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Title

ASSESSMENT OF DECOMMISSIONING ALTERNATIVES FOR THE SHUT-DOWN HANFORD 100 AREA REACTORS

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A Hanford Production Reactor Decommissioning Study

May 15, 1984

Assessment of Decommissioning Alternatives for the Shut-Down Hanford 100 Area Reactors

Prepared by
Office of Surplus Facilities Management
UNC Nuclear Industries, Inc.
Operations Division
Richland, WA 99352
for
U.S. Department of Energy
Richland Operations Office
Under Contract No. DE-AC06-76RLO1857

UNC Nuclear Industries, Inc.
RICHLAND, WASHINGTON

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SUMMARY

Of the nine Hanford production reactors, eight have been deactivated since 1971 and are currently being maintained in a safe storage condition. A cost-effective alternative for the ultimate decommissioning of these facilities must be implemented. Abandonment of the facilities is not a feasible alternative because they are deteriorating and could eventually expose radioactive materials to the environment and to human food and water pathways.

Three feasible decommissioning alternatives for the shut-down Hanford 100 Area reactors and associated fuel storage basins have been identified and assessed. Those alternatives are identified below, along with summary cost, occupational exposure, and schedule data.

SUMMARY COST, OCCUPATIONAL EXPOSURE, AND SCHEDULE DATA FOR DECOMMISSIONING EIGHT REACTOR FACILITIES

Assessment Factor	DECOMMISSIONING ALTERNATIVE		
	In-Situ	Safe Storage/ Deferred Dismantlement	Immediate Dismantlement
Cost	$14 million	$157 million	$153 million
Occupational Exposure	40 man-rem	900 man-rem	520 man-rem
Project Duration	8 yr	103 yr	20 yr

The above data show that the decommissioning alternative with the lowest dollar cost, lowest occupational exposure usage, and shortest project duration is in-situ decommissioning, the technique of demolishing above-ground building structures and then covering the area with clean fill and/or an engineered intrusion barrier.

The in-situ decommissioning mode has been determined to be feasible for the reactor buildings based on site-specific pathway analysis and national requirements for radiological controls. A comparison was also made between the pathway analysis results and the regulations developed by the Nuclear Regulatory Commission (NRC) in their licensing of low-level waste burial grounds. The NRC established allowable concentrations to permit 100 years of radionuclide decay before low-level waste burial sites are released from insititutional control. In-situ decommissioning of the Hanford production reactors would yield results that are well within the Department of Energy (DOE) dose limits and that reflect the intent of the NRC standards.

The deferred dismantlement mode data reflect 75 years of maintenance and surveillance and the associated costs and exposure that will be required while waiting for the high-energy, gamma-emitting radionuclides to decay, plus the costs and exposure for the deferred dismantlement of the facilities. As shown above, the resulting cost and occupational exposure levels make this alternative more expensive than the in-situ mode as an ultimate disposition method for the shut-down 100 Area reactor facilities.

The immediate dismantlement and removal mode data reflect the high waste volumes involved and the special remote handling equipment and procedures that would be needed to dismantle the contaminated facilities before the resident radionuclides have had time to decay to more easily managed levels.

In addition, prioritization criteria and a priority ranking order for decommissioning the shut-down Hanford Area reactor facilities have been identified.

1.0 INTRODUCTION

1.1 BACKGROUND INFORMATION

In 1942, Hanford was commissioned as a site for the production of plutonium by the Manhattan Engineer District of the U.S. Army Corps of Engineers. Eight graphite-moderated reactors were constructed in the Hanford 100 Area between 1942 and 1955 to support the plutonium production effort. They are the 105-B, -C, -D, -DR, -F, -H, -KE, and -KW reactors. These facilities are now declared surplus and will require decommissioning. A ninth production reactor, N Reactor, was started up in 1963 and is still in operation. The decommissioning of N Reactor is not within the scope of this report.

The original eight production reactors, were deactivated during the period 1964 to 1971, and have since been kept in a safe storage condition. Safe storage activities for these reactors have actually consisted only of short-term actions adequate to protect the workers and the environment for the present, and are not considered adequate to assure stabilized, long-term storage. Viable, permanent decommissioning alternatives for these facilities have been carefully assessed, and the results are reported in this document.

1.2 OBJECTIVES

In general, the purpose of this report is to present UNC's comparative analysis of alternative technical approaches for decommissioning the shut-down Hanford 100 Area reactor facilities. Factors considered include cost, exposure, waste burial volumes, manpower, and completion time estimates. This assessment is a primary step in the National Environmental Policy Administration (NEPA) process. The role of this report in the overall decommissioning plan is shown in Figure 1-1.

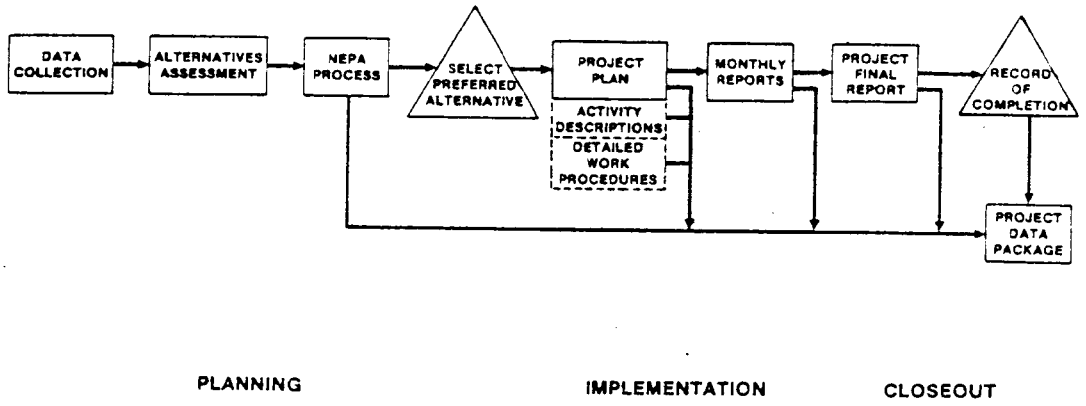

FIGURE 1-1. Project Planning Process.

The specific objectives of this report are to:

1) Develop a preliminary base of information, including general physical and radiological characterization data, on the shut-down facilities;

2) Identify and assess feasible decommissioning alternatives, and provide preliminary estimates of cost, manpower, and schedule requirements for decommissioning alternatives identified as most practicable from an engineering and construction standpoint; and

3) Establish a rank-ordered priority list for accomplishing the decommissioning projects, and describe the criteria used for this prioritizing.

1.3 SCOPE

1.3.1 Facilities Covered by this Report

This report covers only the shut-down production reactors and their associated fuel storage basins in the Hanford 100 Areas, and the alternatives considered for decommissioning those facilities. This report reflects only known values,

and does not consider the potential impacts of civil projects that have not yet been authorized and scheduled, such as the proposed construction of the Ben Franklin Dam on the Columbia River.

The facilities within the scope of this report are described in Section 2. The facilities include: reactor buildings 105-B, 105-C, 105-D, 105-DR, 105-F, 105-H, 105-KE, and 105-KW, including the reactors and the spent fuel storage basins.

1.3.2 Contents and Arrangement of this Report

This report is presented in seven sections, of which this introduction is the first. The remaining sections are:

- Section 2 -- Hanford 100 Area Description. This section provides descriptions of the facilities within the scope of this report, including basic characterization data.
- Section 3 -- Assumptions and Criteria Used in Assessing Decommissioning Alternatives. This section delineates the assumptions and criteria upon which the assessments are based.
- Section 4 -- Description of Decommissioning Alternatives. This section describes the alternatives considered and assessed, including a general description of how each alternative would be implemented, a brief description of key advantages and disadvantages of the alternatives, and identification of those alternatives selected for assessment and comparison in Section 5.
- Section 5 -- Assessment of Decommissioning Alternatives. This section provides quantified and comparative assessments of three feasible alternatives for reactor facility decommissioning.
- Section 6 -- Project Priorities and Ranking. This section describes the criteria used to establish project priorities, and lists the resulting priority ranking.
- Section 7 -- References. Documents cited in this report are listed in Section 7.

2.0 HANFORD 100 AREA DESCRIPTION

The Hanford 100 Reactor Areas, shown in Figure 2-1, are situated along the Columbia River some 30 miles north of Richland, Washington. They are a contiguous part of the U.S. government reservation called the Hanford Site. Eight of these nine reactors (all but N Reactor) are shut down and are included in the scope of this decommissioning alternatives assessment report.

2.1 GENERAL DESCRIPTION OF THE HANFORD AREA ENVIRONMENT

A complete description of the demography, geology, meteorology, ecology, and other physical characteristics of the Hanford Site is contained in ERDA 1538 (Reference 1). General site characteristics relevant to assessment of decommissioning alternatives for the shut-down Hanford reactor facilities are summarized briefly below.

2.1.1 General Ecology

The Hanford Site lies in a semiarid region of Washington State, in the rain shadow of the Cascade mountain range. The area is mostly natural terrain with no commercial or residential development. The Hanford 100 Reactor Areas have the region's natural sparse covering of sagebrush and shallow-rooted grass species. Animal species on the Site are those common to the region, and include abundant game species, fowl, and aquatic life.

2.1.2 General Demography

Human population within 50 miles of the Hanford Site totals about 250,000 people. The Tri-Cities (Richland, Kennewick, and Pasco), containing about 88,000 people, is located about 30 miles to the south of the shut-down Hanford 100 Reactor Areas, downstream on the Columbia River. The metropolitan Yakima area, located about 45 miles to the west of the Hanford Site, is the largest nearby single city. Other population near the Hanford Site is spread out in small communities and agricultural land.

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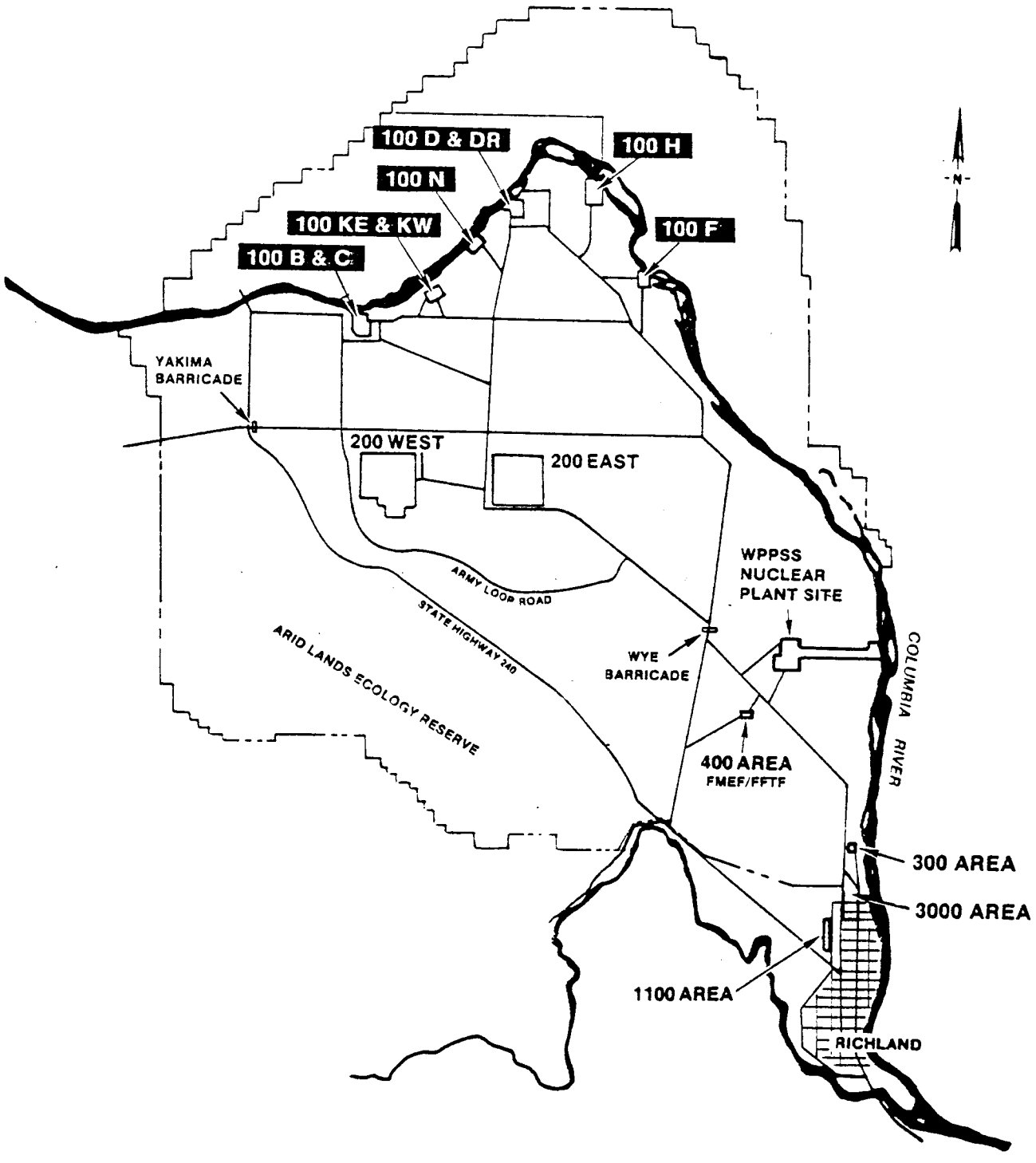

FIGURE 2-1. Hanford Site Map.

2.1.3 Geology

The Hanford Site, situated in the Pasco Basin, is underlain by thousands of feet of stable basalt, which in turn is overburdened by sand and gravel deposits. Studies (Reference 1) show there is little chance of a significant damaging earthquake in this area that would detrimentally affect the shut-down facilities. The area is included in Zone 2 in the Uniform Building Code seismic probability map.

2.1.4 Meteorology

Rainfall in the area is very light, less than 7 in./yr, and most of that during the winter months. Hard (20 to 30 mph), steady winds blow frequently in the area, particularly in the spring. The maximum recorded gust was 80 mph. Tornadoes are rare in the region; no tornado damage has ever been recorded in the Hanford Site. Temperatures are mild in the winter, only occasionally falling below 0°F (-18°C). Summers are hot and dry, with daily highs during July and August frequently in the 90 to 100°F (32 to 38°C) range.

2.2 DESCRIPTION OF SHUT-DOWN REACTOR FACILITIES

The eight shut-down production reactors in the Hanford 100 Area were constructed during the period 1943 to 1955. All of the reactors have been inactive since 1971. Table 2-1 lists these facilities along with their initial startup and final shutdown dates.

The reactor 105 buildings house the production reactors and related systems and equipment. A typical reactor facility (Figure 2-2) is a reinforced concrete and concrete block structure some 250 ft long x 230 ft wide x 95 ft high. The building has massive (3 ft to 5 ft thick) reinforced concrete walls around the reactor block at the lower levels to provide additional radiation shielding, with lighter construction above -- either concrete block or corrugated asbestos cement. Roof construction is primarily precast concrete slab or poured insulating concrete.

TABLE 2-1

SHUT-DOWN HANFORD PRODUCTION REACTORS

Reactor Facility	Initial Startup Date	Final Shutdown Date
105-B	9/26/44	2/12/68
105-C	11/18/52	4/25/69
105-D	12/17/44	6/26/67
105-DR	10/03/50	12/30/64
105-F	2/25/45	6/25/65
105-H	10/29/49	4/21/65
105-KE	4/17/55	1/28/71
105-KW	1/4/55	2/01/70

Except for the reinforced concrete portions, these buildings can be classified as light, non-airtight, industrial structures.

As shown in Figure 2-2, the reactor block is located near the center of the building. Horizontal control rod penetrations are on the left side of the reactor block (when facing the reactor front face), and safety rod penetrations are on the top of the reactor. Fuel discharge and storage areas are located adjacent to the rear face of the reactor. Experimental test penetrations are on the right side of most of the reactors.

2.2.1 Reactor Block

A typical reactor block (Figure 2-3) consists of a graphite moderator stack encased in cast iron thermal shielding, and a biological shield of alternating layers of masonite and steel or concrete. The entire block rests on a massive concrete base and foundation arrangement. A typical reactor block assembly

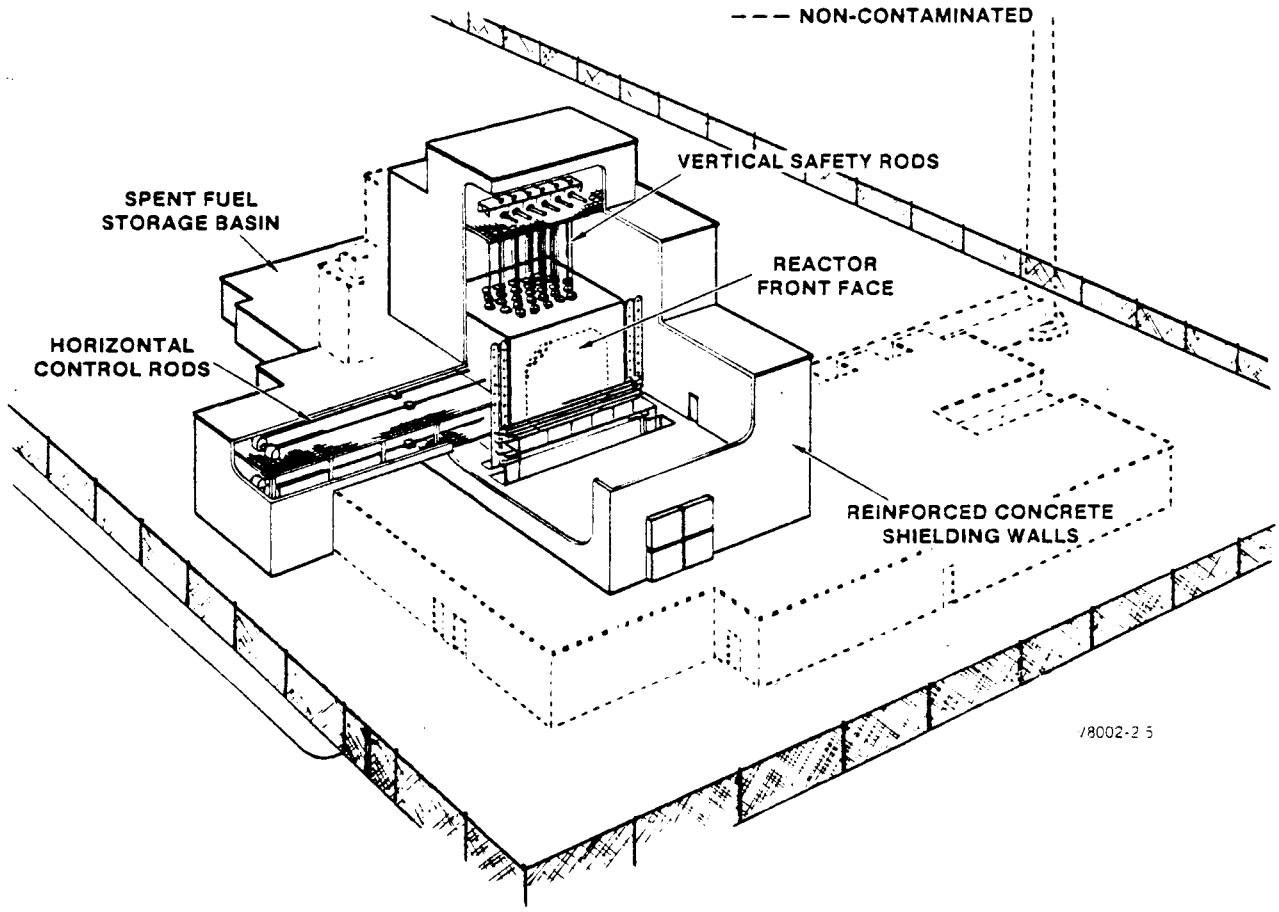

FIGURE 2-2. Typical Reactor Facility.

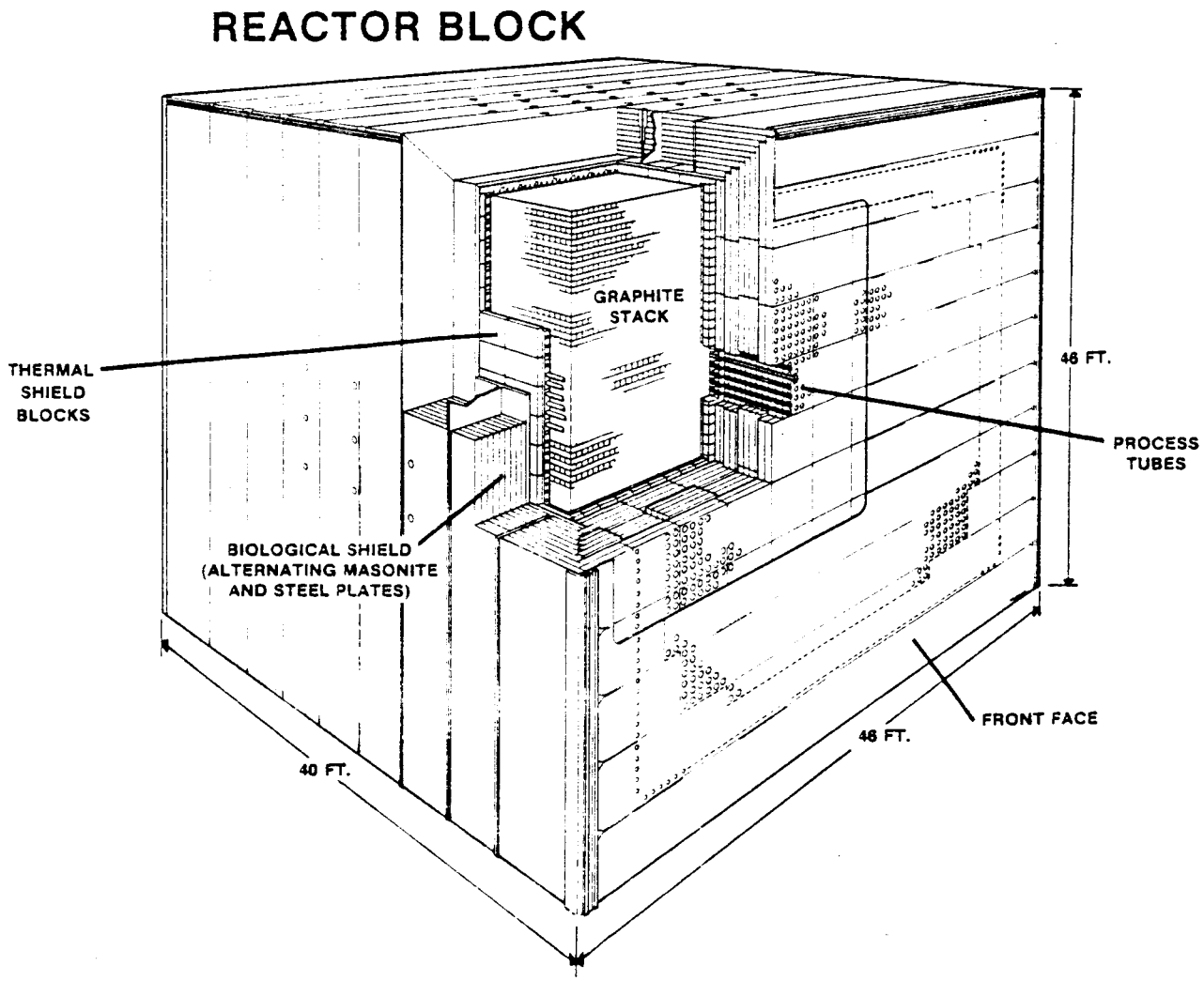

FIGURE 2-3. Reactor Block Construction.

weighs approximately 9,000 tons, and has overall dimensions of 46 ft high, by 46 ft wide, by 40 ft deep.

The principal components of a production reactor block are:

- The reactor moderator stack, an assembly of graphite blocks cored to provide channels for process tubes, control rods, and other equipment;
- Thermal and biological shielding, surrounded by a heavy, vault-like steel outer shell equipped with gas-tight seals for the reactor block penetrations;
- The process tubes, which held the uranium fuel elements;
- Horizontal control rods;
- Vertical safety rods;
- Ball 3X system, for dropping neutron-absorbing steel-and-boron balls into vertical safety rod channels for emergency reactor shutdown; and
- Monitoring equipment and experimental and test equipment.

As shown in Figure 2-3, shielding around the graphite stack consists of a thermal shield (cast iron 8 to 10 in. thick) and a biological shield (alternating layers of steel plate and Masonite or heavy-aggregate concrete 40 to 83 in. thick). Studies show that some powdering of the Masonite has occurred, but this deterioration has not reduced the structural integrity of the reactor block as a whole.

The shut-down production reactors are quite similar in design. The K Reactors differ from the older production reactors mainly in the number, size, and type of process tubes, the size of the moderator stack, and the type of shielding employed. Table 2-2 gives information on reactor block size and construction materials used for all eight shutdown reactors. Because of the type and amount of radionuclide inventory present in the reactor blocks, all radioactive materials in the blocks will classify as low-level waste as defined by DOE and NRC.

TABLE 2-2

HANFORD PRODUCTION REACTOR DESIGN DATA

Reactors	Graphite Stack Dimensions (ft)			Process Tubes			Thermal Shield		Biological Shield	
	Front to Rear	Top to Bottom	Side to Side	Number	Type	ID (in.)	Type	Thickness (in.)	Type	Thickness (in.)
B, C,[a] D, DR, F, H	28	36	36	2004	Aluminum	1.75	Cast Iron	8-10	Steel and Masonite	52
KE, KW	33.5	41	41	3220	Zircaloy and Aluminum	1.8	Cast Iron	10	Heavy-Aggregate Concrete	45-83

[a]C Reactor has slightly larger diameter process tubes than the other reactors in this group. It contains about 60 Zircaloy process tubes, and has a heavy-aggregate concrete biological shield (7 ft thick) atop the reactor in place of steel and masonite.

2.2.2 Fuel Storage Basins

Each reactor 105 building contains a fuel storage basin (Figure 2-4). The basin served as a collection, storage, and transfer facility for the irradiated fuel elements discharged from the reactor. A typical reactor fuel storage basin consists of the fuel element pickup area, the storage area, and the transfer area. Irradiated fuel elements were sorted in the pickup area, transferred to buckets, and transported by monorail to the storage area, where they were held to allow decay of short-lived radionuclides prior to reprocessing. Following the storage period, the buckets of fuel elements were moved to the transfer area, where they were placed in railroad cask cars for transport to the chemical reprocessing facilities.

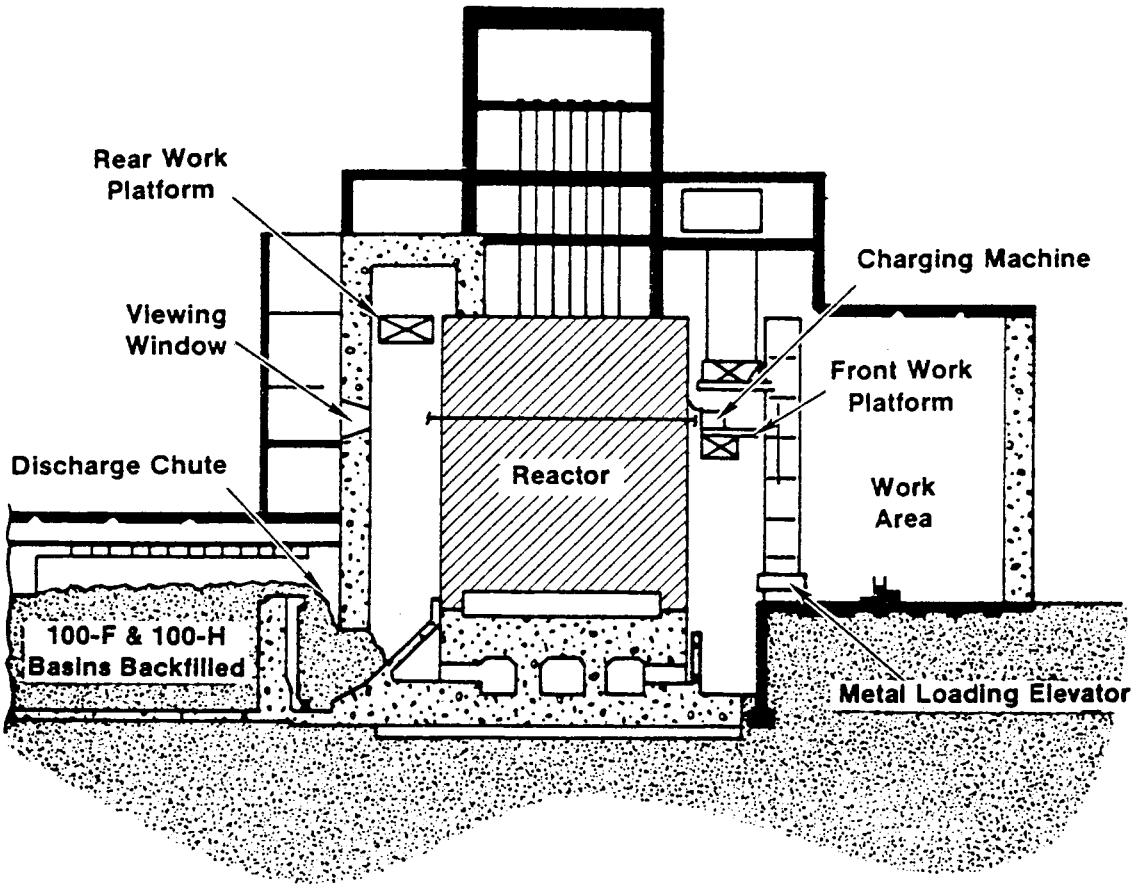

FIGURE 2-4. Side View of Reactor Facility, Showing Fuel Storage Basin: For 105-B, D and F.

The total area of each fuel storage basin, including the element pickup and transfer areas, is 7,000 to 10,000 ft^2. The basins are about 22 ft deep and contained about 20 ft of water during operating periods.

The storage area of each fuel storage basin is equipped with a slotted wooden or steel grating floor. The average thickness of the outside walls of the basin is 20 inches; the bottom of the basin is about 6 inches thick. The total volume of concrete in each basin is about 750 yd^3.

Buckets used to transport and store the fuel elements and other equipment have been left in all the basins except in the 105-KE and 105-KW fuel storage basins. Galvanized buckets at K Area were removed from the basins and buried as solid waste, and the stainless steel buckets were removed and stored inside the 105 Building.

The 105-KE and 105-KW fuel storage basins are currently being used to store irradiated fuel from N Reactor. The basins will continue to be used until the stored fuel can be processed at PUREX. The estimated date for completion of removal and processing of this fuel is 1987.

2.2.3 Radiological Condition of the Reactor Buildings

The residual radioactive material that remains in each 105 Building is contained principally within the reactor block and in residues in the fuel storage basin. (All reactor fuel elements that are currently located in the 105-KE and 105-KW fuel storage basins will be removed prior to decommissioning these reactors.) The radioactive material in the reactor block is contained in the graphite stack, the thermal shield, process tubes, and the control rods. Table 2-3 shows the total inventory, in curies, for a typical reactor block graphite stack and thermal shield. Based on these data, the graphite stack thermal shield and other reactor components within the block would be classified as low-level waste.

The major source of radioactivity outside the reactor blocks is the sludge on the floors of the fuel storage basins. The sludge and other high dose rate materials are currently being removed from B, C, D, and DR fuel storage basins. This work is scheduled to be completed by the end of FY 1984.

TABLE 2-3

INVENTORY OF RADIONUCLIDES IN A TYPICAL SHUT-DOWN PRODUCTION REACTOR BLOCK

Radionuclide	Half-Life (yr)	Inventory* (Ci)
^{3}H	12.33	740
^{14}C	5,730	3,600
^{60}Co	5.27	3,100
^{63}Ni	100	730
^{90}Sr	29	0.002
^{93}Mo	3,500	2
^{94}Nb	20,000	2
^{137}Cs	30.17	0.002
^{152}Eu	13.4	8
^{154}Eu	8.2	0.3
^{238}Pu	87.74	4
$^{239/240}Pu$	24,110	3
Typical Reactor Total Ci Inventory:		9,000 Ci

*Estimated inventory for one of eight production reactors calculated for reference time, March 1, 1985.

The 105-F and 105-H fuel storage basins were backfilled with clean earth in 1969. These basins were surveyed prior to backfilling, and the high dose rate materials were removed. There is, however, a possibility that one or more low-dose-rate irradiated fuel elements were overlooked and buried under the 20 feet of earth backfill. The significance of this, relative to low-level waste classification, will be fully evaluated before selection of a final decommissioning alternative for these two basins.

Other materials remaining in the fuel storage basins are classified as low-level waste. Table 2-4 shows the total inventory, in curies, for a typical fuel storage basin. The data in Table 2-4 do not include the radionuclide content of any fuel elements that might be found in the 105-F or 105-H fuel storage basins.

TABLE 2-4

INVENTORY OF RADIONUCLIDES IN A TYPICAL FUEL STORAGE BASIN

Radionuclide	Half-Life (yr)	Inventory* (Ci)
^{3}H	12.33	0.5
^{60}Co	5.27	8
^{63}Ni	100	46
^{90}Sr	29	2
^{137}Cs	30.17	7
^{152}Eu	13.4	6
^{154}Eu	8.2	2
^{155}Eu	4.76	0.3
$^{238}U+D$**	1,500,000	0.0004
^{238}Pu	87.74	0.01
^{239}Pu	24,110	0.4
Typical Basin Total Ci Inventory:		~72 Ci

*Estimated inventory for one of eight fuel storage basins, calculated for reference time, March 1, 1985.

**Includes total isotopic-estimated uranium and plutonium inventories.

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3.0 ASSUMPTIONS AND CRITERIA USED IN ASSESSING DECOMMISSIONING ALTERNATIVES

The following assumptions and criteria were used in assessing the various decommissioning alternatives for the shut-down Hanford 100 Area reactor facilities.

3.1 ASSUMPTIONS

The assessment of decommissioning alternatives reported in this document are based on the following assumptions:

- Radiological dose rates to occupationally exposed personnel and to members of the public will be controlled in accordance with DOE standards for radiation protection and will be reduced to as low as reasonably achievable (ALARA) levels.
- Radioactive materials in the shut-down Hanford reactor facilities classify as low-level waste.
- Acceptable residual contamination limits for in-situ decommisioning will be calculated by using the pathway analysis methodology described in Reference 2.
- Radioactive wastes not decommissioned in-situ will be disposed of at the Hanford 200 Area. Such disposal will comply with applicable DOE Orders, and with Rockwell Hanford Operations requirements (Reference 3).
- Material or equipment removed from the site and released for uncontrolled use will meet all DOE radiological requirements invoked at the time of removal.
- Radioactive facilities decommissioned in-situ will be isolated in a manner that provides the same degree of protection to the public and environment as afforded by 10 CFR 61 (Reference 4).
- Intrusion barriers will last at least 500 years. Such barriers may be either engineered (concrete, riprap, etc.) or a stable earth cover at least 5 meters thick. The intrusion barrier will limit radiological exposure to an inadvertent intruder to less than 500 mrem/year at the end of its design life.
- The reactor facilities and land they occupy can, if necessary, be institutionally controlled for a period of up to 100 years. A full time resident on the site will receive less than 500 mrem/year at the end of the institutional control period.

- The public and DOE prefers that the land be restored to as nearly a natural condition as practicable.

3.2 ASSESSMENT CRITERIA

The following assessment criteria were used to identify the best alternative within each decommissioning mode:

- Cost
- Public and occupational radiation exposure
- Manpower requirements
- Project duration
- Radioactive waste disposal volumes
- Potential for reuse of equipment, material and facility
- Time until site can be restored to a nearly natural condition

4.0 DESCRIPTION OF DECOMMISSIONING ALTERNATIVES

Four general modes of decommissioning have been considered for the shut-down Hanford 100 Area reactor facilities. They are:

1) In-situ decommissioning of radioactive components and debris

2) Safe storage of radioactive components followed by deferred dismantlement and removal of material for disposal in an approved low-level waste burial site

3) Immediate dismantlement and removal of radioactive components for disposal in an approved low-level waste burial site

4) No action (or status quo).

The decommissioning modes and the alternatives considered for disposition of the shut-down Hanford production reactors and their associated fuel storage basins are shown in summary fashion in Figure 4-1, and described in greater detail in paragraphs 4.1 through 4.4.

4.1 IN-SITU DECOMMISSIONING MODE

In-situ decommissioning would mean disposing of the reactor facility in its present location, as opposed to hauling it away for disposal elsewhere. It would be accomplished by installing some form of long-term protective barrier that would isolate the radioactive residues from pathways to man.

For the Hanford production reactors, the only in-situ decommissioning alternative considered practical would consist of a mound of clean earth and concrete rubble. The earth would be taken from local gravel pits near the reactor sites, and the clean concrete rubble would be provided by the demolished reactor building superstructures. Although such an earthen mound would not provide an eternal barrier between the reactor block and the surrounding soils, it would provide a satisfactory degree of environmental

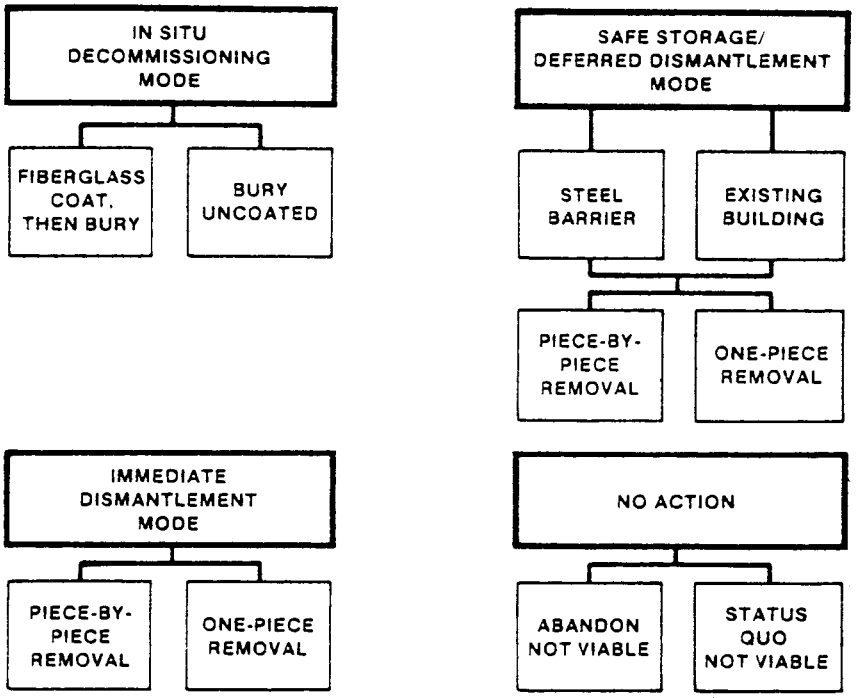

FIGURE 4-1. Decommissioning Modes and Alternatives for Reactor Facilities and Fuel Storage Basins.

isolation, and be superior to that achievable by dismantling the high-integrity reactor shields and block and then transporting and burying the disturbed radioactive material in a conventional, shallow-land, low-level waste disposal site. The 9000-ton reactor block, left intact, would serve as its own high-integrity, long-term radiological burial container. As described in paragraph 2.2.1, a typical reactor block consists of a strong steel outer shell, a 40 to 80 in. thick biological shield comprised of alternating layers of steel and Masonite, and an 8 to 10 in. thick cast iron thermal shield, all encasing a very stable stack of graphite blocks. This structure could reasonably be expected to provide long-term containment capability under environmental conditions far harsher than any that may be encountered in the dry Hanford soil. And even if by accident or design the reactor block were

opened up, any radionuclides still remaining within it would be chemically "locked up" in the physical matrix of cast iron and graphite and would not readily migrate to the environment or contaminate human food pathways.

The procedure for a mound type in-situ decommissioning of a Hanford production reactor would be straightforward. First, the fan room, rod rooms, sample rooms, etc., would be decontaminated to the extent necessary to prevent radionuclide release during building demolition. If the fuel storage basin contains water (at this time all 105 building fuel storage basins are filled with water except for the basins in 105-F and 105-H, which are filled with dirt), the water would first be cleaned to unrestricted release levels, and then released to the environment. The reactor block would be left in place on its foundation. Some reactor equipment would be salvaged for reuse or recycling; other equipment (gamma monitors, work elevators, safety ball hoppers, etc.) would be left in place on or around the reactor block. The vertical safety rods and the horizontal control rods would be left inserted in the reactor block. Water risers, cross headers, down-comers, capped process tubes and nozzles would also be left in place as installed on the reactor block. Large pipes and other voids would be filled with earth and/or grout as necessary to prevent future soil subsidences in the mound. Once the interior preparations were completed, building demolition would proceed.

The upper walls and roof (superstructure) of the building, which are free of radioactive contamination, would be knocked into rubble using ordinary building razing procedures, and the rubble would be left in place for use later as fill. The lower, reinforced shield walls would be left in place around the reactor block. These 42 to 56 ft high, 3 to 5 ft thick reinforced concrete walls would provide a strong extra barrier around the reactor block and would assist in retaining the buried materials in one place. Then the entire facility site would be filled in and mounded over with earth, gravel and building superstructure rubble to a minimum depth of 5 m (16 ft) above the reactor block. The mound would be sloped to minimize run-off erosion, blended with the surrounding terrain, covered with topsoil, and seeded to establish suitable species of shallow-rooted plant growth.

Engineering estimates indicate that the earth mound will last well beyond 500 years with little or no maintenance. Erosion rates have been calculated for the mound based on erosion data for natural soils in similar areas (Reference 5). Based on these calculations very little erosion of the mounds is anticipated. Natural mounds of roughly the same size, shape, and composition have existed in the Hanford Site for over 13,000 years.

The 5-m earth/gravel mound would protect inadvertent intruders and isolate the radioactive materials from pathways to man and the environment for over 500 years. The 5-m depth of the mound would be sufficient so that rain water could not penetrate the site and cause migration of radionuclides down into the water table. In Hanford's semi-arid climate, precipitation evaporates and returns to atmosphere before penetrating 5 m of earth.

Further confidence in the integrity of the in-situ mode is provided by the nature of the buried material itself. More than 99% of the radionuclides of concern in the reactor block are "locked up" in the solid metallic and graphite components of the reactor and cannot readily migrate to the environment. Some radionuclides will be in the bottom of the fuel storage basin, and lesser amounts are expected to be in the piping and other components that would be buried with the reactor block. The integrity of the earth cover, the imperviousness of the reactor block structure, the massive foundation upon which the reactor rests, and the chemical and physical stability of the graphite matrix all provide assurance that the in-situ decommissioning mode will meet present and anticipated requirements for the isolation of the carbon-14 and other radionuclides from pathways that impact man and the environment.

In addition to meeting the technical requirements for decommissioning modes, the in-situ decommissioning mode as described here would yield very favorable cost, schedule, and occupational radiation exposure figures. The materials and equipment required for this mode are all simple, relatively inexpensive, and available on the Hanford Site. The concrete rubble for the backfill and

mound will come from the demolished reactor building superstructure. And for the clean earth/gravel component, the Hanford Site abounds in richly graveled alluvial agglomerates that are ideally suited for forming erosion-resistant earth barriers. This indigenous material is abundantly available near the reactor sites, and can be trucked to the work sites using ordinary earth moving equipment and procedures. About 100,000 yd^3 of fill would be needed for each reactor facility backfill and mound. Gravel pits for this material are close by. For example, the material for the F Reactor fill would be taken from gravel pit No. 18, about 2 miles from the reactor site. Other convenient gravel pits are available for the other reactors. Once installed, the mounds would require no maintenance, and would not have to be removed or modified after any specified time period. The in-situ decommissioning mode described here is an immediate, permanent, and complete decommissioning method for the shut-down Hanford production reactors.

Occupational exposure usage associated with this in-situ decommissioning alternative would be very low compared to modes involving long-term surveillance and maintenance and hands-on reactor dismantlement procedures. Since almost all of the radionuclides (particularly the gamma-emitting cobalt-60) will be left in place, decommissioning worker exposure usage is not expected to exceed 40 man-rem for decommissioning all eight reactors. Almost all of this exposure usage would be used during the pre-demolition decontamination and removal of selected equipment in the reactor buildings. The exposure for the period following the decommissioning preparation work is expected to be minimal. Since there is very little radioactive material outside the reactor block itself, the majority of the described work would not involve additional costs associated with radiation zone work.

Other alternatives within the in-situ mode were consicered. One such alternative considered was moving the reactor block into a below-grade pit at its present location. This was found unsatisfactory because 1) it would place the reactor block closer to or in the water table, 2) would sacrifice the

seismic stability offered by the existing massive foundation of the reactor, and 3) would involve much higher costs without a commensurate improvement in the isolation of the radioactive material from the environs.

Another alternative considered was sealing the reactor block with fiberglass-reinforced plastic prior to mounding over the reactor. The fiberglass, or a similar coating, offers no identified advantage in preventing migration of the radionuclides, since the outer surfaces of the reactor have only minute quantities of contamination, and most of the radionuclides within the reactor are firmly fixed within the graphite and thermal shield metal. Nor would the fiberglass provide any meaningful barrier to an inadvertent or intentional human intruder. A fiberglass coating could possibly make it easier for future generations to retrieve the reactor block should they ever wish to do so. However, retrievability is not a requirement for low-level waste disposition, and no reasonable purpose for performing such work is apparent at this time. For these reasons, a fiberglass coating, at about $1.1 million per reactor, is not cost-justifiable and has been dropped from consideration.

Other "add-on" environmental barriers were considered. A concrete shell using slip-form techniques, or placing a concrete cap over the block and onto the top of the lower shielding walls were also considered. Like the fiberglass coating these alternatives are not cost-justifiable. Another alternative considered was filling all reactor block penetrations (process tube holes, rod penetrations, test assembly penetrations, etc.) with grout for added assurance against radionuclide migration. Since no significant release of radionuclides through these penetrations would occur -- with or without the grout -- the additional cost of grouting all the holes could not be justified.

The in-situ decommissioning of the reactor block by direct earthen entombment and mounding with earth/gravel (Figure 4-2) fully meets the DOE requirements for disposal and long-term control of low-level radioactive waste and also fully meets the intent and objectives of 10 CFR 61 (Reference 4). Section 5

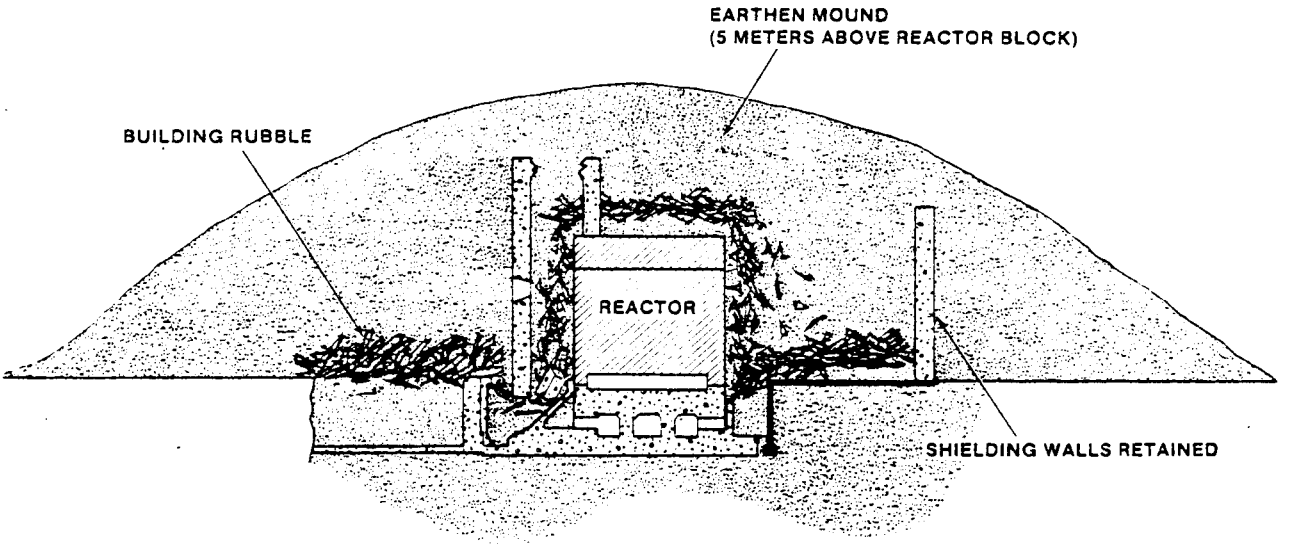

FIGURE 4-2. In-Situ Decommissioning of the Reactor Block by Direct Earthen Entombment.

provides additional details on the cost, occupational exposure estimates, and other factors for the in-situ decommissioning alternative and assesses this alternative relative to other decommissioning alternatives.

4.2 SAFE STORAGE/DEFERRED DISMANTLEMENT MODE

Safe storage/deferred dismantlement would mean storing the reactor in a safe, secure status for 75 years from present, to allow a predetermined amount of radionuclide decay, and then dismantling the reactor and transporting the radioactive material to an approved disposal site. As shown in Table 2-3 (Section 2 of this report), a typical reactor block currently contains 3100 curies of cobalt-60. This is the radionuclide of major concern in this decommissioning mode because it is a gamma emitter. However, the half-life of cobalt-60 is 5.27 years, so after 75 years only about 0.35 curies of cobalt-60 will be left in the reactor. The 3740-curie inventory of carbon-14 in a typical reactor is another matter. With a half-life of 5,730 years, only about 25 curies of the present inventory will have decayed off during the 75 years of safe storage. But since carbon-14 is a low-energy, beta-emitting radionuclide, it can be handled safely by the decommissioning workers employing simple radiological control procedures and equipment. One disadvantage of deferred dismantlement is that it would impose the high cost of maintaining the facility in safe condition for decades, and would impose a long delay on releasing the site for other use.

As shown in Figure 4-1, two alternatives have been considered for the safe storage phase of this mode, and have been identified as practical from an engineering and construction standpoint. Likewise, two alternatives for the dismantlement phase have been identified. These alternatives are:

SAFE STORAGE/DEFERRED DISMANTLEMENT MODE

Safe Storage Alternatives	General Description
No. 1, Install Removable Steel Barrier over Reactor Block	Remove structures surrounding reactor block. Cover reactor with steel dome.

Safe Storage Alternatives	General Description
No. 2, Maintain Existing Building	Upgrade entire 105 Building with major repairs; perform major maintenance and repairs at 20-year intervals, and routine maintenance and surveillance on a continuous basis throughout 75-year safe storage period.

Deferred Dismantlement Alternatives	General Description
No. 1, Piece-by-Piece Removal	Remove structures surrounding reactor block. Cut reactor block into pieces and transport pieces to 200 Area low-level waste disposal site.
No. 2, One-Piece Removal	Remove structures surrounding reactor block. Excavate under reactor. Lift reactor and transport on crawler to 200 Area low-level waste disposal site.

4.2.1 Safe Storage Alternatives

Safe Storage Alternative No. 1, Install Removable Steel Barrier over Reactor Block. In the first safe storage alternative, a large steel dome would be installed over the reactor block. Before the dome is installed, the 105 reactor building would be decontaminated and demolished much as described above for the in-situ decommissioning mode. The fuel storage basin would be emptied (of dirt or water, as applicable) and completely decontaminated and backfilled with clean dirt. When the decontamination and demolition are finished, leaving only the reactor block standing on its foundation, the steel dome would be installed, bermed over with earth, and left standing for approximately 75 years, allowing enough time for much of the resident radioactivity to decay away to safe and manageable levels.

The first step in this safe storage procedure is to decontaminate the building to the extent necessary to prevent radionuclide release during the demolition phase. Salvageable material and equipment would be removed. Contaminated equipment and debris would be removed and shipped to the 200 West Area low-level waste disposal site.

The fuel storage basins in the 105-F and 105-H buildings are each filled with about 4700 yd^3 of dirt. The fuel storage basins in the other six reactor facilities are filled with water. The water would be cleaned up to unconditional release levels, then discharged to the environment. The dirt would be removed using industrial vacuum cleaners in incremental layers of about 2 ft, and each layer would be radiologically monitored. In this way, clean dirt can be identified and segregated, and used later as backfill. Once the basin is empty, its walls and floors would be decontaminated by washing, spalling, complete removal of concrete, or by whatever technique or combination of techniques is necessary to restore the basin surfaces to unrestricted release levels. When the basin is clean, it will be backfilled with clean earth.

The fan room, rod rooms, sample rooms, etc., would be decontaminated and all equipment removed. The reactor block will then be prepared for storage. The horizontal control rods and vertical safety rods would be left inserted in the reactor block. The safety ball hoppers on top of the reactor block would be left in place. The vertical safety rod winch and motor assemblies above the reactor would be removed. Contaminated coolant piping on the rear face of the reactor would be removed and shipped to the 200 Area low-level waste disposal site.

With equipment rip-out and decontamination procedures completed, the 105 building would be razed by conventional demolition techniques, leaving only the reactor block standing on its foundation. Special care would be taken during demolition of the roof to prevent heavy debris from falling directly onto the reactor block. Once the roof is removed, the upper walls and floor

would be demolished by blasting. A bulldozer and clamshell would be used to demolish the lower shield walls. Rubble would be removed as the demolition proceeds and taken to dump sites. At completion of the demolition, only the reactor block, resting on its foundation would remain. At that point, the safe storage encasement dome could be installed over the reactor block.

The safe storage encasement envisioned for this alternative would be a 50-ft high, 70-ft diameter dome, fashioned of 1/2-in. Cor-Ten steel segments joined to a bolted steel frame over the reactor block. The dome would be mounded over with earth and gravel to a depth of about 8 ft above the dome peak. The earth mound would reduce the chances of the site becoming an attractive nuisance, would minimize maintenance requirements such as sandblasting and painting, and would be "cosmetically" compatible with the surrounding terrain. A steel culvert would be installed for access through the mound to the base of the dome; a security door in the base of the dome would provide access into the dome interior in case some special circumstances should make entry necessary during the safe storage period. An access gate would be installed at the culvert entry. No utilities (heat, light, ventilation) would be installed in the dome; temporary services would be brought in for each entry. Security, physical surveillance, radiation surveys, and maintenance services would have to be available for the facility throughout the safe storage period.

About 70,000 yd^3 of earth would be required for the mound construction for each reactor. The earth is readily available near the reactor areas. For example, for the F Reactor, the earth can be taken from gravel pit No. 18, about 2 miles distant from the reactor.

The steel dome alternative would provide a very stable intrusion barrier for as long a safe storage period as desired. A 75-year storage period would provide enough radioactivity decay time to permit some of the stored material and equipment to be removed and released for unrestricted use, and allow hands-on reactor dismantlement work to proceed with occupational dose rates held to less than 50 mrem/hr.

A steel dome barrier could be easily engineered and erected, and would require no special development work, equipment, or skills not readily available at the Hanford Site. Its disadvantage is its high cost, about $23 million for all eight reactors.

Safe Storage Alternative No. 2, Maintain Existing Building. In the second safe storage alternative, the existing 105 reactor building would be converted into a long-term storage covering for the reactor block. This would entail extensive modifications to strengthen the building superstructure (upper walls and roof), seal unused penetrations, remove as much wall-mounted equipment as possible, and other measures to improve the general maintainability of the structure. In short, the building would be stripped of all unnecessary equipment, sealed up against the elements, and maintained as a storage envelope rather than an inhabited building.

During the 75-year storage period, the building would require periodic maintenance and repairs. Major repairs and upgrades would be performed initially, just to bring the buildings up to a maintainable condition. Then there would begin 5-year cycles of inspection and minor repairs (roof flashing, painting, repointing concrete joints, sealing construction joints, etc.). Major repairs would be conducted on 20-year intervals, and would include reroofing, masonry work, resealing of door and window openings, and other repair work as required. Throughout the 75-year safe storage period, the physical integrity of the building would be routinely checked, radiological surveys conducted, security patrols conducted, industrial and environmental safety maintained, and fire protection provided.

This safe storage alternative would provide a feasible safe storage envelope for the reactor for a period of 75 years. It would provide flexibility for implementing alternative strategies in the future, and would cost about $12 million, $11 million less than for use of steel domes for all eight reactors. However, it does have one disadvantage that must be considered. The reactor 105 buildings cannot be expected to provide the same long-term

assurance against human and wildlife intrusion as the steel dome alternative. The costs for routine security patrol have, therefore, been included in the building maintenance alternative.

Use of this alternative is expected to result in about 300 man-rem of occupational exposure usage during the 75-year maintenance and surveillance period, for all eight reactors, most of which would be used during the initial building preparation phase. This compares very favorably to the approximately 520 man-rem of exposure anticipated for the steel dome alternative, in which considerably more "up-front" hands-on dismantlement and cleanup work would be required.

Since the steel dome alternative is considerably more expensive, the second alternative (safe storage by maintenance and surveillance of the existing building) is assessed in Section 5 of this report.

4.2.2 Deferred Dismantlement Alternatives

Dismantlement Alternative No. 1, Piece-by-Piece Removal. In the piece-by-piece removal alternative, the entire reactor facility would be completely removed from the site, and all contaminated materials would be shipped to waste disposal areas. Reactor block dismantlement would begin with stripping all equipment off the reactor. The horizontal and vertical control rods, process tubes, gun barrels, and experiment hole assemblies would all be removed. Highly irradiated components from these assemblies, such as rod tips and in-reactor halves of the gun barrels, would be removed and placed in shielded waste containers.

Then the top biological shield would be removed, exposing the top thermal shield. The thermal shield would be removed from the top and four sides. A "greenhouse" type of contamination control envelope would be set up to permit the environmentally safe removal of the carbon-14 laden graphite moderator blocks. After all the graphite is removed, the bottom thermal shield would be

removed, then the rest of the biological shield walls. Removal of the biological shield walls would require some remote work techniques, particularly on the inner 2 feet of shield material. Flame cutting, arc saws, plasma arc, explosive cutting, and other techniques that will be state-of-the-art at the time would be employed in segmenting the shield material. Once the reactor block is removed, all miscellaneous systems and equipment would be removed from the 105 building and disposed of as clean or low-level contaminated waste, as appropriate. The outlet cooling water piping would be removed, segmented, and packaged as low-level waste. Then all contaminated surfaces in the 105 building would be decontaminated or removed, including activated concrete in the reactor block foundation. Following decontamination, the 105 building would be demolished to 6 feet below grade.

Finally, the site would be restored to its natural state and released for unrestricted use. All cavities created during dismantling would be backfilled with clean rubble and earth. Excess rubble would be dumped into the clearwells. The site would be graded to blend with the surrounding terrain, covered with 1 foot or more of topsoil, and seeded with indigenous growth. Comprehensive final site surveys would be conducted, and when it was established that no contamination above release levels remained, the site would be released for unrestricted use.

Considering the massiveness of the 9,000-ton reactor block, including biological shields up to 80 in. thick, it is anticipated that this decommissioning alternative will require, for all eight reactors, some 600 man-rem of exposure usage and 28 years to complete. About 1.8 million ft^3 of waste would be generated from all eight reactors.

Dismantlement Alternative No. 2, One-Piece Removal. In this deferred dismantlement alternative, the reactor 105 building would be demolished and removed and the 9000-ton reactor block would be transported in one piece to the 200 Area low-level waste disposal site. Building demolition would be conducted in much the same fashion as for the steel dome safe storage

alternative described in paragraph 4.2.1. Once the building is down, the 105 fuel storage basin would be completely excavated (all backfill removed and concrete floor and walls removed), and deepened by about 10 feet. This pit would be the route used by the crawler. Using hard rock mining techniques (or whatever state-of-the-art concrete cutting techniques are available at the time), the center of the reactor foundation would be removed, the crawler would be positioned under the reactor and jacked up to take the reactor block's weight, and then the rest of the reactor block foundation would be removed. With the reactor block secured aboard the crawler, the crawler would be driven out of the excavation and to the 200 Area low-level burial site, an average 16-mile, 48-hour trip per reactor. Roadway preparations and coordination with escort services, utility districts, and Hanford Patrol would be required. Overhead power lines along the route would have to be cut temporarily. With a crawler footprint pressure of about 50 psi and a soil load bearing capability of 28 psi to 70 psi, load-distributing crawler mats will be required to protect shallow-buried pipe lines. Mats would also be used for railroad track crossings and where soft wind-blown sand is encountered. At the 200 Area, the block would be driven down into its burial pit and transferred from the crawler to engineered supports.

Finally, the reactor foundation site would be backfilled with clean rubble and dirt, and graded and seeded to blend with the natural surrounding terrain. Comprehensive site surveys would be conducted, and when it was established that no contamination above release levels remained, the site would be released for unrestricted use.

Both the piece-by-piece dismantlement alternative and the one-piece removal alternative reflect the assumptions in Section 3 of this report. The piece-by-piece dismantlement alternative does not require the requisition of a tractor/crawler and is estimated to cost $8 million less than the one-piece removal alternative. Therefore, the piece-by-piece dismantlement alternative is assessed in Section 5 of this report.

The safe storage/deferred dismantlement of the reactor block, using the existing building as a safe storage envelope and then dismantling the reactor piece-by-piece (Figure 4-3), fully meets the DOE requirements for disposal and long-term control of low-level radioactive waste and also fully meets the intent and objectives of 10 CFR 61 (Reference 4). Section 5 provides full details on this alternative's cost, occupational exposure estimates, and other assessment factors, and assesses this alternative relative to other decommissioning alternatives.

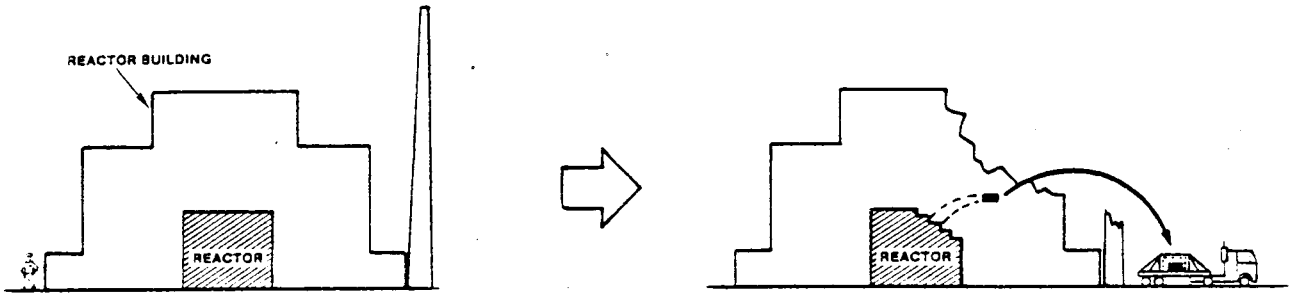

FIGURE 4-3. Safe Storage/Deferred Dismantlement of the Reactor Block.

4.3 IMMEDIATE DISMANTLEMENT DECOMMISSIONING MODE

In the immediate dismantlement mode, the entire reactor facility is immediately removed from the site and the site is restored to unrestricted use status. Two alternative methods for accomplishing this decommissioning mode have been identified as practicable from an engineering and construction standpoint. They are:

IMMEDIATE DISMANTLEMENT DECOMMISSIONING MODE

Alternative	General Description
No. 1, Piece-by-Piece Removal	Remove structures surrounding reactor block. Flood reactor block with water to provide shielding. Cut and dismantle reactor from top down. Transport reactor block pieces to 200 West Area low-level waste disposal site.
No. 2, One-Piece Removal	Remove structures surrounding reactor block and excavate under reactor. Lift reactor and transport on crawler to 200 West Area low-level waste disposal site.

The building demolition, reactor removal, and site restoration procedures for these alternatives would be very similar to those for deferred dismantlement of the reactor following safe storage using the existing building (see paragraph 4.2.2). However, given the current inventory of radionuclides in the reactor block (see Table 2-3), the immediate piece-by-piece dismantlement of the reactor block would involve very high occupational exposure (about 2000 man-rem) and would require the design, fabrication, and use of special containment, shielding, remote work, and water cleanup equipment. These requirements would result in a very high total decommissioning cost (estimated at $200 million) and produce over 4 million ft^3 of solid radioactive waste volume.

In both of the above alternatives, the 105 fuel storage basin would be emptied (of dirt or water, as applicable), and completely excavated and backfilled with clean earth.

No special research and development is required for implementation of either of the immediate dismantlement options discussed above. However, each alternative will require the engineering of special equipment and procedures

to adapt state-of-the-art tools to meet specific job applications. For example, the piece-by-piece reactor dismantlement would require use of electric arc saws, remote handling and viewing equipment, water handling/ cleanup equipment, and contamination containment envelopes. Removal of the reactors in one piece will require an evaluation of the reactor base support and foundation, engineering of an excavation procedure for positioning the crawler, and development of crawler transport technique.

Since immediate dismantlement by one-piece removal results in significantly lower cost, exposure and waste volume than piece-by-piece removal, one-piece removal is discussed and evaluated in Section 5 of this report as the preferred alternative within the immediate dismantlement mode.

The immediate dismantlement of the reactor block by one-piece removal (Figure 4-4) fully meets the DOE requirements for disposal and long-term control of low-level radioactive waste and also fully meets the intent and objectives of 10 CFR 61 (Reference 4). Section 5 provides full details on this alternative's cost, occupational exposure estimates, and other assessment factors, and assesses this alternative relative to other decommissioning alternatives.

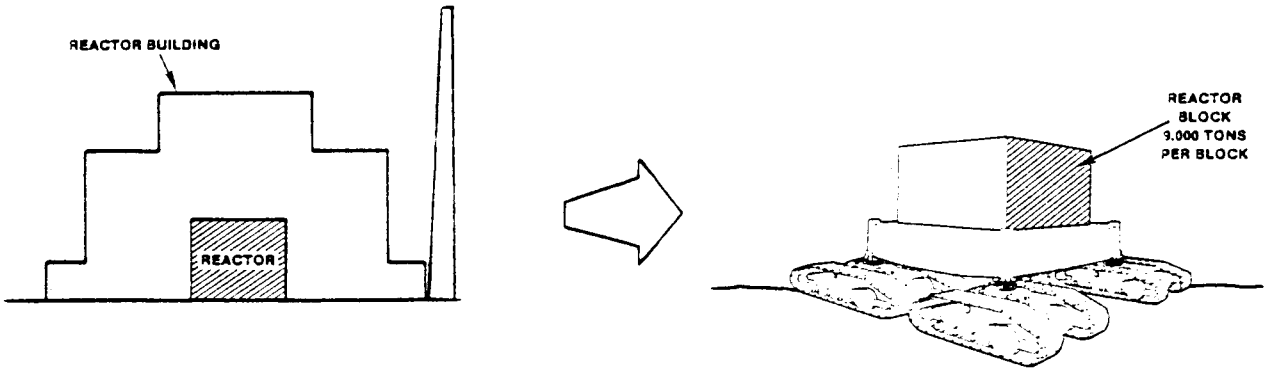

FIGURE 4-4. Immediate Dismantlement of the Reactor Block by One-Piece Removal.

4.4 NO ACTION

Two alternative no-action scenarios were considered for the shut-down reactor facilities.

NO ACTION MODE

Alternative	General Description
No. 1, Abandon Facilities to the Elements	Simply walk away and allow buildings to decay. Conduct no maintenance or surveillance.
No. 2, Continue Status Quo/ Maintenance and Surveillance	Continue minor maintenance routines and surveillance for 300 years with major maintenance at 20-year intervals.

Both of the above alternatives present unacceptable radiological and industrial safety hazards. In the abandonment alternative, radioactive material remaining in the reactor and fuel storage basin could be spread to site personnel and the general public. Industrial hazards will develop as the 105 reactor building structures deteriorate. Stairway and roof dilapidation would soon be so severe as to render the buildings unsafe for future decommissioning and maintenance and surveillance work. If left unattended, the buildings would soon become structurally unsound, which would cause a significant increase in any future decommissioning costs. In short, abandonment could pose high occupational and public health and safety hazards, and high cost liabilities.

To continue the status quo means continuing the current routine of minor maintenance and surveillance work. This alternative has essentially the same disadvantages as the abandonment scenario: the status quo procedure is not keeping pace with the deterioration rate of the buildings. It is estimated that given the current maintenance routines, within 20 years these buildings will begin to suffer serious safety hazards and structural weakening. To

place these buildings in a maintainable condition, major upgrades (reroofing, repointing of concrete block joints, fence repairs, etc.) must first be conducted. Once restored to a maintainable condition, a regular program of routine maintenance with major repairs every 20 years would be conducted until resident radionuclides have decayed to unrestricted release levels. For the Hanford production reactors this would mean a program of major maintenance and surveillance for a period of at least 300 years at a total cost for all eight reactors of $43 million. However, there are several disadvantages to this approach. First, this approach does not reflect the decommissioning assumption in Section 3 of unrestricted release of the site within 100 years. Second, institutional controls of the type required (i.e., routine surveillance, maintenance, and periodic major repairs) are not assumed to be available beyond 100 years. Third, after the expenditure of $43 million and 300 years of site management, the buildings would still exist and would still require some ultimate disposition. For these reasons, the status quo maintenance and surveillance mode, including a thoroughly "upgraded status quo" mode, is dropped from consideration as a viable decommissioning alternative.

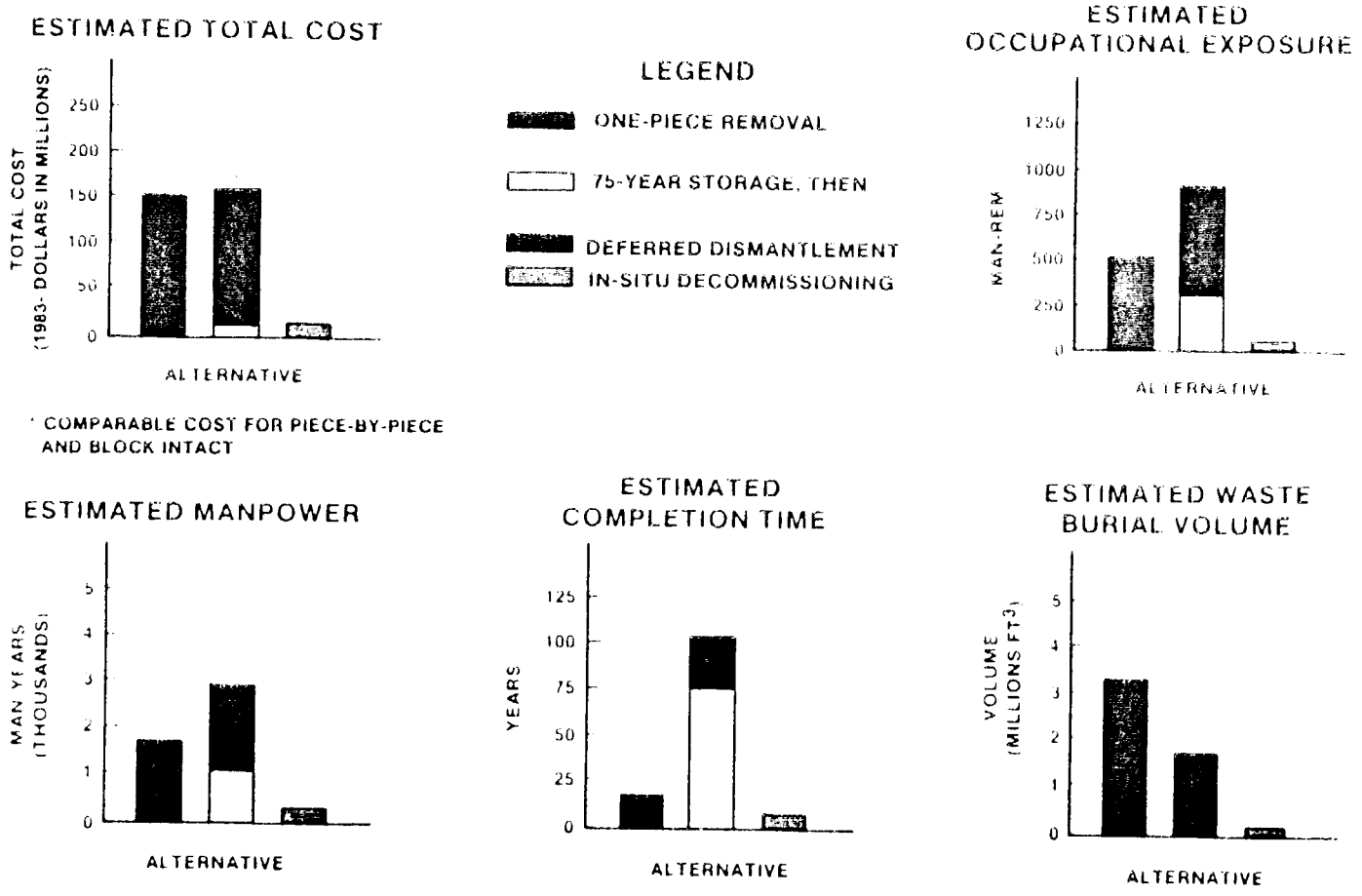

FIGURE 5-4. Comparative Summary Data for Decommissioning all eight Reactor Facilities.

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TABLE 5-4

COMPARATIVE SUMMARY DATA FOR DECOMMISSIONING ALL EIGHT REACTOR FACILITIES

Assessment Factor	DECOMMISSIONING ALTERNATIVE		
	In-Situ	Safe Storage/ Deferred Dismantlement	Immediate Dismantlement
Cost	$14 million	$157 million	$153 million
Occupational Exposure	40 man-rem	900 man-rem	520 man-rem
Manpower	230 man-yr	2900 man-yr	1800 man-yr
Completion Time	8 yr	103 yr	20 yr
Waste Volume*	6000 ft^3	1,800,000 ft^3	3,400,000 ft^3

*That volume of waste removed and taken to an approved waste burial site in the 200 Area.

5.2.4 Reactor Facility Decommissioning Alternatives Summary

The three most practical alternatives for decommissioning the reactor facilities and their associated fuel storage basins are summarized in Table 5-4, according to the five assessment factors of cost, occupational exposure, manpower requirements, completion time, and waste burial volume. For convenience, the same data are shown graphically in Figure 5-4.

Figure 5-4 and Table 5-4 show that the in-situ decommissioning alternative ranks first in all five assessment factors. The immediate dismantlement alternative ranks second in cost, occupational exposure, manpower, and completion time, but involves almost twice as much radioactive waste volume as the safe storage/deferred dismantlement alternative. The safe storage/deferred dismantlement alternative, with its estimated $157 million cost, 900 man-rem occupational exposure, and 103-year project completion time, is the most expensive of the three alternatives.

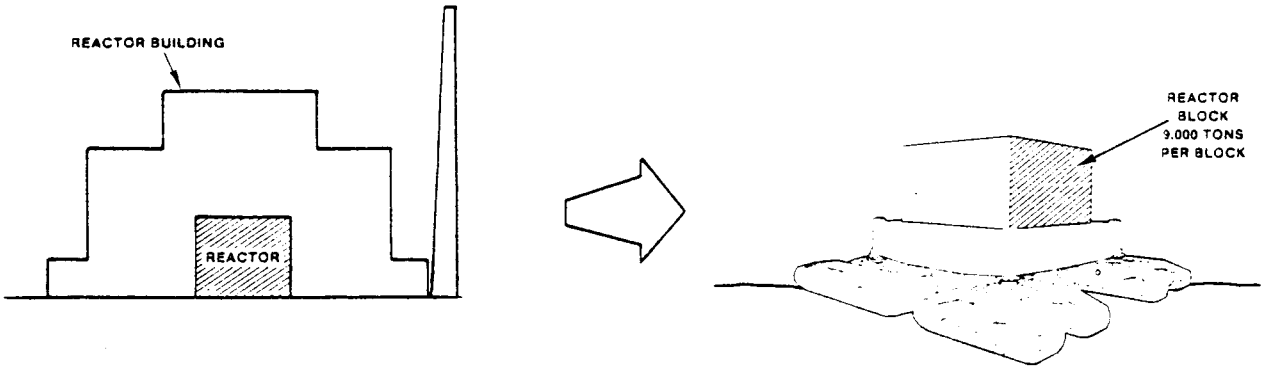
TABLE 5-3

ESTIMATED COST FOR IMMEDIATE DISMANTLEMENT
AND REMOVAL OF ONE TYPICAL REACTOR FACILITY

Immediate Dismantlement

Task	Costs ($000)
Engineering/Planning/Supervision	$ 3,400
Procurement	
• Equipment & Materials (excluding transporter)	600
• Shipping Containers	730
Reactor/Facility Preparation	
• Basin Dismantlement/Road Construction	1,700
• Transporter Access Excavation/Shoring	360
Block Removal	140
Building Dismantlement	6,900
Package/Handling of Radioactive Waste	130
Transportation & Heavy Equipment	200
Site Restoration	140
Radioactive Waste Disposal Fee	1,700
Capital Equipment	3,100*
Total Dismantlement Cost	~ $ 19,000

*One facility's share of $25 million transporter acquisition cost.



TOTALS FOR ALL EIGHT REACTORS

COST	**- $ 153 MILLION**
EXPOSURE	**- 520 MAN-REM**
MANPOWER	**- 1,800 MAN-YEARS**
BURIAL VOLUME	**- 3,400,000 FT^3**
COMPLETION TIME	**- 20 YEARS**

FIGURE 5-3. Immediate Removal of Reactor Block.

The estimated volume of waste material (3.4 million ft^3) is high because this alternative allows no appreciable decay time for short half-life radionuclides, and does not allow for any in-situ disposal of contaminants. All wastes will be transported to the 200 Area for disposal.

The immediate dismantlement alternative is compared with the other two reactor decommissioning alternatives in paragraph 5.2.4.

exposure is anticipated for follow-up routine type maintenance and surveillance work. The 600 man-rem exposure anticipated for the dismantlement phase will be used mostly during the hands-on dismantlement of the reactor block.

The 1.8 million ft^3 of waste material generated during the dismantlement phase would be shipped to the 200 Area for disposal as low-level waste.

The safe storage/deferred dismantlement alternative is compared with the other two reactor decommissioning alternatives in paragraph 5.2.4.

5.2.3 Immediate Dismantlement/One-Piece Removal of Reactor Block

As described in detail in paragraph 4.3, immediate dismantlement of the reactor facility would be accomplished by demolishing the reactor building and transporting the reactor block in one piece to the 200 Area for disposal as low-level waste. A large crawler would be used to transport the 9,000-ton reactor block to the 200 Area.

Figure 5-3 lists the estimated cost, occupational exposure usage, manpower requirements, burial volume, and project completion time for the eight reactor facilities and their associated fuel storage basins.

Table 5-3 breaks down the estimated cost of this alternative for one reactor facility. Costs include labor, special and normal tooling and equipment, waste disposal, and facility overheads required for the project work.

The 520 man-rem estimated occupational exposure for this alternative will be used during removal of the fuel storage basin and in the decontamination and removal of contaminated equipment and material outside the reactor block. Very little exposure usage is anticipated for placing the crawler under the reactor block.

TABLE 5-2

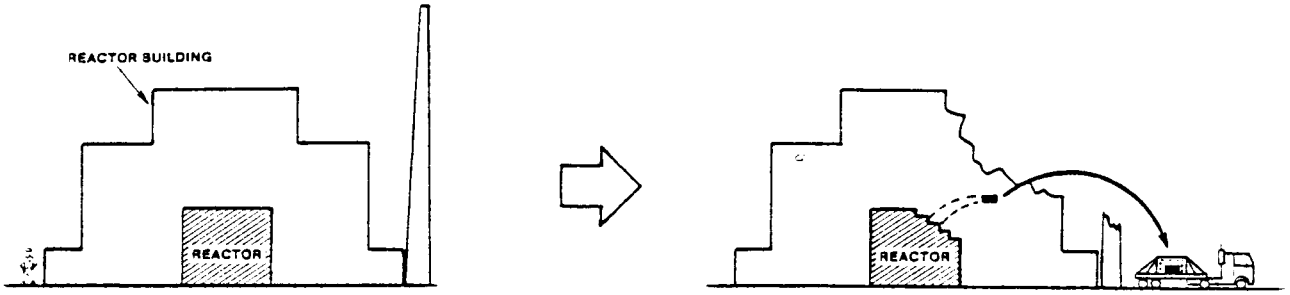
ESTIMATED COST FOR SAFE STORAGE/DEFERRED DISMANTLEMENT OF ONE TYPICAL REACTOR FACILITY

A. 75-Year Safe Storage

Task	Costs ($000)
Initial Upgrade of Building	$ 600
Major Maintenance at 20-Year Intervals	400
Minor Maintenance and Routine Surveillance for 75 years	500
Total Safe Storage Costs	~$ 1,500

B. Cost of Deferred Dismantlement (after 75 years of Safe Storage)

Task	Costs ($000)
Engineering/Planning/Supervision	$ 3,200
Procurement	
• Equipment and Materials	1,200
• Shipping Containers	900
Reactor/Facility Preparation	1,600
Block Dismantlement	2,200
Building/Fuel Storage Basin Dismantlement	7,500
Packaging and Handling of Radioactive Waste	300
Radioactive Waste Disposal Fee	900
Transportation and Heavy Equipment	300
Site Restoration	100
Total Dismantlement Cost:	~$ 18,000



SAFE STORAGE 75 YEARS (ALL EIGHT REACTORS)

COST	- $ 12 MILLION
EXPOSURE	- 300 MAN-REM
MANPOWER	- 1,100 MAN-YEARS
BURIAL VOLUME	- 0 FT^3
COMPLETION TIME	- 75 YEARS

DEFERRED DISMANTLEMENT (ALL EIGHT REACTORS)

COST	- $145 MILLION
EXPOSURE	- 600 MAN-REM
MANPOWER	- 1,800 MAN-YEARS
BURIAL VOLUME	- 1,800,000 FT^3
COMPLETION TIME	- 28 YEARS

TOTALS FOR SAFE STORAGE PLUS DEFERRED DISMANTLEMENT (ALL EIGHT REACTORS)

COST	- $ 157 MILLION
EXPOSURE	- 900 MAN-REM
MANPOWER	- 2,900 MAN-YEARS
BURIAL VOLUME	- 1,800,000 FT^3
COMPLETION TIME	- 103 YEARS

FIGURE 5-2. Safe Storage/Deferred Dismantlement of the Reactor Facilities.

Table 5-2 breaks down the estimated cost of this decommissioning alternative for one reactor facility. Costs include special and normal tooling and equipment, waste disposal, and facility overheads required for the project work.

The total occupational exposure usage estimated for this decommissioning alternative is 900 man-rem, for the eight reactor facilities. Most of the 300 man-rem estimated for the 75-year maintenance and surveillance phase will be used during the initial building upgrade work. Very little occupational

TABLE 5-1

ESTIMATED COST FOR IN-SITU DECOMMISSIONING
OF ONE TYPICAL REACTOR FACILITY

In-Situ Decommissioning

Task	Costs ($000)
Engineering/Planning/Supervision	$ 250
Reactor/Facility Preparation	410
• Remove Salvageable Material • Fix Contamination/Decontaminate • Dismantle and Rearrange Material	
Radioactive Waste Disposal Fee	30
Outer Building (outside shielding walls)	480
• Demolish Above-Grade Facility • Backfill/Partial Mound (over rubble)	
Inner Building (inside shielding walls)	350
• Backfill over Reactor Block • Demolish Structure above Reactor Block (leave rubble layer)	
Complete Earthen Mound (approximately 100,000 yd^3)	230
• Transportation/Heavy Equipment • Stabilize Surface - Pit Run Gravel - Grass Seeding	
Total In-Situ Costs ~	$ 1,800

Table 5-1 breaks down the estimated cost of this alternative for one reactor facility. Costs include labor, special and normal tooling and equipment, waste disposal, and facility overheads required for the project work.

Most of the estimated 40 man-rem of occupational exposure is expected to be used during the removal and/or fixing of loose decontamination in the buildings prior to the superstructure demolition work. This preparatory work will, for the most part, be conducted in a low-radiation (2 to 3 mrem/hr) area.

The 6,000 ft^3 of waste burial volume will consist of solid wastes that will be shipped to the 200 Area for disposal as low-level waste. These wastes will be generated during building decontamination prior to superstructure demolition.

The in-situ decommissioning by direct earthen entombent alternative is compared with the other two reactor decommissioning alternatives in paragraph 5.2.4.

5.2.2 Safe Storage/Deferred Dismantlement

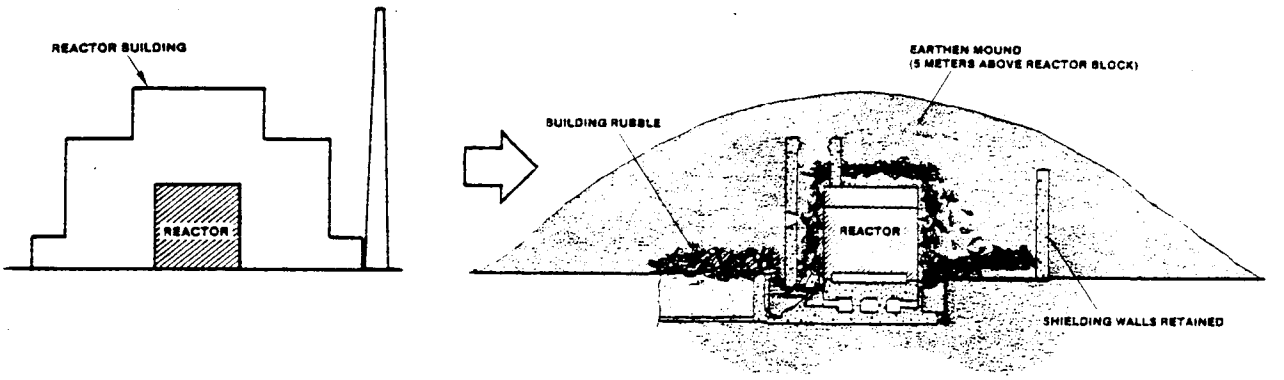
As described in detail in paragraph 4.2, decommissioning the reactor facility by safe storage/deferred dismantlement would be accomplished by upgrading the condition of the existing reactor 105 building and storing the reactor inside the building for a safe storage period of 75 years, then dismantling the reactor and removing contaminated debris to the 200 Area for disposal as low-level waste.

Figure 5-2 lists the estimated total cost, occupational exposure, manpower requirements, burial volume, and project completion time for all eight reactor facilities and their associated fuel storage basins.

75 years followed by complete dismantlement and removal, and 3) immediate dismantlement with one-piece reactor block removal. These alternatives are described in Section 4, and assessed and compared in the following paragraphs.

5.2.1 In-Situ Decommissioning by Direct Earthen Entombment

As described in detail in paragraph 4.1, in-situ decommissioning of the reactor facility would be accomplished by demolishing the reactor building superstructure and covering the reactor block with a permanent mound of clean concrete rubble and local soil and gravel. Figure 5-1 lists the estimated total cost, occupational exposure, manpower requirements, burial volume, and project completion time for the eight reactor facilities and their associated fuel storage basins.



TOTALS FOR ALL EIGHT REACTORS

COST	**- $14 MILLION**
EXPOSURE	**- 40 MAN-REM**
MANPOWER	**- 230 MAN-YEARS**
BURIAL VOLUME	**- 6,000 FT^3**
COMPLETION TIME	**- 8 YEARS**

FIGURE 5-1. In-Situ Decommissioning of the Shut-Down Hanford Reactor Facilities.

Costs expended on future routine surveillance and monitoring after decommissioning project work is completed are not included in the cost estimates. These activities are not considered incremental cost activities and are not reflected in the cost, manpower, and completion time estimates.

Some salvage, decontamination and reuse of equipment would be performed if warranted by cost/benefit analysis. Since no significant cost recovery opportunities through salvage and reuse have been specifically identified for any of the reactor facilities, potential salvage value has not been incorporated in the cost estimates used in this report.

Estimates for occupational radiation exposure are based upon dose rates measured at several areas within the shut-down facilities and were calculated from the estimated manhours to accomplish the decommissioning activity, contact dose rates, and estimates of general area exposure rates. Contact dose rates and isotopic analyses were performed by UNC Nuclear Industries. The occupational exposure usage estimates in this report are conservative (include a high contingency) in that they do not take into account the effects of learning curve on improving detailed work procedures for repetitive decontamination and decommissioning tasks. This includes innovations in reducing the amount of hands-on decontamination work, and optimizing shielding and distance to reduce exposure to As Low As Reasonably Achievable (ALARA) levels.

The waste burial volumes stated are those amounts of contaminated waste material removed from the facility for disposal. Wastes will be buried at the 200 West low-level waste burial grounds.

5.2 REACTOR DECOMMISSIONING ALTERNATIVES

The three alternatives considered to be the most practicable for decommissioning the reactor facilities are 1) in-situ decommissioning by mounding gravel and soil over the reactor and fuel storage basin, 2) safe storage for

- The required utilities are available at all work sites.
- The 200 Area will accept all waste materials shipped from the 100 Area without delays that would impact project schedule.

This report incorporates the pathway analysis approach for determining release limits in estimating costs for in-situ decommissioning activities. Cost estimates for complete dismantlement activities are based on previous decommissioning studies, which conservatively estimated costs assuming that all areas would be decontaminated to less than detectable limits.

All estimates are based on "averages" for like groups of facilities and were derived from baseline estimates made in previous decommissioning studies conducted by on-site architectual engineering firms and by UNC Nuclear Industries.

Cost estimates developed for reactor buildings and support structures reflect available data, including detailed characterization studies and construction drawings. Cost and work duration estimates do not take into account the effects of learning curve improvements, innovations, and procedural streamlining on repetitive, follow-on work.

Costs were normalized to approximate 1983 dollars using an annual escalation rate of 10%. Contingency factors and Washington State taxes are included in the estimates. Contingency factors vary from approximately 25% for contaminated work efforts to 15% for uncontaminated work efforts. The 15% contingency factor used for the noncontaminated structures is based on the method commonly used in projects for conceptual design (Means*). The safe storage maintenance cost estimates do not include a contingency factor.

*Means Cost Data (annual handbooks), Robert S. Means Company, Inc.

5.0 ASSESSMENT OF DECOMMISSIONING ALTERNATIVES

5.1 INTRODUCTION

5.1.1 Alternatives Assessed

Three decommissioning modes for the Hanford 100 Area production reactors are described and identified as practical in Section 4 of this report. Those modes are 1) in-situ decommissioning, 2) safe storage/ deferred dismantlement, and 3) immediate dismantlement. A fourth mode, no-action, is discussed in Section 4 but is dismissed because it does not reflect the assumptions listed in Section 3 of this report. Within each of the major decommissioning modes, various alternatives are identified and described in Section 4. The most practicable alternative within each mode is assessed here in this Section as to five distinct assessment factors: 1) cost, 2) occupational exposure, 3) manpower, 4) completion time, and 5) waste volume. Paragraph 5.2 assesses and compares decommissioning alternatives for the reactor facilities and their associated fuel storage basins.

5.1.2 Bases for Assessment Factors

The assessment factor values (cost, exposure, manpower, time, and waste volume) have been estimated using standard methods of order-of-magnitude conceptual estimates. The estimates reflect the following basic assumptions; changes to these assumptions may change the estimates.

- Sufficient qualified labor is available to support construction needs and schedule requirements.
- A 40-hour work week will be worked, with no scheduled construction craft shift work.
- Construction activities will be year-round with no significant weather delays.
- Access is available to all work areas.

6.0 PROJECT PRIORITIES AND RANKING

This section describes the project prioritization criteria and the resulting priority ranking.

6.1 PRIORITIZATION CRITERIA

A total of eight reactors and their associated fuel storage basins are covered by this alternatives assessment report. In order to decommission these facilities in the most efficient and cost-effective manner, guidelines have been established for the priority ranking process. These guidelines are:

1. Legal and Safety Standards. Those projects which pose an unacceptable safety risk are given highest priority. High priority is also given to projects which do not meet legal or contractual requirements. Surveillance and maintenance of these facilities will be assigned the highest program priority until decommissioning is initiated.

2. Cost of Decommissioning Versus Maintenance and Surveillance. Those projects which will result in lower costs for immediate dismantlement versus continued maintenance and surveillance are ranked second highest in priority.

3. Health and Safety Risks Associated with Postponing Decommissioning. The potential onsite and offsite health and safety hazards of postponing decommissioning are considered. Facilities that pose greater health and safety risks will be given higher priority for decommissioning.

4. Future Site Plans. The facility's potential for aesthetic, functional, and economic compatibility with future plans for the site are subjectively evaluated and considered. Future site plans are then considered after the first three factors have been evaluated.

5. Program Management Cost-Effectiveness. This factor concerns the availability of a developed, efficient organization for the facility project. Where organized programs are already in place at a site, D&D work for facilities on the site will proceed more efficiently and safely than for projects where staff development and training ramp-up are still required. Cost efficient program management may have important influence on the total cost of the project. High weight is assigned to cost, thus this factor may have significant bearing on project prioritization.

6. Special Factors. Special factors, such as local government concerns and public opposition or acceptance of proposed D&D work, may influence a project priority. A project on private land or considered an attractive nuisance with a high potential for public trespass, may be given special attention.

6.2 PRIORITIZATION OF PROJECTS

Using the criteria listed in paragraph 6.1, an analysis was performed of the shut-down Hanford 100 Reactor facilities to establish project priorities; i.e., which facilities should be done first. Based on this analysis, it was determined that for prioritization criteria 1 through 5, no clear priority could be assigned to one facility over another. Each reactor has approximately the same radionuclide inventory; each facility is in approximately the same state of repair; and each presents the same relative postponement risks.

For these reasons, criterion No. 6, Special Factors, was used to establish the priority ranking, which is shown in Table 6-1. F Reactor was selected as the first priority based on its near proximity to a population center (the Tri-Cities). Because of the ongoing reuse of the irradiated fuel storage basins at both the 105-KW and 105-KE reactors, decommissioning of these facilities would be scheduled as later projects.

TABLE 6-1

DECOMMISSIONING PROJECT PRIORITY RANKINGS

Ranking	Project
1	105-F Reactor Facility
2	105-H Reactor Facility
3	105-D Reactor Facility
4	105-DR Reactor Facility
5	105-C Reactor Facility
6	105-KE Reactor Facility
7	105-KW Reactor Facility
8	105-B Reactor Facility

7.0 REFERENCES

The following reference documents are cited in this report.

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2. Kennedy, W. D., Jr. and B. A. Napier, Allowable Residual Contamination Levels for Decommissioning Facilities in the 100 Areas of the Hanford Site, PNL-4722/UNI-2522, Pacific Northwest Laboratory, Richland, WA, 1983.

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5. Schumm, S. A., "The Disparity Between Present Rates of Denudation and Orogeny," U.S. Geological Survey Professional Paper 454-H, 1963.

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Book #	Name	Location
9.	JA Adams	1155/J
10.	GF Bailey	FB/480
11.	JF Beckstrom	108-F
12.	JR Bolliger	1117N/15
13.	JS Brehm	FB/395
14.	DF Brendel	1114N/5
15.	PA Carlson	1105N/3
16.	N Castorina	108-F
17.	JC Chattin	FB/422
18.	RN Coy	FB/395
19.	DS Cunningham	1114N/5
20.	TE Dabrowski	FB/422
21.	LE Denton	1720K/1
22.	JJ Dorian	1114N/20
23.	RE Dunn	FB/475
24.	EM Greager	1114N/20
27.	LL Humphreys	1117N/18
28.	NC Kaufman	1117N/18
29.	WJ Kyriazis	FB/422
30.	BW Mathis	MW/27
31.	NR Miller	1117N/18
32.	RL Miller	1155/J
33.	SR Morgan	FB/475
34.	WL Nees	1114N/16
35.	RF Potter	FB/427
36.	EW Powers	1720K/10
37.	RL Renberger	1117N/14
38.	WG Ruff	313/300
39.	RA Winship	1155/J
40.	UNI Record } F.H.Bouse	FB/436
41.	UNI File }	
42.	KD Jones	FB/468
45.	FD George	1117N/43
46.	JT Fulton	FB/422
47.	TA Przybylski (KEH)	FB/376
49.	CD Corbit (PNL/RADSCI)	520/211
54.	DH Curtiss	1113-N/8

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