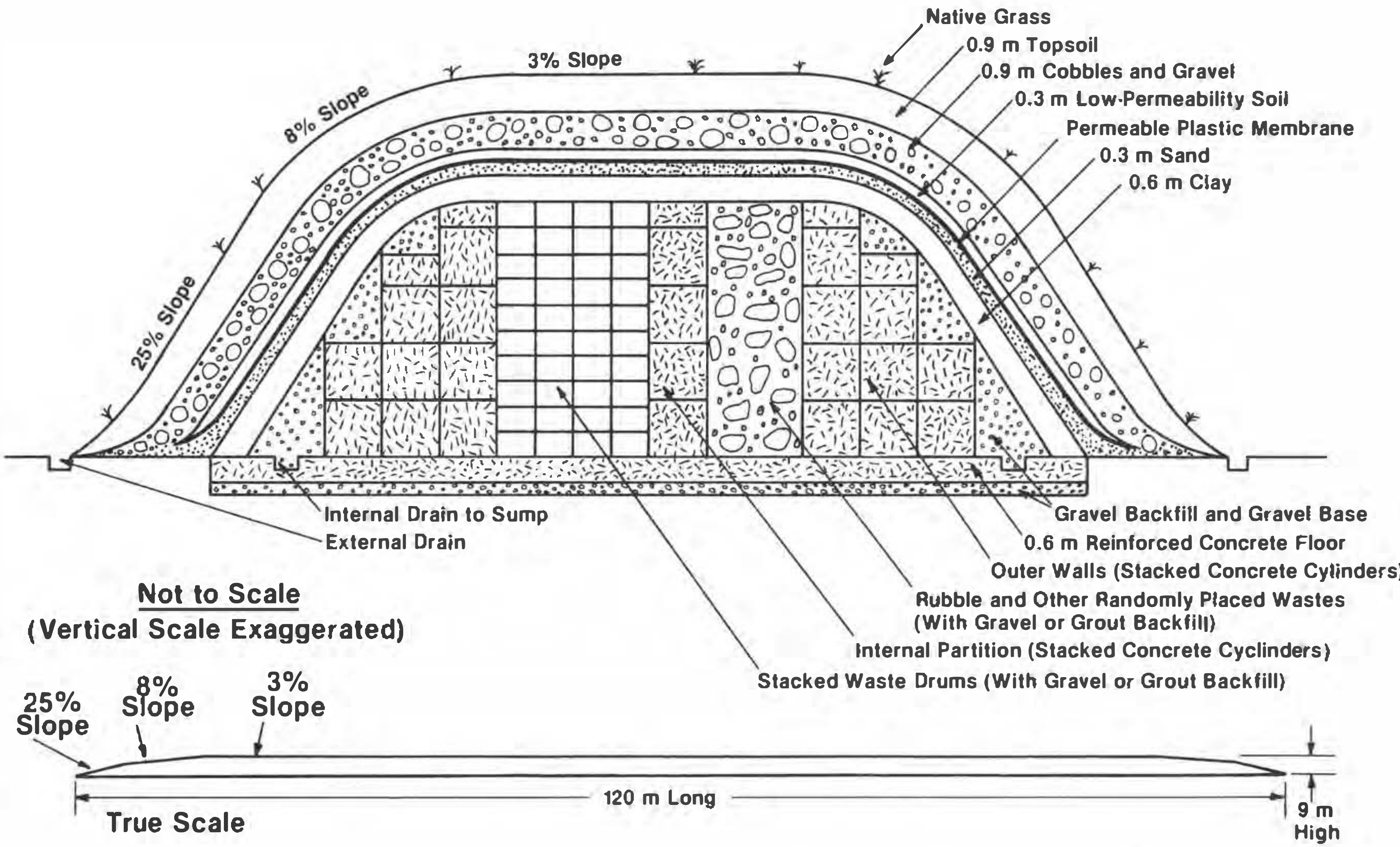


Figure D.3. Schematic Diagram of the Alternative Above-Grade Disposal Design.

D.4.3 Closure of Tumulus Disposal Unit

After a unit was filled with wastes, gravel would be poured into the unit to fill all voids between packages or other waste items. The gravel would provide a stable, packed structure that would control subsidence and also drain freely, minimizing the contact of infiltrated water with the wastes.

The cap design is an adaptation from recent suggestions (U.S. Nucl. Reg. Comm. 1983) based on results of modeling the behavior of trench caps. The first layer would be a 0.61-m (2-ft) thickness of clay, providing the main water barrier. The next layer would be a 0.3-m (1-ft) thickness of sand, providing a pathway to conduct infiltrated water out beyond the edges of the disposal unit. The sand layer would be overlain with a porous plastic membrane to prevent fine particles of topsoil from infiltrating and clogging the pores of the sand drain. The next layer would be a 0.3-m (1-ft) thickness of low-permeability soil to protect the membrane during emplacement of the next layer, a 0.91-m (3-ft) thickness of a mixture of cobble stones and gravel, providing a barrier against intrusion of animals and roots (Hakonson et al. 1983). The final layer would be a 0.91-m (3-ft) thickness of topsoil. The topsoil would be seeded with short-rooted grasses, native to the Oak Ridge area, that would prevent erosion and reduce loss of soil moisture. After the entire disposal unit was filled and capped, the external drain surrounding the unit at its base would be completed. This external drain would channel runoff from the surface of the mound and seepage from the sand layer in the cap.

D.5 OPERATIONS

Movement of the wastes, and procedures and other considerations related to operation of the CWDF, are described in this section. The CWDF would operate under criteria developed specifically for it.

D.5.1 Transport

The sole mode of transporting wastes to the CWDF would be trucks via roads contained within the ORR (see Section D.2.1). Shipments would be of four general types: (1) grout in sludge form, (2) grout in solidified form, (3) packaged wastes, and (4) bulk wastes. The estimated time for processing a truck in and out of the CWDF would be about 2 hours. The estimated time for traveling the distance between the Y-12 Plant and the CWDF, 13 km (8 mi), would be about 26 min. For the ORGDP, the distance would be 5 km (3 mi) and the time 10 min. For ORNL, the distance would be 3 km (2 mi) and the time 6 min.

D.5.2 Receipt and Inspection

When a waste shipment was received at the waste-receipt and inspection area, the manifest document accompanying it would be checked. The waste and its transporting vehicle would be surveyed for penetrating radiation and surface contamination and would be checked for conformance to waste-acceptance criteria. Waste would usually be emplaced the day it is received. The flow of operations for receipt of waste at the CWDF is summarized in Figure D.4.

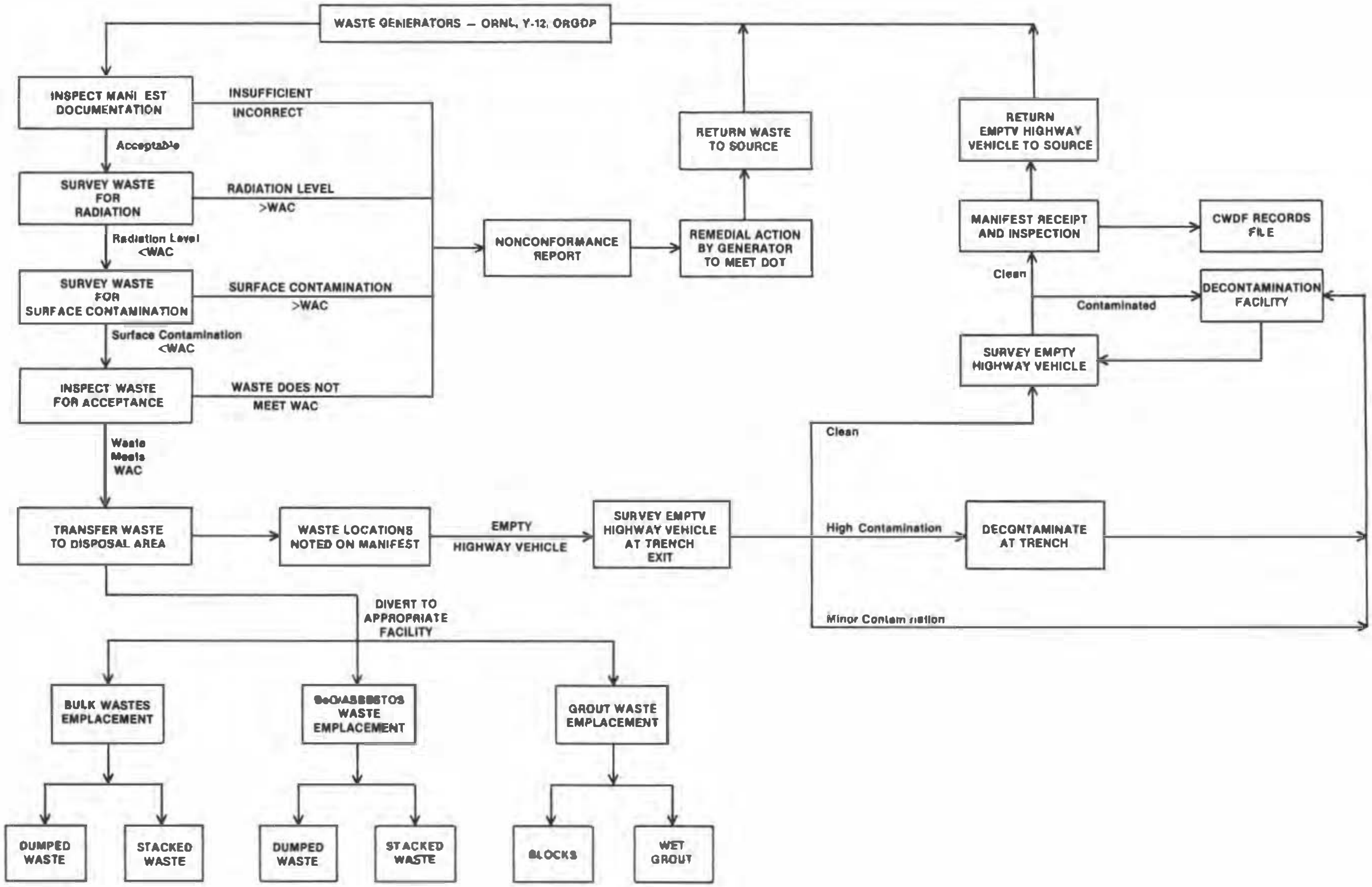


Figure D.4. Flow of Operations for Receipt of Waste at CWDF.
Source: Redrawn from Bates and Van Cleve (1984).

In addition to inspection and maintenance of buildings and equipment, the inspection and maintenance of disposal units and grounds would be carried out on a regular schedule to prevent the development of surface conditions that might lead to water infiltration into the disposal units. This activity would consist of inspecting surfaces and--wherever necessary--repairing surfaces, seeding, fertilizing, and mowing. It would continue from the time the facility opened through the end of the institutional-control period. Any unfavorable drainage effects that developed during the operating lifetime of the facility would be remedied by local recontouring in the vicinity of individual trenches.

D.5.3 Waste Emplacement

Because waste-emplacement operations are closely related to disposal unit design, their descriptions are given immediately after the descriptions of disposal unit designs (see Sections D.3.2 and D.4.2).

D.5.4 Disposal Unit Closure

Disposal unit closure operations also are closely related to disposal unit design, and their descriptions are also given after the descriptions of disposal unit designs (see Sections D.3.3 and D.4.3).

D.5.5 Monitoring

The monitoring program for the CWDF would consist of two main subprograms: site radiological monitoring and environmental monitoring. Moreover, environmental monitoring would have two fields of activity, onsite and offsite.

The site radiological monitoring program would include survey of surfaces for contamination control. As Figure D.4 indicates, the surfaces of vehicles would be subjected to routine survey; surfaces of vehicles and equipment with radioactivity levels in excess of the limits specified by the operating criteria would be decontaminated. The wash liquids from decontamination operations would be transported to the ORNL liquid waste treatment systems.

During operations, an environmental monitoring program specifically devised for the CWDF would be followed. This program would be designed in accordance with DOE requirements, e.g., DOE Orders (5400 series), and in consideration of routine and potential accidental release points from the operations. Furthermore, the monitoring program for the CWDF would be integrated with the ongoing DOE monitoring program for the ORR site (for which an annual report of the results is published).

The plan for environmental monitoring at the CWDF addresses three phases: preoperational, operational, and post-closure. Preoperational monitoring, already in progress, would be carried out during site characterization and initial construction. Operational monitoring would be carried out in and around disposal areas from the time of initial operations to the time of closure. Post-closure monitoring would be carried out after disposal operations have ceased.

Sampling and analysis during the preoperational and operational phases would be similar, but the scope of sampling and analysis would be reduced during the post-closure period.

The first phase, preoperational monitoring, would define a baseline that would permit comparisons with later observations to discover any changes caused by operation of the facility. This preoperational monitoring program would include soil investigations, measurements of surface water discharge, observations of fluctuations in the groundwater table, measurements of the quality of surface water and groundwater, meteorological observations, and air-quality measurements.

0.5.5.1 Preoperational Environmental Monitoring

In preoperational environmental monitoring, the scope of soil investigations includes extensive physical testing of the site soils, mineralogical characterization, and testing of radionuclide sorption characteristics. Physical testing of soils is performed to generally characterize the soils and to provide input data to analytical models used in site performance evaluation and pathways analysis.

Preoperational stream discharge data are being integrated with precipitation and groundwater monitoring data in preparation of a site water balance. The baseline runoff per upstream watershed area for each monitoring location is being determined and seasonal variations are being measured. The baseline data will provide a reference against which effects of area clearing and site operation can be evaluated.

Levels of the groundwater table are being measured through 39 observation wells, in soil and bedrock, installed on site during the site-characterization program. In the preoperational groundwater quality monitoring program, samples are obtained from eight wells, and the general water quality analyses listed in Table 0.1 are performed on each sample.

Parameters to be included in the preoperational baseline analytical program include major anions, cations, total organic carbon, and radionuclides. For routine radiological monitoring parameters during facility operation, only the more mobile radionuclides may be used as migration indicators.

The radionuclide analyses for background monitoring will include the major radionuclides anticipated for disposal in the CWDF; these are listed in Table D.1.

D.5.5.2 Operational Phase Environmental Monitoring

Environmental monitoring during the operational life of the CWDF would evaluate the performance of the site and the disposal system and document site compliance with regulatory criteria. The monitoring program would include site soils, surface water and groundwater systems, and the atmosphere in the site vicinity.

Soil monitoring activities proposed for the operational period focus on monitoring of trench caps to ensure stability of trenches after capping. Visual inspection of closed trenches would be made to identify locations in which remedial measures were required. In selected areas, monitoring of cap settlement and erosional denudation of soils would be performed.

Table D.1. Water Quality Parameters Included in Preoperational Water Monitoring

General Parameters	Anions	Cations		Radionuclides
Temperature	SO_4^{-2}	Ag	Mg	Total alpha, beta, and gamma activity
pH	NO_3^{-2}	Al	Mn	
Specific conductivity	PO_4^{-2}	B	Mo	Be-10
	F^-	Ba	Na	C-14
	Cl^-	Be	Ni	Cm-244
	Br^-	Ca	Pb	Co-60
		Cd	Sb	Cs-137
		Co	Se	H-3
		Cr	Si	Mn-54
		Cu	Sr	Po-210
		Fe	Ti	Pu-238, -240
		Ga	V	Ra-226
		Hf	Zn	Ru-106
		K	Zr	Sn-151
				Sr-90
				Tc-99
				Th-232
				U-238

During facility operation, stream discharge monitoring and water quality monitoring programs similar to the preoperational monitoring program would continue. Effects of facility construction activities on the surface water regime would be evaluated by comparison of preoperational discharge measurement to those obtained during facility operation.

The operational surface water quality monitoring program would include the same general water quality and radiological analyses as the preoperational phase, except that the number of radionuclides for analysis would be reduced to the predominant radionuclides to be disposed and the more mobile elements, i.e., C-14, Co-60, Cs-137, H-3, I-129, and Sr-90. The aim of the operational water quality monitoring program would be to detect radionuclide migration.

During facility operation, groundwater monitoring would include samples from: (1) fluids that may be detected in trench blanket drains and sumps, (2) soil water collected in vacuum lysimeters installed beneath each trench, and (3) water from groundwater monitoring wells.

Vacuum lysimeters would be installed in subgrade soils beneath each trench in tandem with the PVC standpipes that communicate with the bottom of each trench. The purpose for installing the lysimeters would be to allow sampling of soil water beneath the trenches without intrusion. Monitoring wells would also be installed at the perimeter of each disposal area to allow monitoring of water table fluctuations and sampling of groundwater in soil and bedrock zones.

During facility operation, one recording precipitation gauge would be operated to monitor precipitation at the site.

Air quality would also be monitored at the site during operation. Sites for air monitoring facilities and monitoring frequency would be determined during development of detailed monitoring plans. Airborne particulates would be sampled and analyzed for total alpha, beta, and gamma activity; and gaseous samples would be obtained and used for determination of Rn-222 and C-14.

D.5.5.3 Post-Closure Monitoring

Site monitoring during the post-closure period would involve continued surveillance for compliance and would focus on detection of deterioration of the facility or development of unstable conditions in or near disposal trenches. Continued water quality monitoring might be required on a scale reduced from that employed during the operational phase. Details of continued water quality analytical activities would be determined by evaluation of site performance during the operational phase.

In post-closure monitoring, the site would be inspected routinely to identify areas of trench cap subsidence or cap erosion that would require minor filling and revegetation. Post-closure site monitoring might include at least seasonal sampling at selected surface and groundwater monitoring points used during the operational period.

D.5.6 Safety and Emergency Response

Until closure was complete, plans and equipment for responding to emergencies would be maintained. Planning for facility operations would include procedures for meeting emergencies and abnormal operations. Equipment for response to possible emergencies such as fire, explosion, radioactive spill, and injury would be available at the West Chestnut Ridge site. Drills would be conducted, at least annually, to test equipment and procedures. Procedures for filing reports on abnormal operations would be observed. The occurrence of an emergency event would require notification of emergency support groups on the ORR and site management.

0.5.7 Site Closure

The operating lifetime of the CWDF is expected to be 40 years. Near the end of the operating lifetime, DOE would review the closure plan to ensure that final operations conformed to the plan devised at the outset; the plan would be revised to accommodate operational developments that occurred during the lifetime of the CWDF. This review of the closure plan would include disposal unit locations, elevations, capacities, surface contours, and buffer zones. The closure plan would include concepts for disposition of all facilities of the CWDF, including equipment, land, and buildings. At this time, documentation on the facility would also be reviewed to ensure that it was complete and well organized.

At site closure, a final inspection of all disposal units would be carried out, and any threats to disposal unit integrity would be remedied--e.g., subsidence, ponding, and inadequate vegetative cover. Drainage patterns would be observed after final contouring to determine whether they avoided infiltration and erosion as intended or whether additional adjustments to surfaces would be required. Soil available in the area of the disposal units would be used to make any adjustments necessary in contouring and grading, and for repairing any subsidence that might have occurred during the lifetime of the facility. The earthen checkdams constructed on the upstream side of each disposal unit to divert surface runoff around the open units would be left in place after closure to dissipate the energy of surface runoff velocity.

During the five-year active maintenance period, activities would include (1) dismantling, decontamination, and disposal of all structures not required for custodial care; (2) continued inspection of disposal units and grounds and performance of any necessary remedial actions; (3) observation of surface water runoff patterns and adjustment, where necessary, by altering or repairing surfaces; (4) environmental monitoring; (5) repairing or replacement of the security fencing with a system that required minimum maintenance; and (6) pumping and, if necessary, treatment of water collected in disposal unit sumps. The decommissioning of unnecessary buildings and equipment would produce some waste that would be buried in the last active disposal unit.

Activities at the CWDF during the institutional-care period (post-closure) would consist of maintenance of surface cover, cleaning of drainage ditches, and monitoring. Although the security system would be reduced during the institutional-control period, fences would be maintained to continue prevention of unauthorized entry and disposal unit intrusion or removal of equipment and material.

REFERENCES (Appendix D)

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