0012930

FEASIBILITY STUDY
for
LEAD REMOVAL
from
SUBMARINE REACTOR COMPARTMENT
DISPOSAL PACKAGES

PUGET SOUND NAVAL SHIPYARD
BREMERTON, WASHINGTON

MARCH 1990

DEPARTMENT OF THE NAVY
PUGET SOUND NAVAL SHIPYARD
BREMERTON, WASHINGTON 98314-5000

IN REPLY REFER TO:
9211/30/2
2300.1/0174
16 Mar 90

Ms. Christine Gregoire
State of Washington
Department of Ecology
Mail Stop PV-11
Olympia, Washington 98504-8711

Dear Ms. Gregoire:

In a letter dated 16 October 1989 from Mr. Stanley of your office, the Navy was asked to perform a study on the feasibility of removing lead from submarine reactor compartment disposal packages shipped to Hanford for burial. This study was requested in recognition of recent amendments to the State's regulations, specifically RCW 70.105.050 regarding the employment of waste management methodologies designed to mitigate hazards associated with wastes. It was requested that this study be completed prior to the 1990 reactor compartment shipments.

Our report on the feasibility of lead reclamation is enclosed. The study concludes that removal of the lead would cost about $14 million and result in about 184 rem of radiation exposure to Shipyard workers per package. Thus, both the expense and additional exposure would be substantial. The study further evaluates the risk of lead migration affecting drinking water and concludes that even after millions of years lead could not reach the aquifer under the Hanford burial ground in quantities to cause drinking water limits to be exceeded.

Thus, we have concluded that the removal of lead from these reactor compartment disposal packages is not a reasonable method to be employed to mitigate the hazards associated with the lead waste contained within the packages.

Sincerely,

A. Clark
Captain, USN
Shipyard Commander

Encl:
(1) Feasibility Study for Lead Removal from
Submarine Reactor Compartment Disposal Packages

Copy to:
D. Silver, Governor's Office, State of Washington
J. Breckel, Governor's Office, State of Oregon
M. Lawrence, DOE-RL
G. Haselberger, USEPA Region X, Seattle, Wa.

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EXECUTIVE SUMMARY

In the fall of 1989, the Navy, at the request of the State of Washington, agreed to perform a study on the feasibility of removing the over 100 tons of permanently installed lead shielding from submarine reactor compartment (RC) disposal packages being shipped to the Department of Energy's Hanford site for burial.

The study, performed by the Puget Sound Naval Shipyard, found that removal of the lead would cost about $14 million per package, effectively tripling the cost of RC disposal. More importantly, the work would result in about 184 rem of radiation exposure to shipyard workers per package. Thus, both the expense and additional exposure would be substantial.

The specific hazard associated with buried lead is the potential contamination of drinking water. Therefore, for comparison, the Shipyard evaluated the long range impact of leaving the lead in the RC packages. The study, based on Pacific Northwest Laboratory studies of the Hanford site, as well as other sources, concluded that the site characteristics of the Hanford RC burial ground are such that even if the lead in the RC disposal packages were to be exposed to the environment as a consequence of deterioration in package integrity, the lead would not migrate to the ground water for the foreseeable future, if at all. Even with worst case assumptions, after millions of years lead could not reach the aquifer in quantities sufficient to cause drinking water limits to be exceeded.

Thus, it is concluded that the removal of lead from these RC disposal packages is not a reasonable method to mitigate the hazards associated with the lead waste contained within the packages.

SUMMARY AND CONCLUSIONS

The Navy's 1984 Environmental Impact Statement discusses the disposal of decommissioned, defueled naval submarine reactor plants. For disposal, the section of the submarine containing the reactor plant (the Reactor Compartment) is cut from the ship and heavy shipyard fabricated bulkheads are installed over the ends of the compartment and welded in place to produce a strong tightly sealed container. This package meets regulatory requirements for transporting the enclosed radioactive reactor plant components to the Department of Energy's Hanford site for burial. In the period from 1986 to the present, eight reactor compartment disposal packages have been shipped from Puget Sound Naval Shipyard to the Hanford site.

There is over 100 tons of lead installed in each submarine reactor compartment. Most of this lead is permanently installed radiation shielding in the form of panels or poured-in-place lead contained within welded steel canning plates. The presence of this lead was discussed in the 1984 Navy EIS and in subsequent correspondence with the State of Washington. This lead was not evaluated for removal in the Navy's original planning because it provides shielding needed to meet the federal transportation regulation's external radiation limits, and there was no other reason to consider its removal. Since that time, regulations on lead burial have been implemented.

Although the lead shielding in the packages is not regulated under the Federal Resource Conservation and Recovery Act, the lead is a regulated waste under the State of Washington's Hazardous Waste Management Act. In the fall of 1989 the Navy agreed that the lead in the disposal packages was regulated under this act, and began the process of assuring that burial of the RC disposal packages is in compliance with the State's requirements.

In a 17 October 1989 letter to the Washington State Department of Ecology, the Shipyard agreed to perform a detailed study on the feasibility of removing the lead from the RC disposal packages, in compliance with the portion of the Washington State regulations which requires that:

> Prior to disposal, or as part of disposal, all reasonable methods of treatment, detoxification, neutralization, or other waste management methodologies designed to mitigate hazards associated with these wastes shall be employed, as required by applicable federal and state laws and regulations. (RCW 70.105.050)

This report contains the results of this study. The Shipyard evaluated removing all lead prior to shipping RC disposal packages to Hanford for burial, and removing all lead from the RC disposal packages already at Hanford. The cost, personnel radiation exposure, and other risks to workers performing the lead removal were determined. The engineers and production workers who determined how the lead would be removed from the RC packages were experienced in lead installation and removal. They approached this task with the goal of determining the most efficient method of removing the lead, assuming that they might actually have to do the work.

The Shipyard also evaluated the long range benefits that would be derived from not having lead in these packages at Hanford. This provided a basis for judging whether complete removal of lead could be considered a "reasonable method" of mitigating hazards associated with the buried lead waste in the disposal packages.

As shown in appendix B, the cost of lead removal at the Shipyard would be about $14 million per package ($18 million for the packages at Hanford).

More importantly, approximately 184 rem of radiation exposure would be received by workers removing the lead from each package. By comparison, package preparation work currently involves only about 5 rem of exposure. This would be a significant additional exposure to Shipyard radiation workers. Furthermore, rather than being distributed throughout the shipyard's nuclear trained work force, this large additional exposure would be concentrated within the relatively small group of tradesmen having specialized lead worker qualifications.

Additionally, the work will require the removal of asbestos insulating materials which would otherwise be left intact in the RC package; it would also require the melting of lead. Because the Shipyard provides extensive training and requires the wearing of proper protective clothing to minimize the risk to workers from asbestos, airborne lead and other industrial hazards, these risks are difficult to quantify. Even so, they must be considered when deciding whether the long range benefits of lead removal are worthwhile.

To evaluate the long range hazards of leaving the lead in the disposal packages, the Shipyard determined whether it would be possible for lead to reach the aquifer under the Hanford site and its effect on this source of drinking water. This study, presented as Appendix D, was largely based on research accomplished by Pacific Northwest Laboratory in support of the Department of Energy's March 1989 draft environmental impact statement on the Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington (DOE/EIS-0119D). Appendix D concludes that the site characteristics of the Hanford 200E location are such that even if the lead in the disposal packages were to be exposed to the environment as a consequence of deterioration in package integrity, the lead will not migrate to the ground water for the foreseeable future, if at all. Even with worst case assumptions, after millions of years lead could not reach the aquifer in quantities to cause drinking water limits to be exceeded.

Thus, it is concluded that the removal of lead from these RC disposal packages is not a reasonable method to mitigate hazards associated with the lead waste.

DESCRIPTION OF LEAD CONTAINED IN SUBMARINE RC PACKAGES

Permanent Lead Shielding

A submarine RC contains permanently installed lead primarily for the purpose of shielding gamma radiation. The gamma radiation, although greatly reduced after defueling, is still present and largely produced from two sources.

1) 99.9% is activated metal in the reactor vessel and the adjacent structure; and,

2) 0.1% is radioactive impurities in the piping and the interior of other primary coolant system components.

The permanent shielding system installed on nuclear powered ships encompasses the reactor, primary plant components and the majority of the associated piping. The shielding system is constructed of several types of materials including lead, steel, water and hydrogenous shielding material. The lead contained within the shielding system weighs in excess of 100 tons and is installed in a permanent fashion on the RC hull, bulkheads and some internal structures during initial construction. Most of the permanent lead shielding is contained within over 1000 individual steel enclosed panels which make up the RC bulkhead structure. Some of the lead was permanently bonded to internal structure and components during construction by either metallurgical bonding processes or by pouring molten lead into preformed positions. The lead was installed in this manner to ensure that it remained in position even under battle shock conditions. The lead shielding was not designed to facilitate removal.

Ballast Lead

Lead is also installed in submarines as ballast to lower the center of gravity and improve the stability of the submarine. In some older submarine classes, up to 40 tons of ballast lead is actually installed low in the bilge areas of the RC's. This lead, although originally installed for ballast, does in fact provide useful shielding for personnel working under and around the RC disposal packages during package preparation at the Shipyard and during transport operations. Removal would be difficult, since this lead is permanently installed in bilge area frame bays. Personnel would have to work in highly constrained areas under heavy reactor plant components.

Miscellaneous Lead

A submarine RC contains small quantities of lead compounds distributed in paint, adhesives and other similar industrial materials. The total amount of such lead is less than 150 pounds per package. Since this amount is difficult to remove, and is well within the limits allowed by the applicable federal and state laws and regulations, it is not considered further in this study.

ASSUMPTIONS

The lead removal feasibility study was performed based on two key assumptions. First, if the lead were to be removed in the near term, the removal, although possible at the Hanford site, would be most economical at the Shipyard where the industrial facilities exist to support this work. The exception would be a one-time operation to remove the lead from packages already shipped to Hanford. In this instance, it would be more practical to remove the lead at Hanford as opposed to returning the packages to the Shipyard for lead removal. The second assumption is that the basic structural integrity of the submarine RC disposal package would be maintained in order to meet the packaging requirements for shipment of radioactive material and to maintain the long term integrity of the boundary for containing this radioactive material.

CONSIDERATIONS

In the development of methods for lead removal, the structural integrity of the disposal package structure including its ability to withstand the theoretical accident criteria, as required by the transportation regulations, and the long term integrity of the boundary for containing the radioactive material were given primary consideration.

A significant effect of lead removal is the resultant increase in package exterior radiation levels. Calculations, utilizing several different models, indicate that, after the removal of shielding lead, local contact radiation levels on the exterior of the submarine RC disposal packages would exceed 200 mr/hr for selected "hot spots". General contact radiation levels, although increased because of the lead removal, would be less than 100 mr/hr. Hot spot radiation levels of this magnitude are shieldable using built-up steel shielding installed inside the package. The Shipyard would install a zoned shielding package which would reduce all exterior package radiation levels to less than 100 mr/hr which is well below the 200 mr/hr on contact required by federal transportation regulations. For comparison, the existing package external contact readings are generally less than 1 mr/hr with localized areas up to about 20 mr/hr.

LEAD REMOVAL PREPARATIONS

Training

The Shipyard has considerable experience in removing small quantities of permanent lead shielding and employs a sufficient number of skilled lead workers to accomplish the infrequent lead removal work needed to support ongoing work on nuclear powered ships. Shipyard lead workers remove, on average, 30 tons of permanently installed lead each year. The small existing group of lead workers would be insufficient to undertake a major ongoing RC lead removal program and training of additional personnel would be necessary.

In addition to basic skill qualification training, special mock-up training would be required prior to commencement of critical work evolutions. This training, which utilizes mockups of the actual components and structures, has proven effective in reducing nuclear worker exposure to radiation. Job skills, tooling and instructions are rehearsed and verified before accomplishment of the actual work. The costs associated with mockup training for lead removal have been factored into the cost estimate shown in Appendix B.

Hull and Bulkhead Cuts

In order to provide adequate access for personnel and support services (i.e., ventilation, air lines, electrical services, etc.) for lead removal, several hull and bulkhead cuts would be required. Figure 1 illustrates the proposed locations of these access cuts. They are:

- RC Top Cut - In order to provide access for crane service to the RC, a large cut into the hull at the top of the submarine RC disposal package would be required. This cut would facilitate removal of large or heavy items. Additionally, it would provide for an expeditious means for handling tools and support equipment into and out of the RC.

- RC Access Cuts - Three smaller access cuts, in addition to the RC top cut, would be required into the RC for personnel access, temporary service access and to facilitate material removal. These cuts would be made into the RC middle level on the port and starboard sides and into the RC bottom just aft of the reactor vessel.

- RC Disposal Package Forward Bulkhead - An access cut would be required to provide access for personnel to the void space enclosed by the partial bulkhead installed on the upper third of the forward bulkhead. A second access cut would be required for supply and exhaust ducts to ensure adequate ventilation for lead work.

- RC Disposal Package Aft Bulkhead - Two access cuts would be required to provide access for personnel to the void space enclosed by the aft RC containment bulkhead. Additionally, these access cuts would be utilized for supply and exhaust ducts to ensure adequate ventilation for lead work.

Interference Removal

Submarine design inherently attempts to minimize the overall size of the spaces within the ship. Designers attempt to utilize every available space to its maximum extent. Access to areas not requiring periodic maintenance, in most cases, is a secondary consideration. In some cases, access is not considered. Consequently, permanently installed lead, not requiring routine maintenance, is often located behind interfering components (e.g., cabling, piping, deck gratings, hangers, equipment foundations and significant quantities of asbestos thermal insulation on primary plant components). Thus, interference removal would be a major expense and has been factored into the estimates provided as Appendix B.

LEAD REMOVAL TECHNIQUES

A team of Puget Sound Naval Shipyard managers and supervisors with extensive industrial experience was tasked with identifying and determining the most practical method for the removal of all permanently installed lead contained within a typical submarine RC disposal package. It was determined that, with difficulty and with significant personnel radiation exposure, the lead could be removed at the Shipyard prior to package shipment. The lead removal methods envisioned for the Shipyard could also be used at Hanford for the eight submarine RC disposal packages already shipped. For these packages, the lead removal work would be performed at Hanford since it is not practical to ship the disposal packages back to the Shipyard.

The following discussions describe the methods developed by the Shipyard for removing the permanently installed lead. Work procedures such as interference removals, containment tent installations, etc., are routinely accomplished in the Shipyard and are not included in these descriptions, except where they contribute to the complexity of a particular task.

Removal of Lead Which Has Been Metallurgically Bonded To RC Support Structure

This lead is enclosed by steel canning plates. In order to remove this lead without structurally degrading the RC disposal package, the following method of lead removal was selected. The welds on the steel canning plates would be cut by carbon-arc gouging and the plates removed. The exposed lead would then be melted from the structure into troughs using hand-held torches. All removed materials would be transported to a controlled storage building for radiological segregation, survey and release, if possible, from radiological controls.

Removal of Lead Which Has Been Metallurgically Bonded To Canning Plates

This lead is bonded to canning plates, which are then fitted and caulked (lead wool hammered into gaps) between structural members. These panels are supported by welding the canning plates to the RC support structure using special weld joint designs and controlled welding temperatures to avoid melting the lead. To remove this lead, a special handling system would be designed and installed. The respective lead panel canning plate welds would be cut by carbon-arc gouging. Lead caulking would be removed by burning or chipping. Lead panels would be removed from the RC disposal package utilizing the special handling system. In cases where the lead panels cannot be removed on this special handling system, the panels would be removed by conventional rigging methods through the RC and out an access cut.

Removal of Ballast Lead From RC

Ballast lead is installed in the form of lead bars, called pigs, typically weighing 55 lbs. each. They are installed between hull frames and enclosed by canning plate. In some submarine classes, ballast lead is installed low in the RC. This study assumes ballast lead is installed and must be removed. Ballast lead will be removed by carbon arc removal of the canning plate and hand removal of the lead bars (pigs) via the RC bottom hull cut.

DISPOSAL OF REMOVED MATERIALS

The generation of radioactive waste is an unavoidable by-product of maintenance work on Naval Nuclear Reactor Plants. Radioactive waste materials, generated by work on contaminated ship's systems or by removal of activated components, are containerized and shipped to licensed radioactive waste burial sites. Burial sites for low level wastes have limited capacity; therefore, every effort is made by the Shipyard to ensure the volume of radioactive waste is kept as low as practicable.

The Shipyard has established a solid waste minimization program to reduce the volume of radioactive waste. At the center of this program is the concept of waste segregation. Waste would be segregated at the worksite into one of three categories: non-contaminated, potentially contaminated, or known contaminated. Radiological surveying would then eliminate the potentially contaminated category and this material would then be reclassified as either known contaminated or non-contaminated. All known contaminated waste would be disposed of as radioactive waste while non-contaminated waste would be disposed of in accordance with State and Federal regulations.

Another method for reducing waste is to recycle materials to the maximum extent possible. Recycling consists of such things as reusing tools and laundering anti-contamination clothing.

It is anticipated that each submarine RC disposal package would yield well in excess of 60 tons of recyclable lead which could be released from radiological controls. The lead can be sold to local recycling facilities at a rate of about $500/ton. However, the return on recycled lead is insignificant when compared to the $14 million expended to acquire it. It is also anticipated that some lead may have impurities which have become radioactive as the result of exposure to neutron irradiation; therefore, this lead would not be able to be released from radiological controls. Lead which cannot be released from radiological controls must be managed as radioactive mixed waste, since lead is regulated as Dangerous Waste by Washington State regulations.

PERSONNEL HEALTH AND SAFETY HAZARDS

Personnel Exposure to Ionizing Radiation

Control of radiation exposure in the Naval Nuclear Propulsion Program has always been based on the assumption that any radiation exposure, no matter how small, involves some risk. However, radiation exposure within the accepted exposure limits, as promulgated by federal regulations, represents a small risk compared with the normal hazards of life.

Current federal regulations allow personnel over 18 years of age to receive a whole body penetrating radiation dose of 3 rem/quarter with a cumulative radiation exposure limit of 5 rem for each year of a person's life over age 18. Beginning in 1967, the Navy established more restrictive limits for individuals receiving radiation exposures from the Naval Reactors Program. As many personnel as practicable have been assigned local control levels of 0.5 rem per calendar year. In some rare cases, it is necessary for selected personnel to exceed this local control level. In these cases, local control levels, not to exceed 2 rem per calendar year, may be assigned. The Navy has established these limits as a commitment to maintain radiation exposure to personnel as low as reasonably achievable.

For RC disposal work, external exposure to gamma radiation is limited to the vicinity of the reactor plant. The principal source of gamma radiation is the Cobalt-60 activity which is relatively short-lived, decreasing by a factor of two every 5.27 years. Hence, in 53 years the initial rate of gamma exposure is reduced by a factor of 2^{10} or about 1000.

The initially large total number of curies of other nuclides (See Appendix C) has no significant effect on external gamma exposure in comparison to Cobalt-60. For example, the nuclides ranking second and third to Cobalt-60 in initial activity are Nickel-63, which emits a short-range beta particle when decaying to stable Copper-63, and Iron-55, which emits a low energy X-ray when decaying to stable Manganese-55. Other nuclides which emit Gamma radiation, such as Cobalt-58 and Manganese-54, are initially present in much smaller quantities of activity than Cobalt-60, and also have shorter half-lives than Cobalt-60. Thus the external gamma radiation decreases with time according to the 5.27 year half-life of Cobalt-60. After about 100 years, the external gamma radiation would be reduced by a factor of more than 100,000 from its initial rate and would thereafter be essentially constant due to the presence of trace amounts of Niobium-94 (20,000 year half-life).

In studying how to remove permanently installed lead, the Shipyard considered techniques which would minimize the amount of radiation exposure that personnel would receive. This includes sequencing shielding removal so as to utilize the benefits of the shielding as long as possible.

Removal of all permanently installed lead from an RC disposal package, and installation of a permanent steel shield package to reduce package external radiation levels, would result in an estimated 184 rem of personnel radiation exposure per disposal package. The Shipyard developed this estimate based on; (1) reducing radiation levels within the RC an average of 80% by installing temporary shielding; and, (2) applying an estimated 9,600 mandays during which workers would be subjected to this reduced exposure (out of the total 35,477 mandays required for the entire operation). Appendix A provides a tabulation of this radiation exposure estimate.

Personnel Exposure to Lead

Puget Sound Naval Shipyard has accumulated data from monitoring lead melting removal operations at the Shipyard. Typical 8-hour (Time-Weighted Average) lead exposures, without regard to respirator protection, have not exceeded 1.9 mg lead per cubic meter of air. Actual personnel exposure has been kept well below the OSHA PEL, permissible exposure limit, (0.050 mg lead per cubic meter of air) by use of protective clothing, air supplied respirators and engineering controls including industrial ventilation. Exhaust air would be filtered using a high efficiency particulate air (HEPA) filtration system and discharged outdoors away from air intakes or other work areas. With the use of this air filtration system and proper personnel protection, there should be no adverse health effects from airborne lead exposure during shielding removal.

Personnel Exposure to Asbestos

Large amounts of asbestos thermal insulation would have to be removed, since its installation on components interferes with the removal of lead shielding. Asbestos removals would be performed using established techniques with the insulation wetted to minimize release of airborne asbestos. There will be no adverse health effects from asbestos exposure during insulation removal as long as the established asbestos abatement controls are used and the prescribed protective clothes are worn.

Engineering abatement controls for asbestos work would include the use of local exhaust ventilation, equipped with high efficiency particulate air (HEPA) filtration used at each point of asbestos fiber generation. The use of a negative pressure system during major asbestos rip-outs would be employed to ensure negative flow through all openings or accesses in the enclosure surrounding the regulated area or space. All hand-operated and power-operated tools would be equipped with local exhaust ventilation systems approved for asbestos use or with a HEPA filter equipped vacuum cleaner, to preclude a release of asbestos fibers in excess of the allowable limits.

Personnel Heat Stress

Personnel heat stress problems would be encountered for personnel wearing impermeable protective clothing during lead and asbestos removal operations when ambient temperatures exceed about 70°F. Adverse health effects, however, would be prevented by using air conditioning, where possible, and setting stay times to limit the time personnel are in a high temperature environment.

RADIOLOGICAL CONTROL REQUIREMENTS

Since most lead removal would be in radiation areas, only trained radiation workers would be allowed to perform this work. Their exposure would be monitored using established Navy procedures. In addition, radiological contamination controls will be required for the various lead removal operations.

Several temporary containment structures would require fabrication and installation on the RC disposal package to control the potential spread of radiological contamination and to protect the environment from release of unfiltered lead vapors. Containments as used in the Shipyard are usually metal or herculite structures that provide a boundary between controlled and uncontrolled work areas. They have a negative ventilation system to assure air flow is inward, and they are generally sized to permit room for personnel in proper protective clothing to work within them. Figure 2 illustrates the proposed containment structures as they might appear installed on the RC disposal package.

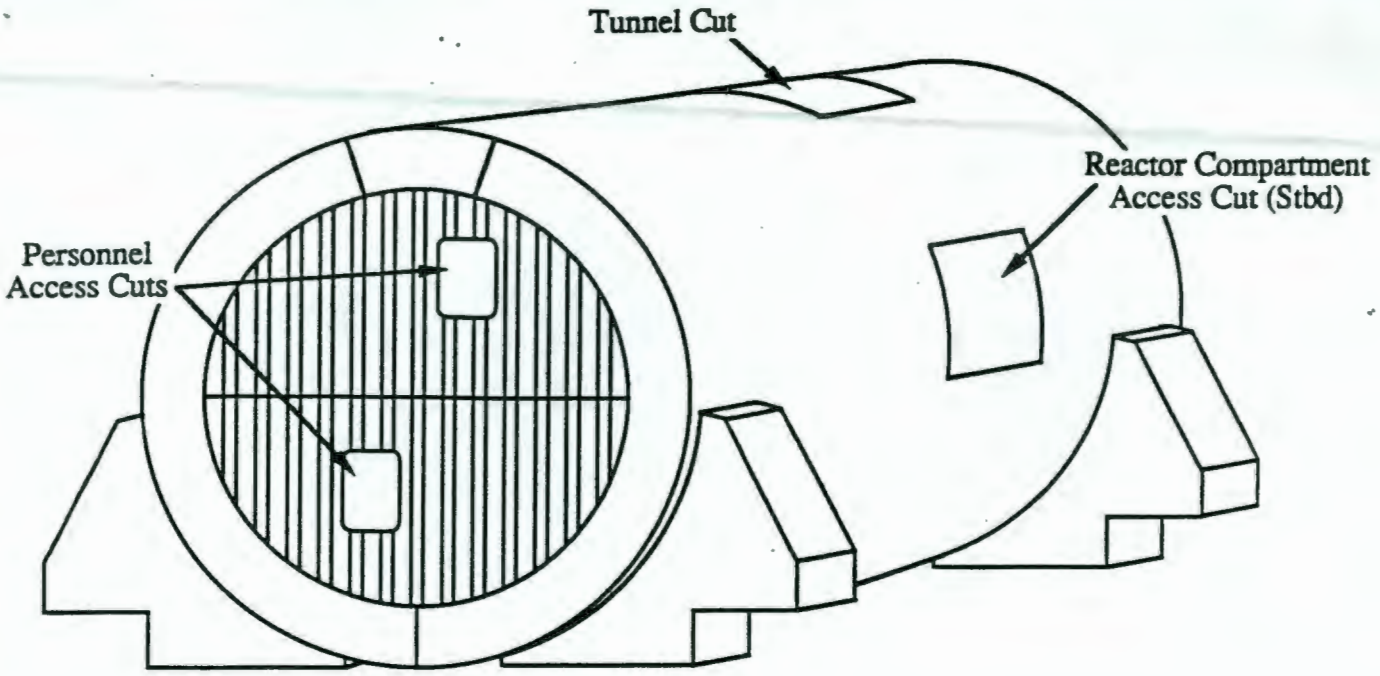
In addition to containment structures, several other support facilities and services (i.e., air conditioning, HEPA ventilation, lead vapor filtration system, etc.) would be required to support this work. These specific requirements are not discussed in detail in this study; however, these requirements were taken into account in the formulation of the cost estimates.

COST ESTIMATE

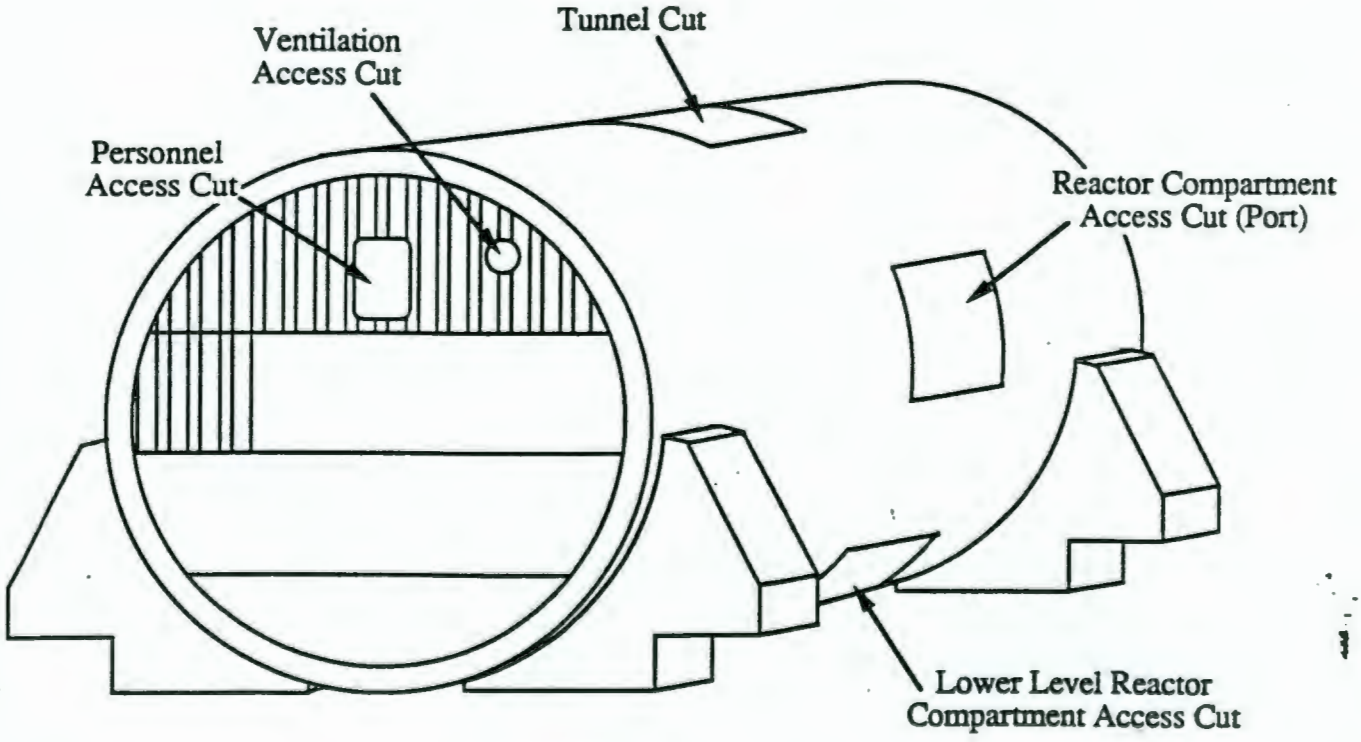
Using the techniques described in this report, the Shipyard estimated the man-hours necessary to remove all permanently installed lead contained within the RC disposal packages. Training costs and support services were factored into this estimate. It was determined that, for a typical RC disposal package, 35,477 mandays of labor and $14,190,800 would be required for complete lead removal at the Shipyard. Furthermore, this work could be accomplished in a 179 day schedule.

The lack of an industrial facility at the Hanford burial trench would drive these estimates higher for the lead removal work to be performed there. The cost per package would be approximately 25% higher, resulting in a total cost of $17,738,500. In addition, site set-up and close-out would result in an extended schedule of 211 days.

A tabulation of this estimate is provided in Appendix B.



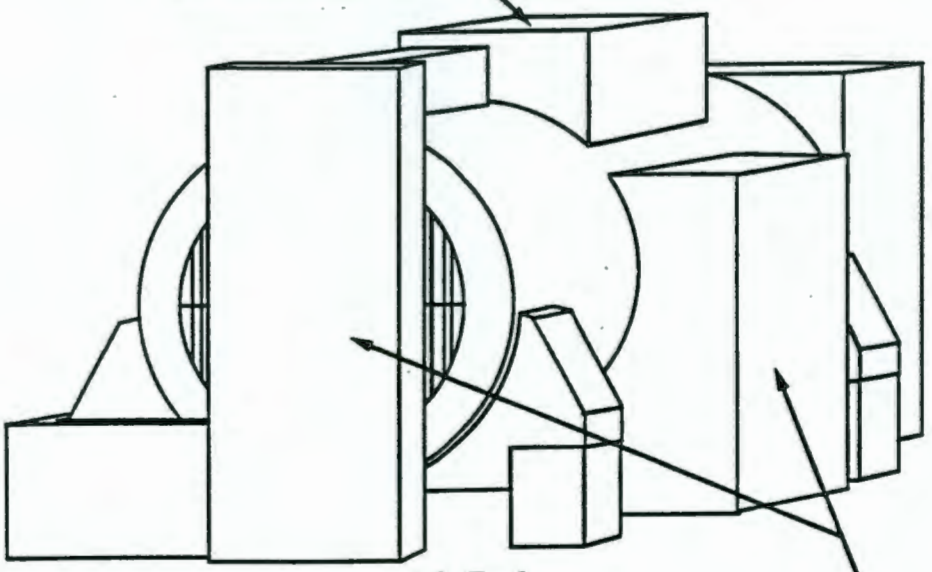
Aft End
(Looking Forward)



Forward End
(Looking Aft)

Hull/Bulkhead Cuts
Figure 1

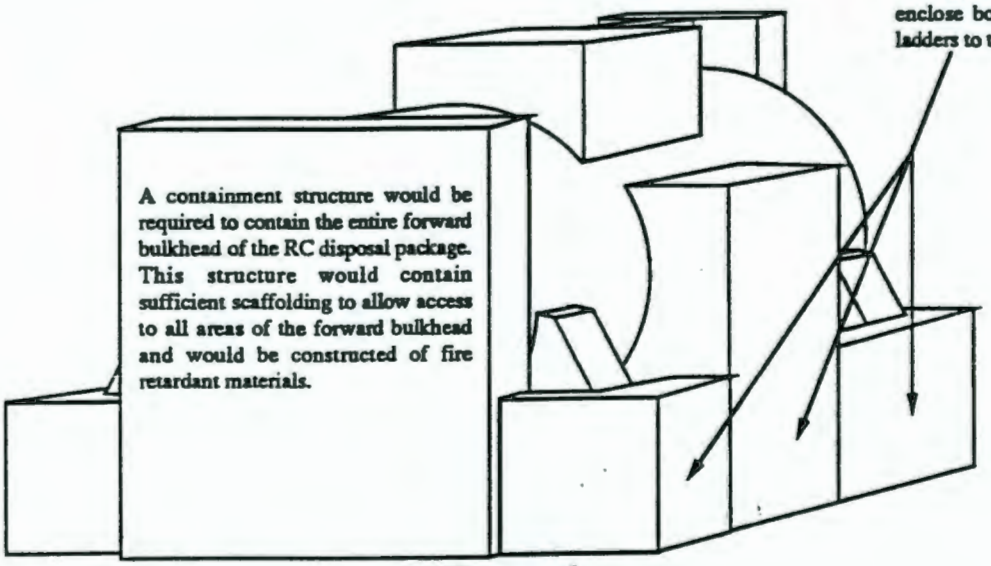
A containment house installed on top of the RC disposal package would require access both from an enclosed ladder to the ground and through the roof for crane service.



Aft End
(Looking Forward)

All remaining RC disposal package personnel access cuts would require containment structures which would enclose both the access cut and the ladders to the ground.

A containment structure would be required to contain the entire forward bulkhead of the RC disposal package. This structure would contain sufficient scaffolding to allow access to all areas of the forward bulkhead and would be constructed of fire retardant materials.



Forward
End
(Looking Aft)

Notes:

1. A control point structure, separate from the RC disposal package would be required and would contain dressing rooms, showers, restrooms, and a centralized control point.
2. A storage building would be required for temporary storage of potentially contaminated materials
3. A network of personnel access tunnels would connect each containment structure allowing for a single control point. These tunnels would be equipped with overhead trolleys to aid in the transport of removed materials

Containment
Structures
Figure 2

RADIATION EXPOSURE ESTIMATES FOR REMOVAL OF LEAD FROM RC DISPOSAL PACKAGES

SHIP	INSTALL/REMOVE TEMPORARY SHIELDING (REM)	REMOVE PERMANENTLY INSTALLED LEAD (REM)	TOTAL EXPOSURE TO REMOVE ALL PERMANENTLY INSTALLED LEAD (REM)	
			At Inactivation	50 Yrs Later
ex-SSN 588	17.6	144	162	0.226
ex-SSN 592	7.7	144	152	0.212
ex-SSN 607	7.0	144	151	0.210
ex-SSBN 620	31.1	241	272	0.379
AVERAGE EXPOSURE	15.8	168.2	184	0.256

NOTES:

1. These estimates are based on installing temporary shielding thus reducing radiation levels within the Reactor Compartment an average of 80%.
2. These estimates were developed utilizing known survey results from four submarines whose RC's were disposed of immediately after defueling /inactivation
3. REM - The amount of radiation which will cause damage to human body tissue equivalent to the damage that would be caused by absorbing 100 ergs of gamma radiation per gram of body tissue.
4. Each person in the United Statesreceives about 170 mrem each year from natural background radiation and various medical exposures.

LEAD REMOVAL COST ESTIMATE

MANDAY RATE ..... $400.00 (Includes Labor And Material Costs)
179 DAYS, 537 SHIFTS

	MANDAYS
Nuclear Engineering Division	2600
Industrial Engineering Division	715
Radiological Control Office	2340
Nondestructive Testing Division	130
Laboratory Division	78
Welding Engineering Division	195
Nuclear Inspection Division	520
Central Tool Shop	130
Transportation Shop	468
Shipfitter Shop	12290
Sheet Metal Mechanic Shop	91
Welder Shop	8048
Machinist Shop	65
Marine Machinery Shop	78
Electrician Shop	39
Pipefitter/Insulator Shop	1118
Insulator Shop	195
Woodcrafter Shop	195
Painter Shop	26
Rigger Shop	1175
Tank Cleaner Shop	962
Fabric Worker Shop	482
Temporary Services Shop	390
Environmental Engineering	130
Occupational Safety and Health	156
Mock/Training	2600
Rad Waste	260
TOTAL	35477
SHIPYARD COST (Labor and Materials)	$14,190,800
HANFORD WORK PERCENT OF PUGET	125%
HANFORD COST (Labor and Materials)	$17,738,500

APPENDIX B

ESTIMATED RESIDUAL RADIOACTIVITY IN A TYPICAL RC DISPOSAL PACKAGE

Nuclides	Shipment Total Activities (Curies)
Co-60	2.2×10^{4}
Ni-63	1.8×10^{4}
Fe-55	1.7×10^{4}
Co-58	3.2×10^{3}
Cr-51	1.0×10^{3}
Mn-54	6.5×10^{2}
Ni-59	1.2×10^{2}
Fe-59	5.1×10^{1}
Zr-95	1.0×10^{0}
C-14	1.0×10^{0}
S-35	4.5×10^{-1}
Sc-46	3.9×10^{-1}
Hf-181	1.2×10^{-1}
Nb-94	8.2×10^{-2}
Mo-93	1.3×10^{-2}
Tc-99	3.6×10^{-3}
TOTAL	**6.20×10^{4}**

APPENDIX C

POTENTIAL FOR LEAD TRANSPORT TO GROUND WATER

The model for transport of infiltrating water from the burial trench to the unconfined aquifer is shown on Figure D.1 taken from DOE/EIS-0119D. The relationship of this model to the burial grounds is shown on Figure D.2 from the same document. It is assumed that moisture percolates downward through the ground until it reaches an unconfined aquifer streamtube, which then transports it to a well location or to the Columbia river.

The corrosion of solid metallic lead in the dry, slightly alkaline soil at Hanford will be at an extremely low rate. For comparison, intact metallic artifacts dating back to 5,000 BC have been found. Intact 2000 year old lead water pipes in Roman cities have been unearthed. Lead roofs erected in the 15th century remain in service today (U.S. Department of The Interior Bureau of Mines bulletin 675, Mineral Facts and Problems, 1985 Edition). This resistance of lead to corrosion is one of the reasons why lead has traditionally been used for many applications where it is exposed to the environment, including lead lined coffins, lead shielded cables, sailboat keels, and other similar uses.

Although the solubility of metallic lead is extremely low (the Handbook of Chemistry and Physics indicates that lead is essentially insoluble in both hot and cold water) the detrimental health effects of lead cause it to be of concern even at the very small dissolved quantities that can potentially migrate into drinking water. Tests have shown that lead water piping, copper piping with lead solder, and lead lined water coolers can cause the limit for lead in drinking water to be exceeded. An EPA notice (WH-FRL-3552-7) in the 10 April 1989 Federal Register indicated that water from some lead lined water coolers was found to have lead levels up to 400 times EPA's existing lead standard of 50 parts per billion. Testing data indicates that as time passes , mineral deposits form a coating on the inside of pipes (if the water is not too corrosive) and that after about five years this coating insulates the water from the lead. It should be noted that these examples are the primary sources of lead found in drinking water, and result from drinking water being in direct contact with lead, typically in piping systems at the point of use. A Washington State Toxic Substances Fact Sheet on Lead issued by the DSHS Division of Health in August 1977, stated that "In Washington State, no cases of elevated blood levels or lead poisoning have been linked with lead in drinking water."

Studies have shown that dissolved lead in ground water does not stay in solution, but instead is retained in soils by a number of mechanisms, including adsorption on mineral interfaces and interaction with organic matter and calcium carbonate (Singh & Sekhon in Volume 28 of the Journal of Soil Science, 1977). The common range of lead in soils is 2 to 200 ppm. Assuming a source of water, reactor compartment lead that is eventually exposed would be leached to the soil. The lead would not travel any significant distance before being retained in the soil, either as adsorbed lead or a lead compound such as cerussite ($PbCO_3$). Ultimately, the quantity of lead or lead compound building up in the soil near the package would saturate the soil's ability to retain it, at which time lead would be available for transport to adjacent unsaturated soil. This transport of dissolved lead would be on a geologic time frame and, as discussed below, it is questionable whether lead would ever reach the aquifer below the 200E area.

The draft EIS for decommissioning the surplus Hanford production reactors, considers the several hundreds of tons of lead that would be buried with the reactors in the Hanford 200W area. Comparisons can be drawn between this discussion and the lead in the reactor compartment disposal packages. This draft EIS describes the mechanism for lead transport. Because metallic lead is thermodynamically unstable, over time it will tend to form a more stable compound. For example, in air lead oxide forms on the exposed surface of metallic lead. In soil, other reactions can occur. This could include the formation of a protective mineral coating, or perhaps the type of reaction described in the following paragraphs.

The DEIS study assumes that the lead in soil at Hanford will ultimately become cerussite ($PbCO_3$), which is a probable product in this soil environment. This assumes that exposure to carbonic acid (water plus CO_2) or to water plus calcium carbonate in the soil eventually converts the lead to $PbCO_3$. An equilibrium reaction then occurs: $PbCO_{3(cerussite)} + 2H^+ = Pb^2 + CO_2(g) + H_2O$. This study then calculates a solubility-limited transport time for lead to reach the aquifer. Assuming that all the metallic lead is converted to $PbCO_3$, the solubility-limited lead (Pb^{+2}) concentration in water percolating downward through the soil, is determined to be 0.29 milligram per liter. The time for water to percolate downward through the soil to the aquifer is about 4,200 years. The soil, however, will retard the lead migration by a fixed distribution coefficient (K_d) of between 200 and 2,000 milliliters per gram of soil, and the transport of the lead will be very slow. The time to reach the peak concentration of lead in the soil column is estimated to be between 4.5 million and 45 million years (note that this does not include the time for metallic lead to become $PbCO_3$).

Lead breakthrough is assumed after the soil is saturated. Therefore, if there is enough lead to saturate the soil column, lead could eventually reach the aquifer. The study, considering a breakthrough, uses a model which assumes that the leachate water, at the assumed recharge rate of 0.5 cm per year, mixes with and is diluted by the regional ground-water system. At the time of peak lead concentration in the leachate reaching the aquifer, the maximum lead concentration in a well located 5 kilometers away would be 4.9×10^{-4} milligrams per liter. The allowable limit for lead in drinking water is presently 0.05 milligrams per liter (50 parts per billion) per the Washington State Board of Health Drinking Water Regulations,WAC 248-54. There are proposals to lower this limit to 20 and even further to 5 parts per billion. Even at these lower levels, it can be seen that the limit would not ever be exceeded.

It is concluded that the site characteristics of the 200E location are such that even if lead were to be exposed, it will not migrate to the ground water for the foreseeable future, if at all. In fact, the conversion of metallic lead to cerussite or other compounds will occur at an extremely slow rate in this environment and the ability of soil to retain lead will assure that any migrating lead is retained in the soil adjacent to the RC disposal package for the hundred or thousand year time frames under consideration Even with worst case assumptions, after millions of years, lead could not reach the aquifer in quantities to cause drinking water limits to be exceeded.

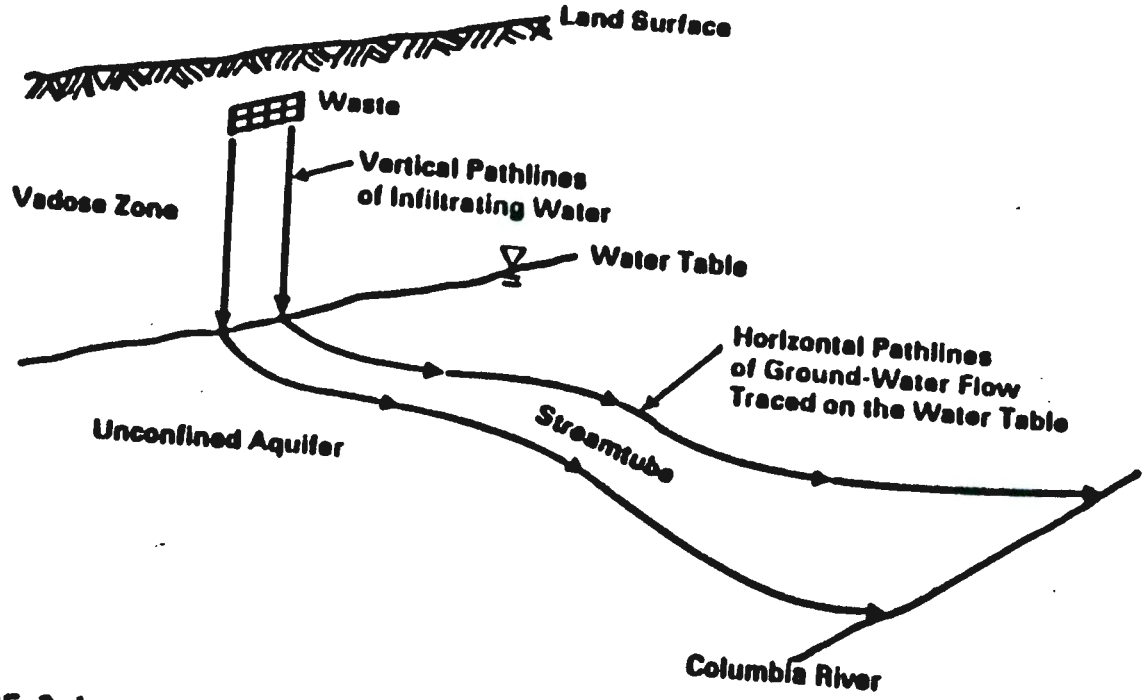


FIGURE D.1 Depiction of the Streamtube Approach to Transport in the Vadose Zone and the Unconfined Aquifer

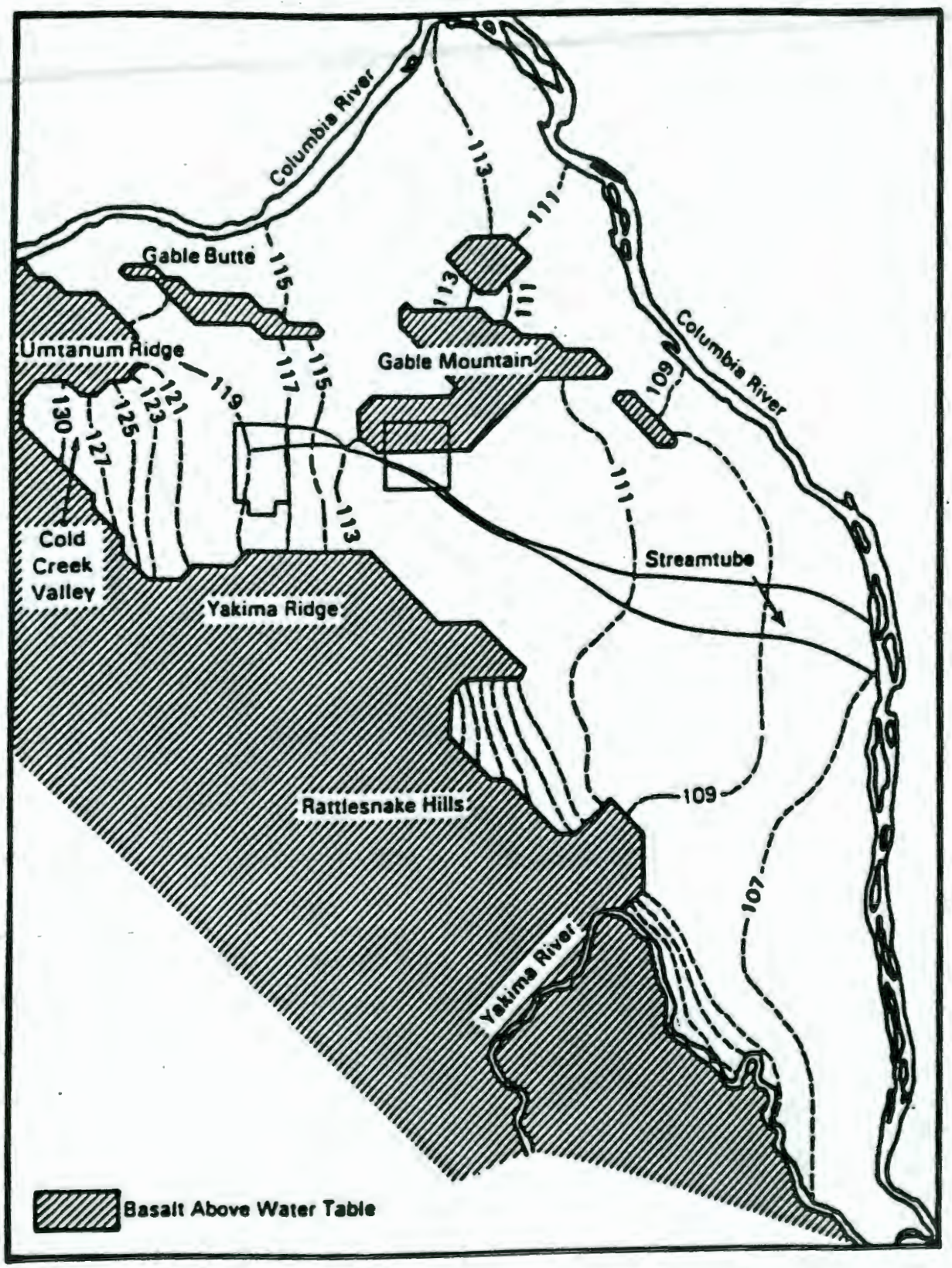
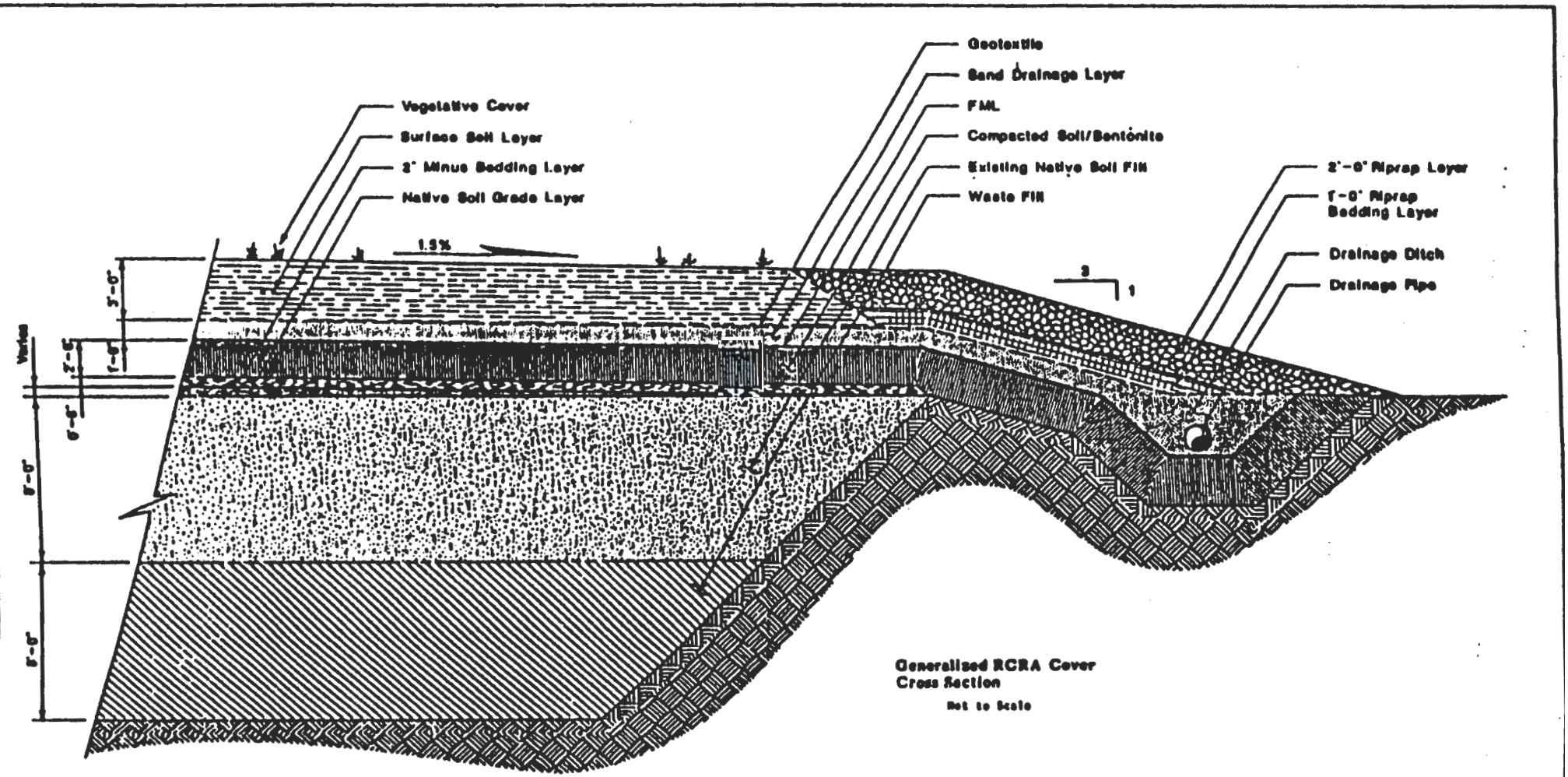


FIGURE D.2 Ground-Water Contours (meters above MSL) and Streamtube from the 200-West Area Burial Ground to the Columbia River, Assuming Steady-State Conditions, 0.5-Centimeter-Per-Year Annual Average Recharge



Generalized RCRA Cover
Cross Section

Not to Scale