ORIGINAL

BEFORE THE R-00973953

PENNSYLVANIA PUBLIC UTILITY COMMISSION

APPLICATION OF PECO ENERGY COMPANY FOR APPROVAL OF ITS RESTRUCTURING PLAN UNDER SECTION 2806 OF THE PUBLIC UTILITY CODE

Exhibit 1
VOLUME IV

Contents:

Statement No. 8 - Direct Testimony & Exhibits of Thomas S. LaGuardia

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PECO STATEMENT NO. 8

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PENNSYLVANIA PUBLIC UTILITY COMMISSION

**APPLICATION OF PECO ENERGY COMPANY
FOR APPROVAL OF ITS RESTRUCTURING PLAN
UNDER SECTION 2806 OF THE PUBLIC UTILITY CODE**

DIRECT TESTIMONY OF

THOMAS S. LAGUARDIA

Regarding Stranded Investment (Decommissioning - Nuclear and Fossil)

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ORIGINAL

DIRECT TESTIMONY OF THOMAS S. LAGUARDIA
ON BEHALF OF
PECO ENERGY COMPANY

I. QUALIFICATIONS

Q. Please state your name and business address.

A. Thomas S. LaGuardia, 148 New Milford Road East, Bridgewater, CT 06752

Q. What is your occupation?

A. I am President of TLG Services, Inc. (TLG)

Q. What are your responsibilities with TLG?

A. I am responsible for the technical and business management of engineering and field services in the areas of decontamination, decommissioning, waste management and general engineering for nuclear and fossil-fueled generating stations.

Q. What is your educational and professional background?

A. I completed my Bachelor of Science in Mechanical Engineering at Polytechnic Institute of Brooklyn in 1962 and my Master of Science in Mechanical Engineering at the University of Connecticut in 1968. I am a registered Professional Engineer in Connecticut (No. 10393), New York (No. 059389) and New Jersey (No. 38193). I have been actively conducting business as TLG since January 1, 1994. TLG acquired certain operating assets on January 1, 1994 from TLG Engineering, Inc. I founded

TLG Engineering in April, 1982. I was employed by Nuclear Energy Services in Danbury, Connecticut, from 1973 until I founded TLG Engineering. My prior employment was with Gulf Nuclear Fuels Corporation, formerly United Nuclear Corporation (UNC), and Combustion Engineering.

II. PURPOSE AND SCOPE

Q. What is the purpose of your testimony in this proceeding?

A. The purpose of my testimony is two-fold. First, I will present the results of the decommissioning cost studies prepared by TLG for the Limerick Generating Station (Limerick) (Exhibit TLG-1), the Salem Generating Station (Salem) (Exhibit TLG-2) and the Peach Bottom Atomic Power Station, Units 2 and 3 (Peach Bottom) (Exhibit TLG-3) and Peach Bottom Unit 1 (Exhibit TLG-4). PECO has 100% ownership share in Limerick and Peach Bottom Unit 1, 42.49% in Peach Bottom and 42.59% in Salem. PECO operates Limerick and Peach Bottom. Salem is operated by Public Service Electric and Gas Company. The primary objective in preparing these studies was to develop accurate cost estimates to decommission the nuclear units. This will allow the owners to verify the adequacy of current funding levels and, if necessary, adjust contributions to reflect current cost projections. The studies are not detailed decommissioning engineering plans and, therefore, do not commit the owners to a specific course of action for the stations following the ultimate cessation of operations.

Second, I am presenting the results of a dismantling cost study, Exhibit TLG-5, prepared by TLG for the following fossil-fueled power plants:

Station	No. of Units	Megawatts (per unit)
Eddystone 1&2	2	300 MWe
Eddystone 3&4	2	380 MWe
Cromby 1	1	144 MWe
Cromby 2	1	201 MWe
Schuylkill 1	1	166 MWe
Delaware 7&8	2	125 MWe
Keystone 1&2	2	850 MWe
Conemaugh 1&2	2	850 MWe

All of the foregoing units except Keystone 1&2 and Conemaugh 1&2 are owned and operated solely by PECO. PECO has a 20.99% ownership share in Keystone and a 20.72% ownership share in Conemaugh. Keystone and Conemaugh are operated by GPU.

Q. What is covered by the term "decommissioning" as used with reference to the PECO generating stations?

A. Decommissioning is the planned and orderly retirement of a generating station. In the case of nuclear plant decommissioning, it requires the complete removal and controlled disposal of radioactive materials to levels prescribed by the U.S. Nuclear

Regulatory Commission (NRC) and termination of the NRC license(s). The owner may then dismantle the remaining non-contaminated systems and structures. In the case of a fossil-fueled power plant, upon retirement the facility may either be rendered safe indefinitely (through on-going maintenance, repair and security measures) or dismantled. A specific discussion of public safety and dismantling is included later in this testimony.

Q. Please summarize the costs identified in the nuclear decommissioning and fossil dismantling studies.

A. Decommissioning of the two nuclear units at Limerick was estimated to cost approximately $835.4 million (in 1995 dollars). Decommissioning of the two nuclear units at Salem was estimated to cost approximately $681.0 million (in 1995 dollars). The cost for decommissioning Units 2 and 3 at Peach Bottom was estimated at approximately $831.4 million (in 1995 dollars). The studies assume that the units will complete their fully licensed operating lives and that the stations will be completely dismantled following the removal of radioactivity. Low-level radioactive wastes were destined for future facilities within the Northeast and Appalachian Compacts, while high-level waste (spent fuel) was assumed to be stored on-site until the transfer to the Department of Energy's (DOE) geologic repository could be completed.

Dismantling and demolishing of the aforementioned fossil-fired steam electric generating stations was estimated to cost approximately $306.8 million (1997 dollars). The fossil estimate addressed 13 units at the six sites and included the razing of site structures to grade. Each site was decommissioned upon the cessation of the final unit's operation. Costs were specifically identified for the remediation of asbestos, which is found throughout many of the units. A credit was included for the potential value of the scrap steel and copper generated in the dismantling process.

III. EXPERIENCE

Q. Do you have experience in the design and construction of fossil-fueled generating stations?

A. Yes. During my employment with Combustion Engineering, Inc. from 1962 to 1968, I was a boiler design, performance and construction engineer for 500 megawatt electric (MWe) coal-fired power boilers and merchant and Naval oil-fired marine boilers.

Q. What decommissioning experience do you have?

A. My decommissioning experience began as site representative for UNC during the BONUS reactor decommissioning in 1969 and 1970. BONUS was a 17 MWe demonstration power reactor located in Puerto Rico that was owned by the U.S. Atomic Energy Commission (USAEC), now the U.S. Department of Energy (USDOE), and operated by the Puerto Rico Water Resources Authority. It was the largest reactor decommissioned by entombment up to that time. The program involved extensive chemical decontamination of radioactive systems, selective piping and component removal, and entombment of the reactor vessel within a massive concrete barrier. The entombment has a design life of 125 years. My role as site representative was to act as a technical liaison and provide project engineering and schedule management assistance during system decontamination, component removal, vessel entombment and facility close-out.

Following the BONUS program, I was lead engineer for UNC during the Elk River Reactor decommissioning between 1970 - 1973. Elk River was a 20 MWe demonstration power reactor located in the state of Minnesota that was owned by the USAEC and operated by United Power Association. Elk River was decommissioned by complete dismantling. The program involved segmentation of the reactor vessel and internals using remotely-operated cutting torches, as well as the packaging, shipping and controlled burial of the segments. Similarly, radioactive piping and components were removed, packaged, shipped and buried. Radioactive concrete was demolished by controlled blasting, and nonradioactive concrete was demolished by wrecking ball to completely dismantle the facility. Initially, my role for UNC was Consulting Engineer and later Lead Engineer for UNC technical support for on-site activities.

I was Project Engineer, while at Nuclear Energy Services, for the detailed engineering and planning of the Shippingport Station Decommissioning Project from 1979 - 1982. Shippingport was a 72 MWe light water breeder reactor located in the state of Pennsylvania, owned by the USDOE and operated by Duquesne Light Company. The facility is now dismantled, and TLG Engineering, with its joint venture partner, Cleveland Wrecking Company, dismantled all of the clean and contaminated piping and components and removed contaminated concrete. My role for TLG/Cleveland was Project Director, and I selected and managed an on-site project management team to hire and supervise work crews to accomplish the dismantling. All work was completed on schedule and within budget.

I also assisted Atomic Energy of Canada, Ltd. in the detailed engineering and planning for the decommissioning of the 238 MWe Gentilly Unit 1 reactor located in Three Rivers, Canada. My role was to provide overall decommissioning consulting services and detailed cost estimation of alternatives.

TLG Engineering worked with the Northern States Power Company between 1988-89 in the preparation of the decommissioning plan for the Pathfinder Atomic Power Plant. Pathfinder, located in Sioux Falls, S.D., was a 60 MWe reactor initially placed in a safe storage condition (SAFSTOR) after an abbreviated operating life. TLG Engineering prepared detailed cost and schedule estimates and vessel activation estimates, analyzed the reactor vessel to be used as its own shipping container, and prepared the decommissioning plan in support of plant decommissioning.

TLG Engineering has also assisted the Sacramento Municipal Utility District since 1989 with the decommissioning planning for the Rancho Seco Nuclear Generating Station. This work included a detailed reactor vessel activation analysis, preparation of decommissioning alternative cost and schedule estimates, and assistance with the preparation of the decommissioning plan originally using the SAFSTOR method and more recently reflecting the DECON method.

TLG Engineering worked with the Long Island Lighting Company in the planning for the decommissioning of the Shoreham Nuclear Power Station. This work included the preparation of a detailed reactor vessel activation analysis, cost estimates, schedules, management organization, waste volume estimates and draft decommissioning plan.

In 1990, TLG Engineering was selected by Cintichem, Inc. (a subsidiary of Hoffman-LaRoche) as Decommissioning Co-Manager of a 10 megawatt thermal (MWt) research reactor and associated hot cells and facilities. TLG's staff prepared a reactor core activation analysis as well as cost and schedule estimates for the project. TLG Engineering assisted in the preparation of the decommissioning plan, which has received NRC approval. TLG's field management staff has been on-site assisting in the project management and supervision of the work crews in decommissioning and dismantling the facility. The program is essentially complete. My role in the project was Senior Decontamination and Decommissioning Expert on the Nuclear Safeguards Committee.

TLG has also been involved in the engineering and planning activities associated with the decommissioning of the Yankee Rowe, Trojan and Big Rock Point nuclear units. This work includes activation analyses, preparation of decommissioning alternative cost and schedule estimates, and assistance with the preparation of the decommissioning plans. In addition, TLG was selected to prepare the steam generators and the pressurizer at Trojan for transport to the burial facility at Richland, WA. TLG was responsible for certifying package integrity, overseeing the grouting of the components and preparing any supporting transportation analyses. The project was successfully completed in October 1995. TLG is currently supporting Portland General Electric (PGE) in the detailed planning required for completing the decontamination and dismantling of the Trojan nuclear unit, including the intact removal and disposal of the reactor vessel and the highly radioactive internal components.

In addition, TLG prepared the decommissioning plan for Dresden Unit 1 and the Environmental Reports (ER) for Dresden Unit 1 and Indian Point Unit 1. Under my supervision and direction, TLG has prepared site-specific decommissioning studies for 80% of the nuclear units in the United States and approximately 150 fossil-fueled units.

TLG was responsible for overseeing the dismantling and demolition of a fossil-fueled steam plant for a major Connecticut hospital facility. In connection with this demolition project, I participated in the site inspection and cost estimate development. The work was subcontracted and TLG personnel supervised the contractors.

Q. Have you prepared or co-authored any studies and reports on decommissioning cost estimating and technology?

A. Yes. While at Nuclear Energy Services, I was Principal Investigator for the Atomic Industrial Forum's National Environmental Studies Project (NESP) decommissioning study entitled "An Engineering Evaluation of Nuclear Power Reactor Decommissioning Alternatives" (AIF/NESP-009). The Atomic Industrial Forum (now NEI) is an industry supported advocate and sponsor of research to promote the advancement of nuclear power. This study evaluated the costs, schedules and environmental impacts of decommissioning 1100 MWe reactors (Pressurized Water Reactors [PWRs], Boiling Water Reactors [BWRs], and High Temperature Gas-Cooled Reactors [HTGRs]).

I also co-authored the "Decommissioning Handbook" for the USDOE. The Handbook reported the state-of-the-art in decommissioning technology (as of 1980), including decontamination, piping and component removal, vessel segmentation, concrete demolition, cost estimating and environmental impacts.

At TLG Engineering, in 1986, I co-authored "Guidelines for Producing Commercial Nuclear Power Plant Decommissioning Cost Estimates" (AIF/NESP-036) for the Atomic Industrial Forum's National Environmental Studies Project. The Guidelines identify the elements of costs to be included in the estimation of decommissioning activities for each of the principal decommissioning alternatives. Specific guidance in cost estimating methodology and reference cost data is provided in this study. The major objective of this study is to provide a basis for consistent cost estimating methodology.

In 1986, TLG Engineering also prepared a study for the NRC, which I co-authored, entitled, "*Identification and Evaluation of Facilitation Techniques for Decommissioning Light Water Power Reactors*" (published as an NRC contractor report - NUREG/CR-3587). The study evaluated the costs and benefits of techniques to reduce occupational exposure and waste volume from decommissioning.

TLG personnel also authored the paper "How to Determine the Cost of Dismantling a Fossil-Fuel Electric Power Plant" (A. Carlstrom, Cost Engineering Magazine, April, 1989).

Q. Were the decommissioning and dismantling studies prepared for the PECO generating stations prepared under your direction and supervision?

A. Yes. I developed the basic methodology used by TLG to estimate the costs to dismantle both nuclear and fossil-fueled power plants. I trained my engineering and estimating staff in this methodology.

With respect to the estimates prepared for PECO, I personally inspected each of the power stations with the TLG staff assigned to this project. This included an inspection of the power blocks, turbine-generators, radwaste, condensate and feedwater systems at the nuclear units, and the boilers, fuel handling and pollution control systems at the fossil units. The purpose of these inspections was to familiarize myself and the TLG staff with the site-specific features of each unit so that the drawings and specifications used in the estimate would be better understood at the engineering offices of TLG. During the preparation of the cost estimate details, I provided guidance and interpretation to the TLG staff on how to estimate specific areas of the units. I reviewed the results of each cost estimate to ensure the results were reasonable and representative of the features of each unit. Finally, I supervised the preparation of the report summarizing the results of the estimate.

Q. What was the basis for the decommissioning studies?

A. The decommissioning studies were developed using detailed engineering drawings, together with plant description and inventory documents. These drawings and documents were used to identify the general arrangement of the facilities and to estimate building concrete volumes, steel quantities, the numbers and size of components, and the degree of site restoration required.

For the fossil studies, the information available on the PECO generating units was supplemented with TLG's data base for plants of similar size and type. This provided the basis for estimating the disposition of the components and structural materials addressed in the dismantling of each site.

Because decommissioning is labor-intensive, representative labor rates for the geographical region and for each craft or salaried work group are essential for a meaningful site-specific decommissioning cost estimate. Accordingly, typical craft labor rates and utility salary data were used in the estimate. This type of information is obtained from the utility's existing labor costs for the area/site.

Low-level radioactive waste, for purposes of the cost estimates, was assumed to be shipped to a regional burial facility. Since the facilities designated for the Appalachian States and Northeast Compacts are in the conceptual stages, the burial costs for radioactive materials were developed from rate schedules published for the Barnwell Low-Level Radioactive Waste Management Facility, which is a reasonable proxy for shallow land burial.

Q. For purposes of the estimate, when did you assume the units at each site would be dismantled?

A. For the fossil studies, we assumed dismantling would occur upon retirement of the last unit at each site. This approach is reasonable because it would be more difficult and costly to protect the operating units from potential damage when demolishing the retired units. Moreover, the dismantling staff and crew would only have to mobilize and demobilize once for the site instead of each time a unit is retired. Using the same staff and crew would take maximum advantage of the lessons learned as the units are dismantled in sequence.

The nuclear units were assumed to shutdown upon the expiration of their operating licenses. We also assumed that decommissioning activities would be coordinated between the two units at a station to the maximum extent possible.

IV. METHODOLOGY

Q. What methodology was used to prepare the estimates?

A. The methodology used to develop the cost estimates followed the basic approach presented in the AIF/NESP-036 study report, "Guidelines for Producing Commercial Nuclear Power Plant Decommissioning Cost Estimates," and the DOE "Decommissioning Handbook." The basic methodology described in these documents for preparing dismantling estimates is widely accepted by the electric power industry and regulatory agencies throughout the United States, including the NRC, and is applicable for nuclear as well as fossil plants.

Q. How was this methodology applied to the PECO generating units?

A. The aforementioned references recommend the use of a unit factor method for estimating decommissioning activity costs to standardize the estimating calculations. Unit factors describe the sequence of events required to remove a specific plant or structural component, the labor and material needed to support the activities identified, the impact of expected working conditions on the duration of performance and the associated cost (on a per unit basis). Unit factors for activities such as concrete removal ($/cu yd), steel removal ($/ton), and cutting costs ($/in) were developed from the labor information provided by PECO. Consumable material and equipment rental costs (crane and truck rental, operating costs for heavy equipment, torch cutting gas consumption, etc.) were taken in large part from R.S. Means, "Building Construction Cost Data," a standard construction industry cost guide. The costs for removal, shipping and disposal were then estimated using the item quantity (cu yds, tons, inches, etc.) developed from plant drawings and inventory documents. The activity duration critical path for key activities, such as the removal of the nuclear steam supply system, boiler or turbine, were used to determine the total dismantling program schedule.

The program schedule is used to determine the period-dependent costs such as program management, administration, field engineering, equipment rental, and security. The salary and hourly rates are typical for personnel associated with period-dependent costs. In addition, collateral costs were included for heavy equipment rental or purchase, safety equipment and supplies, energy costs, permits, taxes, and insurance.

The activity-dependent, period-dependent, and collateral costs were added to develop the total dismantling costs. A contingency was added to allow for the effect of unpredictable program problems on costs. Such a contingency is appropriate for a project of this size and type, for the reasons explained hereafter. The total dismantling costs plus contingency provide the total project cost. One of the primary objectives of every dismantling program is to protect public health and safety. The cost estimates for the dismantling activities include the necessary planning, engineering and implementation to provide this protection to the public.

Q. Has the NRC approved site-specific cost estimates utilizing TLG's cost estimating methodology?

A. Yes. The NRC has reviewed TLG's cost estimating methodology and is completely familiar with it. TLG prepared decommissioning estimates for inclusion within the decommissioning plans submitted by Northern States Power, New York Power Authority, Sacramento Municipal Utility District, Yankee Atomic Electric Company, Portland General Electric, Southern California Edison and Consumers Power Company for the Pathfinder Atomic Power Station, Shoreham Nuclear Station, the Rancho Seco Nuclear Generating Station, Yankee Nuclear Power Station, Trojan Nuclear Plant, San Onofre Nuclear Generating Station Unit 1 and for the Big Rock Point Plant, respectively. The Decommissioning Plans for each of the units have been approved by the NRC, with the exception of the Big Rock Point submittal, which is still pending.

Q. What are the major differences between nuclear and fossil power plants?

A. The major difference is the radioactivity inherent in nuclear power plants. Removal of radioactively contaminated piping, components and structures from a nuclear plant is more difficult and costly than for comparable items at a fossil plant. The activities of decontaminating, removing, packaging, shipping and burying radioactive materials from a nuclear plant require strict radiological controls, special containments and packaging, and licenses for the transport for disposal. There are many more opportunities for problems to arise in nuclear plant decommissioning than in fossil plants.

Because fossil plants have no radioactivity dismantling them is comparable to reverse construction. There are fewer potential hazards for the worker and, therefore, productivity is higher overall than with nuclear plants and the overall potential for problems is lower.

Q. Does your experience in the decommissioning of nuclear power plants aid in the preparation of a dismantling study for a fossil-fueled power plant?

A. Yes. The parallelism in approach between nuclear plant decommissioning and fossil plant dismantling enables us to rely on the field experience from nuclear decommissioning to prepare fossil plant studies. In particular, the following major areas of planning and estimating exhibit similar characteristics.

1. <u>Site Characterization</u>

The process and planning to identify the composition and extent of radionuclide contamination at nuclear power plants is similar to that required for potentially hazardous materials in fossil-fueled power plants.

2. <u>Removal of Hazardous Material (Asbestos)</u>

Planning and removal of asbestos-containing materials in nuclear and fossil plants is identical.

3. Sequencing of Work Activities

Identifying systems that are essential or non-essential to the decommissioning task and establishing the sequence for their removal entails the same considerations in both nuclear and fossil plants. Essential systems include electric power, lighting, heating, ventilation and liquid processing systems. For example, power and lighting would be retained as long as possible to avoid bringing in temporary services prematurely.

4. Management Staff

Identification of utility and decommissioning (dismantling) staffing composition and levels follows the same process in both types of units. The specific job functions will differ but the logic is the same. Management staff costs are period-dependent; that is, they are a function of the overall project duration.

5. Removal of Non-Contaminated Equipment/Structures

Removal of non-contaminated piping, components and structures are activity-dependent. The methods for their removal are identical for most of the systems and structures in each type of plant. Piping diameters and lengths are essentially identical (size-for-size plants), and the removal rate will be the same. Clean components, such as feedwater heaters and pumps, condensate pumps, demineralizer systems, etc., in nuclear plants, are the same sizes and types found in fossil plants. Steel and concrete structures are removed in the same manner in both types of plants. Removal of equipment unique to fossil plants, such as coal handling and air cleaning systems, relates to the weight of sub-components, and is accomplished by rigging and segmentation.

6. Scheduling

The scheduling of work activities for either type of plant follows the proven planning techniques of activity precedence networks and critical path management. An activity precedence network is a flow diagram of sequenced activities based upon the priority or "precedence" of completing one or more activities before starting another activity. The critical path is the longest sequence of work activities in a precedence network from project initiation to completion.

7. Collateral Cost

Collateral costs are neither activity-dependent nor period-dependent costs. They include items such as engineering, energy, licenses, permits, and taxes, etc. These items are identical in both types of plants, although specific cost values will differ.

8. Contingency

Contingency, as described more completely later in this testimony, is a cost allowance for field-related problems that are likely to occur. These problems include, for example, tool and equipment breakdown, late deliveries of supplies and equipment, and adverse weather. These field problems occur in both nuclear and fossil plant dismantling, although the specific allowances differ in each case.

9. Field Experience

The field experience in both nuclear and fossil plant dismantling for clean equipment is essentially the same. Heavy lifts of components weighing 50 to 450 tons are common in both plant types, and the planning and implementation activities are virtually identical.

In summary, nuclear plant decommissioning experience is directly applicable to fossil plant dismantling.

Q. How does this estimating process differ from construction estimating?

A. There is very little difference in the elements of cost between fossil plant dismantling and construction. Both activities must account for labor, materials, equipment, services and collateral costs (as defined earlier). The activities related to construction are similar to those for dismantling. Specifically, construction activities such as rigging components into position and welding connecting piping are comparable to dismantling activities such as cutting connecting piping and rigging components out of the structures. In the case of construction however, the pipe welds must be inspected by non-destructive methods (such as X-Ray examination), and cut out and re-welded if flaws in the weld are identified. This re-work causes schedule delays and incurs additional expense. In the case of dismantling, the pipe need only be cut once.

Problems in dismantling occur when plant drawings and specifications do not properly reflect the plant as constructed. This occurs when changes to the plant are made that have not been recorded on the as-built drawings. This can result in additional dismantling costs. However, in general, fossil dismantling estimating is comparable to construction cost estimating.

V. CONTINGENCY

Q. What is meant by "CONTINGENCY" as used in cost estimating?

A. In simplest terms, "contingency" is equivalent to "experience." Unit costs used to estimate work tend to be ideal numbers that must be adjusted to fit the real world of experience. Professional cost engineers use the term contingency to refer to these predictable costs confirmed through experience.

Q. Is the use of contingency a long established approach to cost estimating?

A. Yes. The NRC standard formula for calculating decommissioning costs (as defined in 10 CFR §50.75 and based upon studies originally prepared by Pacific Northwest Laboratory in 1978-80) provides for such a contingency, and cost engineers routinely include contingency dollars in project cost estimates.

Q. What level of contingency is incorporated within the decommissioning cost estimates relied upon by the NRC for rulemaking?

A. A 25% contingency factor was applied to the costs estimated for decontaminating and dismantling the nuclear units used as model plants in the estimates prepared for the NRC.

Q. What is the purpose of the contingency?

A. The purpose of the contingency is to allow for the costs of high probability program problems occurring in the field where the occurrence, duration, and severity cannot be accurately predicted and, as a consequence, their associated costs have not been included in the basic estimate. The American Association of Cost Engineers (AACE) (in their Cost Engineers Notebook) defines contingency as follows:

> *Contingency - specific provision for unforeseeable elements of cost within the defined project scope; particularly important where previous experience relating estimates and actual costs has shown that unforeseeable events which will increase costs are likely to occur.*

Past decommissioning experience has shown that unforeseeable elements of cost are likely to occur in the field and may have a cumulative impact. Fossil-fueled and nuclear power plants share some of the same potential problems leading to the need for contingency in cost estimates. These problem areas include:

Schedule slippages:	leading to crew overtime payments and/or project extensions
Weather delays:	loss of productivity, overtime, slippages
Labor strikes:	loss of productivity, slippages
Workers injuries:	production interruptions, additional safety training, workers compensation claims, possible increased insurance premiums

Material shipping:	rescheduling of activities, out-of-scope backcharges from subcontractors
Equipment breakdowns:	rescheduling of activities, out-of-scope backcharges from subcontractors
Regulatory inspections:	insurance inspectors, Occupational Safety and Health Act (OSHA) inspectors, federal and state EPA inspectors, state building inspectors
Hazardous materials:	special handling requirements beyond planned requirements

Nuclear power plants additionally have to deal with the special handling requirements of radioactive materials for decontamination, removal, packaging, shipping and disposal. A more extensive discussion of nuclear contingency is included in the AIF/NESP-036 Guidelines Study (Chapter 13) referred to earlier.

In the AIF study, individual contingencies ranged from 10% to 75%, depending on the degree of difficulty judged to be appropriate from our actual decommissioning experience. The overall contingency, when applied to the appropriate components of nuclear plant decommissioning costs, results in an average contingency of up to 25%.

For fossil plant dismantling, the absence of radioactive materials and their attendant potential problems simplifies the dismantling process. Individual activity contingency estimates for fossil-fueled power plants amount to an overall average of approximately 15% contingency. Independent of our preparation of this estimate for PECO, R.S. Means, "Building Construction Cost Data," suggests that a 15% contingency factor for conventional construction be used.

Q. Is a contingency an integral component of the estimate?

A. Yes. The purpose of a contingency is to provide assurance that sufficient funding is available to accomplish the intended tasks during the decontamination and dismantling process. Contingency funds are expected to be fully expended throughout the program. The contingency allowance is used in estimating decommissioning-related activities regardless of when they are performed, i.e., the contingency, in itself, does not offer protection against evolving costs and would be equally prudent on an estimate being planned in the near term as it would for future work.

Q. What experience does TLG have with the application of contingencies?

A. Contingencies are an integral part of the estimating methods employed by TLG. In addition, the use of a contingency has been recognized by many state regulatory agencies as well as the Federal Energy Regulatory Commission (FERC or Commission) as a valid cost component in decommissioning estimates. Most recently, in Docket No. ER95-1042-000, the Presiding Administrative Law Judge reaffirmed that "Commission policy supports the use of contingencies ... and, consistent with Commission precedent, there is nothing unreasonable about SERI's 21 percent contingency factor [the level requested in the decommissioning cost for the Grand Gulf Nuclear Station]. It is allowed." The use of a contingency has also been approved in estimates submitted before numerous state regulators.

Q. Have you compared estimates and actual costs for decommissioning projects that have been undertaken to date.

A. Yes. Based upon information available, TLG's estimates for recent work performed are on average within 4% of the actual costs reported (including contingency).

Q. Is the variation between estimated and actual costs due to contingency costs?

A. No. The differentials were either the result of modifications in the management of the intended program or savings in disposal costs negotiated by the licensee with the burial facility during the project. Northern States Power (NSP) had originally planned to decommission the Pathfinder facility using a decommissioning contractor. However, the company was able to realize a savings by using surplus personnel from its two operating nuclear stations to manage and perform the required decontamination and dismantling activities. Chem-Nuclear (operator of the Barnwell, South Carolina disposal facility) was awarded the large component removal project at Yankee Rowe. As the operator of one of the only commercially available disposal facilities, disposal cost reductions were not only possible but competitively advantageous in securing larger contracts. Since the contingency, as applied in the TLG's estimates, is not pricing or scope related, the correlation of estimated and actual project costs validates the need for contingency in decommissioning planning.

Q. Pennsylvania Power & Light Company's Pennsylvania base rate proceeding at Docket No. R-00943271 was the Pennsylvania Public Utility Commission's most recent opportunity to review a utility's decommissioning cost estimate prepared by TLG. In that case, did the Commission accept the inclusion of a contingency

in the decommissioning expense approved for the Susquehanna Steam Electric Station (SES).

A. No. The Pennsylvania Pubic Utility Commission (Pennsylvania PUC) adopted the ALJ's recommendation to disallow the contingency, although for reasons different than those offered by the ALJ. The ALJ characterized the contingency as a "safety factor" that may or may not be required. The Pennsylvania PUC, in its Order and Opinion dated September 27, 1995, equated contingency with the uncertainty in "evolving costs" over the funding lifetime. That is, they assumed that the contingency was included to reflect the forces that would drive increases in basic decommissioning costs in the future. Therefore, they recommended that "periodic cost updates should be substituted for the use of a one-time contingency factor."

Q. Do you agree with the definition of contingency as defined by either the ALJ or Pennsylvania PUC in Docket R-00943271?

A. No. Both the ALJ and the Pennsylvania PUC deviated from the definition and application of contingency as stated within the cost estimates developed by TLG for the Susquehanna SES. The ALJ interpreted contingency as a "safety factor." Rather, contingency funds are an integral part of the base estimate and are expected to be fully expended throughout the program. Absent the contingency, there is a significant probability that sufficient funding would not be available to accomplish the intended tasks. If expenses are accrued on the basis of an estimate without contingency, or from which contingency has been removed, the orderly progression of events in the decommissioning process can be disrupted and the financial success of the project can be jeopardized.

For example, one of the more technologically challenging tasks in decommissioning a commercial nuclear station is the disposition of the reactor vessel and internal components which have become highly radioactive after a lifetime of exposure to neutrons produced in the reactor core. The removal, segmentation and packaging of these highly radioactive components forms the basis for the critical path (schedule) for decommissioning operations. Cost and schedule are inter-dependent and any deviation in schedule has a significant impact on cost.

Disposition of the reactor vessel internals involves the underwater cutting of the complex components containing millions of curies of radioactive material. Costs are based upon optimum segmentation, handling and packaging scenarios. The schedule is primarily dependent upon the turn-around time for the heavily shielded shipping casks, including preparation, loading and decontamination of the containers for transport. The number of casks required is a function of the pieces generated in the segmentation activity, a value calculated on optimum performance of the tooling employed in cutting the various subassemblies. The risk and uncertainty associated with this task is that the expected optimization may not be achieved, resulting in delays and additional program costs. For this reason, a contingency is included to properly reflect the consequences of the expected inefficiencies in this complex activity, along with related concerns associated with specialty tooling modifications and repairs, field changes, discontinuities in the coordination of plant services, unexpected conditions, systems failure, water clarity, lighting, computer cutting software corrections, etc. Experience has shown that many of these problem areas have occurred during, and in support of, the reactor vessel segmentation activity. Contingency dollars are an integral part of the total cost to complete this task. Exclusion of this component puts at risk a successful completion of the intended tasks and, potentially, follow-on activities.

The following listing is a composite of activities, assembled from past decommissioning programs, in which contingency dollars were spent to respond to, compensate for, and/or provide adequate funding of decontamination and dismantling tasks.

Incomplete or Changed Conditions:

- Unavailable/incomplete operational history which led to a re-contamination of a work area, as a sealed cubicle incorrectly identified as being non-contaminated, was breached without controls;
- Surface coatings covering contamination that, due to an incomplete characterization, required additional cost and time to remediate;
- Additional decontamination, controlled removal and disposition of previously undetected (although at some sites, suspected) contamination due to enhanced access of formerly inaccessible areas and components;

- Unrecorded construction modifications, facility upgrades, maintenance, enhancements, etc., which precipitated scheduling delays, more costly removal scenarios, additional costs (e.g., for re-engineering, shoring, structural modifications), and compromised worker safety.

Adverse Working Conditions:

- Lower than expected productivity due to heat exhaustion in underground vaults, resulting in a change in the working hours (shifting to cooler periods of the day) and additional manpower;
- Confined space, low-oxygen environments where supplied air was necessary and additional safety precautions prolonged the time required to perform required tasks;

Maintenance, Repairs and Modifications

- Facility refurbishment required to support site operations, including those needed to provide new site services as well as to maintain the integrity of existing structures;
- Damage control, repair and maintenance from bird fouling of equipment and controls;

- Building modification, i.e., re-supporting of floors to enhance loading capacity for heavily shielded casks;
- Upgrading onsite roadways to handle heavier and wider loads; roadway rerouting, excavation and reconstruction;
- Requests for additional safety margins by a vendor;
- Requests to analyze accident scenarios beyond those defined by the removal scenario (requested by the NRC to comply with "total scope of regulation");
- Additional collection and processing of site run-off due to disturbance of natural site contours and drainage;
- Concrete coring for removal of embedments and internal conduit, piping and other potentially contaminated material not originally identified;
- Modifications required to respond to higher than expected worker exposure, water clarity, water disassociation and hydrogen generation from high temperature cutting operations;
- Additional waste containers needed to accommodate cutting particulates, inefficient waste geometries and excess material.

Labor

- Turnover of personnel, e.g., craft and health physics. Replacement of labor is costly, involving additional training, badging, medical exams, and associated processing procedures. Recruitment costs are incurred for more experienced personnel and can include relocation and living compensation;

- Additional personnel required to comply with NRC mandates and requests;
- Replacement of personnel due to non-qualification and/or incomplete certification (e.g., welders).

Schedule

- Schedule slippage due to a conflict in required resources, i.e., the licensee was forced into a delay until prior (non-licensee) commitments of outside resources were resolved;
- Weather related delays in the construction of facilities required to support site operations (with compensation for delayed mobilization made to vendor);
- Rejection of material by NRC inspectors, requiring refabrication and causing program delays in activities required to be completed prior to initiating decommissioning operations.

Weather

- Frozen crane hydraulics prior to a major lift;

- Destruction of an exterior asbestos containment enclosure due to violent winds.

Although not included within the application of the contingency, the factors listed below have an equal probability of affecting the cost and performance of the decommissioning program:

- Transition activities and costs: ancillary expenses associated with eliminating up to 80% of the site labor force shortly after the cessation of plant operations. Added cost for worker separation packages throughout the decommissioning program, state mandated retraining and retention incentives for key personnel;
- Delays in approval of the decommissioning plan due to intervention, public participation in local advisory committees, state and local hearings, etc.;
- Regulatory changes, such as those affecting worker health and safety, site release criteria, waste transportation, and waste disposal; and
- Policy decisions altering federal and state commitments, e.g., in the ability to accommodate certain waste forms for disposition, or in the timetable for such.

These concerns (with the exception of the first, which in some instances can be quantified), are typically addressed in a Risk and Uncertainty analysis against which probabilities are assigned and confidence traded against cost. Other areas addressed in such an analysis would include the probabilities associated with the uncertainties in predicting the costs of goods and services prior to their actual purchase, scope omission and error, escalation, schedule, scope growth, and "Acts-of-God".

Q. How are these uncertainties addressed in decommissioning funding?

A. While uncertainties can be addressed through probabilistic assessment, these areas of uncertainty are more in line with the "evolving costs" referred to by the Pennsylvania PUC. TLG has and continues to address these changes in periodic updates, rather than through the use of contingency. However, the opportunity to revisit an estimate and adjust collections may not always be available.

VI. DECOMMISSIONING REGULATIONS

Q. Are there any federal regulations applicable to nuclear plant decommissioning?

A. Yes. The NRC published the Final Rule entitled "General Requirements for Decommissioning Nuclear Facilities" in the Federal Register of June 27, 1988 (53 Fed. Reg. 24018) to establish technical and financial criteria for decommissioning licensed facilities. The regulations addressed decommissioning planning needs, timing, funding methods, and environmental review requirements with the intent to assure that decommissioning of all licensed facilities would be accomplished in a safe and timely manner and that adequate licensee funds would be available for this purpose. In 1996, the NRC published revisions to the general requirements for decommissioning nuclear power plants. The Commission amended the decommissioning regulations to clarify ambiguities and codify procedures and terminology as a means of enhancing efficiency and uniformity in the decommissioning process. The amendments allow for greater public participation and better define the transitioning process from operations to decommissioning. The decommissioning cost estimates prepared for PECO's stations fully satisfy the requirements set forth in these regulations.

Q. Describe the decommissioning alternatives delineated in the NRC Rule for *nuclear utilities.*

A. The supplemental information to the NRC Rule (53 Fed. Reg. 24022-23) describes three decommissioning alternatives as acceptable: DECON (prompt removal/dismantling), SAFSTOR (mothballing) and, under special circumstances, ENTOMB (entombment). They are defined as follows:

> **DECON** is the alternative in which the equipment, structures, and portions of a facility and site containing radioactive contaminants are removed or decontaminated to a level that permits termination of the license and allows the property to be released for unrestricted use shortly after cessation of operations;
>
> **SAFSTOR** is the alternative in which the nuclear facility is placed and maintained in a condition that allows the nuclear facility to be safely stored and subsequently decontaminated (deferred decontamination) to

levels that permit termination of the license and release for unrestricted use.

ENTOMB is the alternative in which radioactive contaminants are encased in a structurally long-lived material, such as concrete; the entombed structure is appropriately maintained and continued surveillance is carried out until the radioactivity decays to a level permitting termination of the license and unrestricted release of the property.

It should be noted, however, that the NRC provides that delayed decommissioning following initial mothballing or entombment activities should not exceed 60 years, unless it can be shown that a longer period is necessary to protect public health and safety (10 CFR 50.82 (b) (1)). This rule discourages the use of the ENTOMB alternative unless specific advantages can be shown (see 53 Fed. Reg. 24023-24). The presence of long-lived radioisotopes at commercial generating units diminish any advantage from delay. However, both the DECON and SAFSTOR alternatives are considered reasonable options for decommissioning the PECO nuclear stations.

Q. Is it necessary to select a specific decommissioning method at this time?

A. No. The actual method or combination of methods selected to decommission Limerick, Salem and Peach Bottom should be based on a detailed economic, engineering and environmental evaluation of the alternatives considering the sites and surroundings at the time of decommissioning and reflecting the latest experience in the decommissioning of similar nuclear power facilities.

Q. What are your recommendations regarding the alternative selection?

A. I recommend that, for planning purposes, the decommissioning cost funding be based upon removal of Limerick, Salem and Peach Bottom using the DECON alternative. This alternative provides the most reasonable means for terminating the license for the site in the shortest possible time, consistent with the NRC's timeliness objectives. Furthermore, this alternative avoids the long-term costs and commitments associated with the maintenance, surveillance and security requirements of the conventional delayed dismantling alternatives.

The recommended alternative also allows use of the plant's knowledgeable current operating staff, a valuable asset to a well-managed, efficient decommissioning program. All equipment needed to support decommissioning operations such as cranes, ventilation systems and radwaste processing equipment would be fully operational.

Q. Would you describe the process of decommissioning a nuclear power reactor utilizing the DECON alternative?

A. Yes. The conceptual approach that the NRC has identified in their amended 10 CFR Part 2, 50 and 51 regulations is to divide decommissioning into three phases. Phase I commences with the effective date of permanent cessation of operations and involves the transition of both plant and licensee from reactor operations, i.e., power production to facility de-activation and closure. During Phase I, notification is to be provided to the NRC certifying the permanent cessation of operations and the removal of fuel from the reactor vessel. The licensee would then be prohibited from operating the reactor. Within two years of notification to cease reactor operations, the licensee must provide a Post-Shutdown Decommissioning Activities Report (PSDAR). This report would provide a description of the licensee's planned decommissioning activities, a corresponding schedule and an estimate of expected costs. The PSDAR should also address whether environmental impacts associated with the proposed decommissioning scenario have already been considered in a previously prepared environmental statement(s). Ninety days after the NRC's receipt of the PSDAR, the licensee can initiate certain decommissioning activities without specific NRC approval, under a modified §50.59 review process. The amended regulations would permit the licensee to expend up to 3% of the generic decommissioning cost for planning, with an additional 20% available following the 90-day waiting period and certification of permanent defueling. Remaining funds would be available to the licensee with submittal of a detailed, site-specific cost estimate.

Phase II as identified by the NRC in its rule, addresses licensed activities during a storage period. The Phase II requirements are applicable to the dormancy phases of deferred decommissioning alternatives, i.e., SAFSTOR and ENTOMB.

Phase III pertains to the activities involved in license termination. The submittal of an application to terminate the license, along with a termination plan, marks the start of this phase. The termination plan should contain a detailed site characterization, i.e., location, type and amount of radioactivity, a description of any remaining dismantling activities to be accomplished, detailed plans for a final survey and the planned end use of the site. An updated cost-to-complete would be required along with the reporting of any new or altered environmental consequences.

TLG's estimate for DECON addresses Phases I and III in three subperiods, as follows:

Period 1 - Site Preparations: This period begins upon shutdown of the facility and involves site preparations to initiate decommissioning. The reactor would be defueled, with the fuel placed in the spent fuel pool until it is cooled sufficiently to be transferred to DOE or an alternative storage facility. Transportation and disposal of spent fuel at a DOE facility is not considered part of decommissioning, and no costs associated with these activities are included in the decommissioning estimates. However, transportation and disposal can affect the decommissioning schedule due to the presence of such material on-site. The potential impact of these activities on the schedule has been addressed in the study. Wastes remaining from plant operations would be removed from the site, and all systems that are not essential to decommissioning would be isolated and drained.

Period 2 - Decommissioning Operations: This period begins upon NRC acceptance of the PSDAR and the mobilization of the decontamination and dismantling workforce. This phase of the work involves the removal of radioactivity from the site and concludes with termination of the NRC operating license. The activities in this period include selective decontamination of contaminated systems, e.g., using aggressive chemical solvents to dissolve corrosion films holding radionuclides, thereby reducing radiation levels. Decontamination will reduce personnel exposure and permit workers to operate in the immediate vicinity of most components while cutting and removing them for controlled disposition at a low-level radioactive waste burial facility. Although the on-site decontamination processes are effective for their intended purposes, they are not designed to reduce residual radioactivity to the levels necessary to release the material as clean scrap. Therefore, all contaminated components will have to be removed for controlled burial.

Contaminated piping connecting major components will be cut and removed. Selected major components such as the reactor recirculation pumps, moisture separators and feedwater heaters will then be removed intact and sealed so that they may be shipped as their own containers for disposal. Smaller components, such as sampling system pumps, filters, filter housings, strainers, etc., will be loaded into containers and shipped for burial.

The reactor vessel and its internals will be segmented and remotely loaded into steel liners for transport to the burial facility in heavily shielded shipping casks. The reactor vessel and internals will have sufficiently high radiation levels to require all cutting to be done underwater or behind heavy shields, using cutting torches operated by remote control to reduce radiation exposure to the workers.

Concrete immediately surrounding the reactor vessel is expected to be radioactive and will be removed by controlled blasting. This blasting process is well-developed and safe and is the most cost effective way to remove the heavily-reinforced concrete from the structure. The surface of sections of interior floors within areas of the Reactor Building (Containment) and other buildings in the power block is expected to be contaminated from exposure to contaminated air/water as a result of plant operations. This contamination will be removed by scarification (surface removal) so that the remaining surface will be clean and will not require costly controlled burial.

Finally, an extensive radiation survey will be performed to ensure all radioactivity above the levels specified by the NRC has been removed from the site. With NRC confirmation, the facility may be released for unrestricted access, and the operating license terminated (once the spent fuel has been relocated to an independent licensed facility).

Period 3 - Site Restoration: This period, which begins once the operating license termination activities have concluded, involves the demolition of all remaining structures to a depth, typically, of three feet below grade. Clean rubble would be used on-site for fill, and additional soil would be used to cover each subgrade structure.

Q. Please describe the process of dismantling a fossil power plant and how that process was reflected in the PECO study.

A. Approximately three months prior to final shutdown, engineering and planning would begin on the preparation of the Dismantling Engineering Plan (Plan) and Environmental Report (ER). The Plan describes the status of the facility at shutdown, work to be accomplished, safety analyses associated with each of the major activities, general procedures and sequence to be followed, and final site condition upon completion of all work. Similarly, the ER would evaluate environmental effects to workers and the public and waste generation effects on the site and environment. These documents would be submitted to the Environmental Protection Agency and other applicable regulatory agencies for review, approval, and authorization to proceed. The sequence of work would proceed as follows:

Period 1 - Site Preparations: Site preparations would begin upon shutdown of the facility and would involve site work needed to initiate dismantling. It is assumed that all fuel was burned prior to shutdown or was transferred to another operating unit.

Period 2 - Dismantling Operations: This work would begin upon receipt of all necessary regulatory approvals. This phase of the work involves the removal of all components of the boiler, air quality treatment systems (electrostatic precipitators, flue gas desulfurization systems, etc.), fuel handling systems (coal conveyors, crushers, oil storage tanks, etc.), the turbine-generator, and the condensate and feedwater systems. In general, the boiler will be dismantled in a bottoms-up mode, whereby the lower sections of the boilers will be cut at grade level, and remaining upper sections lowered to grade or scaffolding erected to cut the upper sections of the boiler furnace. This method of dismantling is necessary for the top-hung type of boiler that is supported from the steel structure. Care must be taken to ensure that sections are removed uniformly from the bottom to avoid any unbalanced load on the steel structure that may cause it to become unstable.

Steel structures used to support the boiler and turbine-generator components will be dismantled by controlled demolition and lowering sections to grade by cranes to prevent injury to workers on lower floors. The steel structures will be dismantled from the top down which essentially reverses the construction sequence.

Concrete structures such as boiler foundations, floors, turbine-generator pedestals and support buildings will be demolished by conventional wrecking methods. These may include the use of wrecking balls, pneumatically-operated rams on a backhoe, or controlled blasting.

Period 3 - Site Restoration: Site restoration involves the re-grading of all areas that were disturbed by the dismantling process. Structures will be removed to three feet below grade to permit re-vegetation of the site or to eliminate at-grade hazards. Clean rubble would be used on site for fill, and additional soil would be used to cover each subgrade structure. The site would be graded and stabilized.

VII. HIGH-LEVEL RADIOACTIVE WASTE

Q. Does the estimated cost of decommissioning include an allowance for disposal of high-level radioactive waste?

A. No. It is important to note that, although decommissioning of a site cannot be complete without the removal of all spent fuel and source material, the disposition of high-level waste is outside the scope of decommissioning. In accordance with the Nuclear Waste Policy Act of 1982 (Public Law 94-425), the DOE is required by law to enter into contracts with owners and/or generators of spent fuel, pursuant to which the DOE is contractually responsible for final disposition of spent fuel as high-level nuclear waste. To cover the cost of spent fuel disposition, the DOE assesses the facility operator 1 mill/Kwh based on electrical generation. Therefore, the cost of disposal of spent fuel is accounted for separately and is specifically excluded from the decommissioning cost estimates.

Q. Does the presence of spent fuel on-site, following plant shutdown, impact the decommissioning processes?

A. Yes. Although the decommissioning studies do not address the removal or disposal of spent fuel from the nuclear sites, they do consider the constraint that the presence of spent fuel on the site can impose on other decommissioning activities. In particular, the decommissioning scheduling performed in support of the cost studies recognizes delays due to the present uncertainties surrounding the disposal of spent fuel in the United States. It is currently anticipated that all three of PECO's nuclear generating sites will need to provide for extended storage and caretaking of their respective spent fuel inventories until such time as off-site disposal becomes an option.

The presence of the spent fuel storage facilities will necessarily delay the final release of the sites for alternative/unrestricted use. This delay is reflected in the increased cost of the period-dependent activities. To the extent possible, the decommissioning estimates were structured around the spent fuel areas of the stations and their availability for decontamination, such that delays in decommissioning other portions of the facility could be minimized. The study assumed that an Independent Spent Fuel Storage Installation (ISFSI) would be available at each site in support of plant operations. These facilities are assumed to be expanded to accommodate the additional spent fuel residing in the spent fuel storage pools at shutdown so that the Reactor Building can be released for decommissioning (for the DECON scenario). Decommissioning would proceed on the surrounding facilities and non-essential systems during the transfer period. Current expectations are for the last spent fuel bundles to remain at the Limerick site until 2046, the Salem site until 2043 and at the Peach Bottom site until 2041.

Q. What is the basis for the spent fuel management plan?

A. The transfer of spent fuel from the two stations to the government's geologic or interim storage facility is based upon a 2010 startup date and fuel shipments at the acceptance rate proposed in current legislation.

VIII. SITE RESTORATION

Q. Does the process of decommissioning extend beyond the removal of contaminated and activated material from the site?

A. Yes. There are additional activities, beyond the removal of contaminated material, that will be undertaken in the process of releasing the site for alternative use. This work includes costs for the remaining dismantling and grading operations.

Q. Are there any regulations or codes applicable to dismantling?

A. Yes. The Building Officials & Code Administrators (BOCA) National Building Code, widely adopted by most states, including Pennsylvania, requires that retired structures may not be left in an unsafe condition. Specifically, Section 120.1, "Right to Deem Unsafe," states:

> *All buildings or structures that are or hereafter shall become unsafe, unsanitary or deficient in adequate means of egress facilities, or which constitute a fire hazard, or are otherwise dangerous to human life or the public welfare, or which involve illegal or improper use, occupancy or maintenance, shall be deemed unsafe buildings or structures. <u>All unsafe structures shall be taken down and removed or made safe and secure, as the code official deems necessary and as provided for in this section.</u> A vacant building, unguarded or open at door or window shall be deemed a fire hazard and unsafe within the meaning of this code.*

(Emphasis Added)

A retired power plant fits this definition of an unsafe structure which must be taken down and removed or made safe and secure.

Q. Why is dismantling after a power plant is taken out of service the appropriate alternative?

A. Securing, maintaining and guarding retired power plants indefinitely is costly, requiring either a full-time guard force or intrusion detection devices and alarms monitored by local law enforcement agencies, as well as general building maintenance to keep the structures in a safe condition.

Q. Is reuse of the site for a power plant a potential use?

A. Yes.

Q. If the site could be reused, why couldn't the power plant components be reused in repowering?

A. The designs of new generation power plants are not likely to use the same size and configuration of components, nor require the same type of building enclosures. Optimum facility design will be sized to match the megawatt size of a replacement power plant, if any, either larger or smaller. For example, new combustion turbine-generators are modular, self-contained units that don't need a building enclosure. Combined cycle units may require larger turbine buildings to enclose the waste heat steam generators which supply steam to the turbine. The cost to renovate older buildings and bring them to current safety code standards, combined with the less-than-optimum facility design makes reuse of the existing buildings an unlikely scenario. Furthermore, the existing components are likely to be of an obsolete design, more costly to operate and maintain and may not be compatible with new instrumentation and control systems.

Q. Please describe the cost components of site restoration.

A. The largest component of the site restoration costs is for dismantling the decontaminated structures. Next largest are costs incurred to remove certain non-contaminated systems and components. This work must be accomplished to provide access to all areas of the plant for the radiation surveys required by the NRC prior to license termination and release of the site for another use.

Q. Why is it necessary to dismantle the remaining structures at the site?

A. Efficient removal of the contaminated materials and verification that the radionuclide concentrations are below the stringent NRC limits will require substantial damage to many of the structures. Blasting, coring, drilling, scarification (surface removal), and the other decontamination work will damage power block structures including the Reactor, Radwaste and Turbine Buildings.

Verifying that subsurface radionuclide concentrations meet NRC site release requirements may require removal of grade slabs and lower floors, potentially weakening footings and structural supports. This will be necessary for those facilities and plant areas where historical records indicate the potential of radionuclides having been present in the soil, where inventory losses have been recorded, or where required to confirm that subsurface process and drain lines did not leak over the operating life of the units.

It is also important to remember that the structures were custom designed and built to support a specific nuclear unit that went into service in the 1970s in the case of Peach Bottom and Salem and the 1980s in the case of Limerick. They would most likely be an impediment rather than a benefit to any potential future plant, if one were ever to be constructed at the site. Moreover, the facility's infrastructure degrades without continual maintenance. Unless the site is redeveloped shortly after release of its NRC license, the value in reusing plant facilities quickly diminishes. For example, following NASA's development of TVA's abandoned Yellow Creek nuclear power plant for its Advanced Solid Rocket Motor program, a Lockheed spokesman was quoted as stating: "[t]he abandoned nuclear power plant contributed little to the NASA project. Some of the power and water infrastructure was used but had to be reconstructed after eight years of neglect."

Dismantling is clearly the most appropriate and cost-effective option and should serve as the foundation for the decommissioning cost estimate. It is unreasonable to anticipate that these structures would be repaired and preserved after the radiological contamination is removed.

Q. Why is it necessary to dismantle a fossil-fired plant?

A. Remediation of fossil-fired facilities is inherently destructive, including creation of large access ways, dismantling of peripheral structures, controlled blasting, removal of roofs and walls, excavation of footings, etc. Precluding reconstruction, a retired fossil facility poses hazards including large interior open areas, pits, shafts and underground tunnels. With many of the plant services removed from service, the structures would be unheated, dark, littered with concrete rubble and structural debris obstructing means of egress. Condensation and groundwater intrusion and bird infiltration would soon create hazardous conditions, promoting unsanitary biological infestations, accelerating corrosion and general facility deterioration. A dedicated and systematic maintenance program is necessary to maintain the facility in a "safe" condition. Security measures are necessary to limit the liability inherent in casual or deliberate intrusion by the public. These maintenance and surveillance programs are expensive.

The steel and concrete or brick structures at fossil sites were not designed to prevent deliberate intrusion. Large glass windows, sheet metal siding, loading ramps and multiple ingress points allow easy entry into the station confines. Visitation of older, shutdown units has conclusively demonstrated both the speed and effects of facility deterioration. Such deterioration includes broken windows, leaking roofs, torn or damaged siding, obstructed stairwells with poor egress, and unsanitary conditions caused by the effects of weather, corrosion, ground water intrusion and vermin. Stacks, mine openings, fill ponds and lagoons with steep sloped banks, and river intake structures are high exposure liabilities and inherently dangerous to human life.

The alternative to perpetual caretaking and site surveillance is to dismantle the site as soon as practical. This activity is the most cost-effective when included within the schedule for site remediation, due to resources available on-site and the expected condition of the facilities.

The Pennsylvania Public Utilities Commission has acknowledged that dismantling of the decommissioned structures, following license termination at nuclear power plants, is an appropriate measure to protect public health and safety. The same safety concerns exist at retired fossil power stations, and for this reason TLG recommends dismantling fossil power plant structures

IX. SALVAGE AND SCRAP

Q. How was scrap or salvage credit included in the overall estimate?

A. Credit for carbon steel, stainless steel and copper scrap was included in the overall fossil estimates based on current published scrap values. No credit was included for salvage of any components because these components will be of an obsolete design by the time these plants are dismantled. The labor cost to recover potentially salvageable materials (valves, pumps, motors, etc.), and to store, protect, package and transport these components is not warranted. As such, these materials were considered as scrap.

No positive value was assumed for the scrap generated in the decommissioning of the nuclear units primarily due to the off-setting expense of the surveying required to verify to a 100% confidence level that material leaving the site has no detectable radionuclide contamination.

X. DECOMMISSIONING FEASIBILITY

Q. What is the feasibility of the decommissioning premise?

A. There is extensive experience in the United States and in other countries for the complete dismantling of fossil and nuclear power plants and other large industrial facilities such as chemical refineries and steel mills. This directly related experience shows that the PECO units can be completely dismantled safely.

Between 1960 and 1995, 103 licensed nuclear reactors in the U.S. were designated for decommissioning or were in the process of being decommissioned. Of these, sixteen were designed as commercial nuclear power plants, four were demonstration nuclear power plants, eight were licensed test reactors, and 55 were research reactors. The remaining 20 were critical (non-power producing) reactors and/or critical facilities decommissioned or scheduled to be decommissioned. They have been or will be totally dismantled, and their licenses have been or will be terminated. Many other reactor facilities in Europe, Japan and Canada have been successfully decommissioned using demonstrated techniques. France has decommissioned 13 reactors, Germany 6, Italy 8, Japan 7, Switzerland 2, United Kingdom 5 and Canada 2.

The International Atomic Energy Agency (IAEA) indicates that 147 decommissioning programs have been undertaken or completed by its member countries. However, no breakdown is available for the various types of reactors from the IAEA.

The feasibility of decommissioning in the U.S. is well documented in the successful dismantling of Shippingport Atomic Power Station, Elk River Reactor, Walter Reed Army Research Reactor, Ames Laboratory Reactor and Sodium Reactor Experiment (SRE) facilities. Internationally, the decommissioning programs underway in England (Windscale Reactor), Germany (Gundremmingen), and Japan (Japan Power Demonstration Reactor) are further evidence of demonstrated technology. The basic activities of cutting pipe, segmenting vessels, demolishing reinforced concrete and decontaminating contaminated systems and structures are the same on a unit cost factor basis ($/cut, $/cubic yard, etc.) regardless of the size of the structure or megawatt rating of the plant. For example, a contaminated 12-inch diameter pipe in a 3000 MWt plant takes as long to cut as it does in a 58 MWt plant, although the length of pipe to be cut will be greater in the larger plant.

The major activities include removal of contaminated piping and components using conventional power hack saws, oxyacetylene torches or plasma arc torches within a contamination control tent. Removal of the reactor vessel and internals can be accomplished using an arc-gouging fuel gas torch or an arc saw, which is currently capable of cutting through carbon and stainless steel up to 12 inches thick (current vessels are less than 10 inches thick).

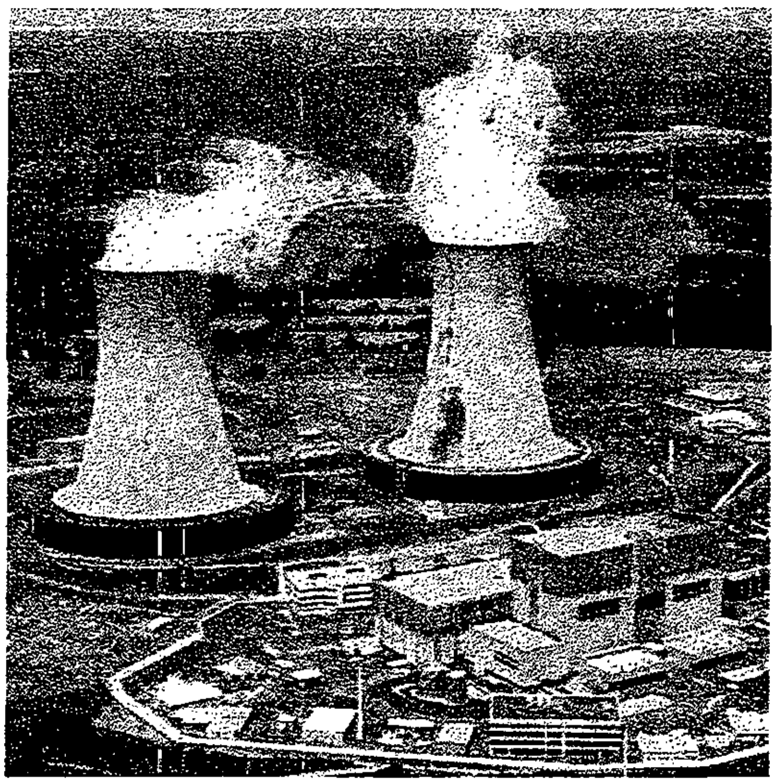
The remote manipulator technology required to cut the reactor vessel and internals was developed by Oak Ridge National Laboratory for the Elk River Reactor dismantling. This technology uses the plasma arc torch for cutting. This same tool was used in the SRE vessel cutting activity. Many of the tools and techniques used in decommissioning have been used in operating plants for maintenance and equipment replacement programs. Such technology, therefore, is not unique and further shows the feasibility of decommissioning.

Controlled blasting concrete demolition methods are well developed and have been used extensively in the mining industry. These same techniques were successfully employed in the demolition of the Elk River Reactor, where eight-foot thick, heavily reinforced concrete sections of the biological shield were safely removed with explosives without damaging or interfering with the operation of adjacent operating power generating units. The successful application of these decommissioning techniques in both small and large nuclear power plants assures decommissioning feasibility. Both the technology and the methodology for efficient decommissioning are available and fully tested.

Q. Does this conclude your prepared direct testimony?

A. Yes.

DECOMMISSIONING COST ESTIMATE
for the
LIMERICK GENERATING STATION
UNITS 1 AND 2



prepared for

PECO ENERGY COMPANY

May 1996

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TLG Services, Inc.

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0		5/6/96		Original Issue

EXECUTIVE SUMMARY

This study, prepared for PECO Energy Company (PECO) by TLG Services, Inc., evaluates two different decommissioning alternatives for the Limerick Nuclear Generating Station Units 1 & 2 (LGS), following the final cessation of plant operations. The estimated costs for the DECON alternative are $368,890,000 and $466,542,000 for Unit 1 and Unit 2, respectively (in 1995 dollars). For the SAFSTOR alternative, with deferred decommissioning to be completed within 60 years, the costs are estimated to be $421,706,000 and $539,268,000 for Unit 1 and Unit 2, respectively.

This study provides cost estimates for decommissioning LGS under current requirements and is based upon present-day technology. Using plant drawings and inventory documents and databases, TLG estimated quantities and volumes of equipment and material to be removed during decommissioning. Unit cost factors are applied to the volumes and quantities to develop the activity-dependent costs. The period-dependent costs are then determined from a detailed critical path schedule based on the removal activity durations.

This study includes the following considerations:

> Burial of low-level radioactive waste is assumed to be at a regional site to be designated at a future date by the Appalachian Compact. Disposal costs are based on rates in effect as of July 1, 1995, at the Barnwell Low-Level Radioactive Waste Management Facility, as a proxy;
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> Volume reduction and decontamination of low-level radioactive waste, as a means of reducing disposal costs, is assumed to be performed by an off-site radioactive waste recovery vendor;
>
> Low-level waste classified as "Greater-Than-Class-C" is packaged for disposal along with the high-level spent nuclear fuel and disposed of at a cost comparable to that envisioned for spent fuel.

Contingency is included in the estimate to address the many uncertainties that exist in a project of this nature. The analysis, prepared on a line item basis, uses a range of contingencies selected to reflect conditions and uncertainties to be present at the time of decommissioning.

In addition to the estimated costs, the report includes program schedules, scrap projections and estimates of occupational radiation exposures and low-level radioactive waste volumes inherent in the proposed decommissioning scenarios.

1. SUMMARY

The Limerick Generating Station (LGS) is located in southeastern Pennsylvania on the Schuylkill River about 1.7 miles southeast of the limits of the Borough of Pottstown and about 20.7 miles northwest of the Philadelphia city limits. The Schuylkill River passes through the site and separates the western portion, which is located in East Coventry Township, Chester County, from the eastern portion, which is partly in Limerick Township and partly in Lower Pottsgrove Township, both in Montgomery County, Pennsylvania. All of the major plant structures are located in Limerick Township. This study addresses the decommissioning of LGS Units 1 and 2 which are essentially identical boiling water reactors with supporting facilities. PECO Energy Company (PECO) is the primary owner and operator of the two nuclear units. In addition to cost, this study also evaluates schedule, waste generation/disposition, and occupational exposure. The study is based upon the DECON (prompt removal/dismantling) and SAFSTOR (mothball with delayed dismantling) decommissioning alternatives.

DECON of a power reactor consists of the removal of all fuel assemblies and source material, radioactive fission and corrosion products, and all other radioactive materials having activities above Regulatory Guide 1.86, "Termination of Operating Licenses for Nuclear Reactors", NUREG 5512, "Residual Radioactive Contamination from Decommissioning" and other applicable release limits shortly after the cessation of plant operations. The facility operator may then have unrestricted use of the site with no requirement for a Nuclear Regulatory Commission (NRC) license. This scenario is equivalent to the DECON mode as described in the rule on decommissioning issued by the NRC, "General Requirements for Decommissioning Nuclear Facilities." The balance of plant systems and structures are assumed to be removed to below site grade. The site is then made available for alternative use.

There are advantages to the DECON alternative. The alternative is less costly, in 1995 dollars, than the scenarios involving extended delays in the station dismantling. (The ultimate cost for any alternative will depend upon future economic factors such as inflation and policy factors, e.g., future NRC regulations and waste policy decisions and actions.) DECON eliminates a potential long-term safety hazard and those individuals familiar with the nuclear facility will still be available to support the dismantling effort. DECON also relieves the utility of long-term obligation and liability for maintenance of the property.

SAFSTOR consists of placing and maintaining the facility in protective storage once the spent fuel and source material are removed or relocated. Concurrently, the plant staff conducts general plant decontamination activities, radiation surveys, and the processing and removal of any radioactive waste materials remaining from operations. Modified security, surveillance and maintenance plans for the delay period are implemented. Delayed dismantling (decontamination) activities are initiated such that license termination is accomplished within the 60-year time period set by the NRC. As with the DECON alternative, this study further assumes that the remainder of the reactor facility is dismantled and site restoration is performed.

The cost for the SAFSTOR alternative is increased by the cost incurred in maintaining the station in protective storage. However, there are advantages over the DECON alternative. Primarily, the dormancy period provides a period of decay for the residual radioactive material, resulting in potentially lower personnel radiation exposures during dismantling, than are incurred in the DECON alternative. There is also the potential savings (at current prices), in the cost for disposal of the waste volume generated during decommissioning operations due to a reduction in activity levels.

While the disposal cost of spent fuel assemblies generated during plant operations is not considered a decommissioning expense, the presence of those assemblies on site does have a bearing on the cost to decommission. This study recognizes that the current wet spent fuel storage facilities at LGS Unit 2 will remain active for approximately 5 years after operations cease at the unit. This duration is based upon the current minimum design criteria for dry storage as well as the Department of Energy's (DOE) minimum acceptance criteria for fuel turnover and transfer to a federal repository. It is assumed that the spent fuel pool inventory at shutdown will be transferred within this period, to an on-site Independent Spent Fuel Storage Installation (ISFSI) to await DOE acceptance.

This study provides cost estimates for decommissioning LGS under current requirements based upon present-day costs and available technology. Cost and schedule estimates presented herein are based upon the complete removal of all components and structures within the property lines, as the station is presently configured, except as noted within the body of this report. A summary of costs and schedule, for each alternative, are provided in Table 1.1. Detailed cost reports for each decommissioning alternative and nuclear unit are provided in Appendix C. The schedule and sequence of decommissioning activities is identified in Section 5 of this document.

TABLE 1.1

LIMERICK GENERATING STATION UNITS 1 AND 2 COST AND SCHEDULE ESTIMATE SUMMARY

	Cost, 95$ (thousands)[1]	Schedule (months)[1]
DECON (Prompt Removal/Dismantling)		
Unit 1	368,890	138.78[4]
Unit 2	466,542	84.60
STATION TOTAL	**835,432[2]**	**138.78[3]**
SAFSTOR (Mothball with Delayed Dismantling)		
Unit 1		
Preparations	47,294	18.0
54.6 year maintenance cost	71,679	655.2
Delayed dismantling	302,733	78.5[5]
Subtotal Unit 1	421,706	751.7
Unit 2		
Preparations	37,752	18.0
51.2 year maintenance cost	135,684	614.4
Delayed dismantling	365,832	65.2
Subtotal Unit 2	539,268	697.6
STATION TOTAL	**960,974**	**751.7**

1. Columns may not add due to rounding.
2. Post-decommissioning dry storage operating costs included with the Unit 2 total.
3. Does not include 120 months for ISFSI operations and demolition.
4. Includes a 75.7-month site restoration delay period.
5. Includes a 16.1-month site restoration delay period.

2. INTRODUCTION

This analysis is designed to provide PECO Energy Company (PECO) with sufficient information to prepare financial planning documents required by the Pennsylvania Public Utility Commission, the U.S. Nuclear Regulatory Commission, or other regulatory bodies. It is not a detailed engineering document, but a cost estimate prepared in advance of the detailed engineering preparations which will be necessary to carry out the decommissioning of Units 1 and 2 at the Limerick site.

2.1 OBJECTIVE OF STUDY

The objective of this study is to prepare an estimate of the cost, schedule, occupational exposure and waste volume generated to decommission LGS including all common and supporting facilities. The study considered the integration of the two-unit dismantling, as discussed below.

For the purposes of this study, the shutdown dates were taken as October 26, 2024, for Unit 1 and June 22, 2029, for Unit 2. This time frame was used as an input in scheduling the decommissioning activities.

2.2 SITE DESCRIPTION

LGS is located in southeastern Pennsylvania on the Schuylkill River approximately 21 miles northwest of Philadelphia, Pennsylvania. The station is comprised of two essentially identical boiling water reactors with supporting facilities.

The Nuclear Steam Supply System (NSSS) consist of a boiling water reactor system designed by General Electric. The Reactor Recirculation System is comprised of the reactor vessel and two recirculation pump loops external to the reactor vessel which provide the driving flow of water to the reactor vessel jet pumps. Each external loop contains one high-capacity, motor-driven recirculation pump and two motor-operated gate valves for pump maintenance. The recirculation loops are a part of the nuclear system process barrier and are located inside the containment structure. The design reactor thermal power level is 3,458 Megawatts thermal (Mwt). The corresponding net electrical output is approximately 1,055 Megawatts electric (MWe).

The containment system at LGS is comprised of a primary containment and a secondary containment. Primary containment is a Mark I type containment. It is comprised of a steel, light-bulb shaped pressure vessel (drywell) with a steel torus-shaped pressure chamber below, encircling the drywell. The drywell and the suppression chamber are connected by pipes. The drywell is anchored to a reinforced concrete envelope. The torus-shaped suppression chamber is housed in a dedicated room. Secondary containment is comprised of the reactor building, in conjunction with the HVAC (Heating, Ventillation and Air Conditioning) and standby gas treatment system.

Heat produced in the reactor is converted to electrical energy by the power conversion system. A turbine-generator system converts the thermal energy of steam produced in the reactor into mechanical shaft power and then into electrical energy. The turbine consists of a high-pressure, double-flow turbine element, and three double-flow, low-pressure turbine elements all aligned in tandem. The generator is driven at 1800 rpm and rated at 1265 MVA. The exhaust steam from the turbine is condensed and deaerated in the main condenser. The heat rejected to the main condenser is removed by the circulating water system.

The Circulating Water System provides the heat sink required for removal of waste heat in the power plant's thermal cycle. The system has the principal function of removing heat by absorbing this energy in the main condenser. Water is withdrawn from the Schuykill River via the intake tunnels by the circulating water pumps. After passing through the plant condensers, the discharge is routed through two cooling towers then back to the river.

2.3 REGULATORY GUIDANCE

The NRC provides decommissioning guidance in the rule "General Requirements for Decommissioning Nuclear Facilities" (Ref. 1) in addition to that previously set forth in Regulatory Guide 1.86 (Ref. 2). This rule defines three decommissioning alternatives acceptable to the NRC, i.e., DECON (prompt removal/dismantling), SAFSTOR (mothball), and ENTOMB (entombment).

<u>DECON (Prompt Removal/Dismantling)</u> is defined by the NRC as "the alternative in which the equipment, structures, and portions of a facility and site containing radioactive contaminants are removed or decontaminated to a

level that permits the property to be released for unrestricted use shortly after cessation of operations."

SAFSTOR (Mothball) is defined by the NRC as "the alternative in which the nuclear facility is placed and maintained in a condition that allows the nuclear facility to be safely stored and subsequently decontaminated (deferred decontamination) to levels that permit release for unrestricted use."

ENTOMB (Entombment) is defined by the NRC as "the alternative in which radioactive contaminants are encased in a structurally long-lived material, such as concrete; the entombed structure is appropriately maintained and continued surveillance is carried out until the radioactive material decays to a level permitting unrestricted release of the property." However, this process is restricted in overall duration and therefore limited in application unless it can be shown that a longer duration is necessary to protect the health and safety of the public.

Prior to this rule, no endpoint was identified for either the SAFSTOR or ENTOMB process, i.e., a facility could remain in either state indefinitely. This is no longer the case as the rule places limits on the time allowed to complete the decommissioning process. Consequently, with the new restrictions, the SAFSTOR and ENTOMB options are no longer decommissioning alternatives in themselves, as neither terminates the license for the site. At the end of the dormancy period, up to 60 years, both alternatives would still require site decontamination/decommissioning.

In most situations, the DECON alternative is the preferred mode of decommissioning. This decommissioning alternative is favored because it immediately eliminates a potential long-term safety hazard and individuals familiar with the nuclear facility will still be available to support the dismantling effort. In addition, both the mothball and entombment alternatives still require eventual decontamination/decommissioning even after the maximum-allowed dormancy duration. This would result in higher overall costs as yearly dormancy costs and reactivation costs could offset any potential savings gained from the delay.

3. DECOMMISSIONING ALTERNATIVES

Two specific decommissioning alternatives were examined for the LGS study: DECON and SAFSTOR. The ENTOMB alternative was not considered, having no significant advantage over the SAFSTOR alternative. ENTOMB requires larger up-front capital expenditures and incurs greater levels of occupational exposure to the worker, without eliminating the necessity for eventual plant decontamination.

Although the DECON and SAFSTOR alternatives share similar methodology, they differ with respect to technique, process, cost, and schedule. Both alternatives attain the same result: removal of all radioactive materials from the site and ultimate release of the site for unrestricted and/or alternative use. The dormancy duration selected for use in the SAFSTOR alternative is based on accomplishing license termination within the 60-year time period established by the NRC.

The following sections describe the basic activities necessary for each alternative. Although detailed procedures for each activity required are not provided, and actual sequences of work may vary, these activity descriptions may provide a basis for detailed engineering planning and scheduling at the time of decommissioning.

3.1 DECON

The DECON alternative deals with the removal of all radioactive materials from the site beginning shortly after the cessation of operations. This study does not address the cost of the removal of spent fuel from the site because such costs are assumed to be covered by the 1 mill/kWhr DOE surcharge. However, the study does consider the constraints that the presence of spent fuel on site may impose on other decommissioning activities. The continued operation of a dry spent fuel storage facility, for maintenance and shipment of the residual inventory of spent fuel from the LGS site at shutdown, is assumed. In addition to the removal of radioactive material, this study also assumes the removal of the remaining structures from the site except as noted in Section 4.4, thereby permitting release of the LGS site for alternative use.

3.1.1 Period 1 - Preparations

Prior to the commencement of decommissioning operations, detailed preparations are undertaken to provide a smooth transition from plant operations to site decommissioning activities. These preparations include engineering planning, surveys of plant areas to determine

contamination levels, activation analyses of the vessel and vessel internals, as well as the assembly of a decommissioning management organization. Final planning for activities and writing of activity specifications and detailed work procedures also begin at this time.

Engineering and Planning

Prior to the commencement of decommissioning operations, PECO Energy Company (PECO) will file with the NRC an application for termination of the NRC license accompanied by a Decommissioning Plan (DP) describing how it will remove all radioactive components and essentially all radioactive material from LGS. This request for dismantling of the reactor and termination of the facility's license should include a detailed plan describing the organization and program that will be used during the decommissioning of the facility. The plan will accomplish the required tasks within the As-Low-As-Reasonably-Achievable (ALARA as defined in 10 CFR 20) guidelines for protection of personnel from exposure to radioactive contaminants. It will also clearly describe how PECO will continue to protect the health and safety of the public and the environment during the dismantling activities.

Prior to the start of decommissioning operations, work begins on the documentation and planning necessary for both licensing change applications and for accomplishing the work required. The development of a decommissioning organization within the utility is essential to this planning. This development includes identification of the staff requirements and commitment of key personnel.

In preparation for a change in license, regulatory criteria applicable to decommissioning are reviewed. The existing technical specifications are reviewed and modified to reflect decommissioning requirements and to delete non-applicable operating specifications. A DP is prepared during this time.

In addition, any supporting reports required by the NRC and all applicable records (i.e., as-built or revised drawings and specifications, operating records, and site-specific background data) will be needed to support this submittal.

Much of the work in the development of the DP is also relevant to the development of the detailed engineering plans and procedures. This work includes items such as:

- Site preparation plans for decommissioning activities;
- Detailed procedures and sequences for removal of systems and components;
- Evaluation of the disposition alternatives for the reactor vessel and its internals;
- Plans for decontamination of structures and systems;
- Design/procurement and testing of tooling and equipment;
- Identification/selection of specialty contractors;
- Procedures for removal and disposal of radioactive materials; and
- Sequential planning of activities to minimize conflicts with simultaneous activities.

<u>Site Preparations</u>

Following final plant shutdown and in preparation for actual decommissioning activities, the following activities are initiated:

- Prepare site support and storage facilities as required.
- Isolate the Reactor Building's fuel handling systems from the power block such that decommissioning operations can commence on the balance of the plant. This activity may be carried out by existing plant personnel in accordance with standard operating technical specifications. Decommissioning operations are assumed to be scheduled around the Reactor Building fuel handling systems, to the greatest extent possible such that the overall project schedule is optimized. Current dry storage cask designs are licensed for spent fuel with a core discharge decay time averaging approximately five years or greater. Decommissioning operations for the fuel storage facilities cannot be expected to begin until all fuel assemblies have

been removed from the pool. As spent fuel decays to the point that it meets the heat load criteria of the dry storage casks, it will be transferred to the dry storage facility. It is assumed that all fuel will be available for transfer to dry storage approximately 5 years following its discharge from the reactor core. To optimize the schedule for Unit 1, all fuel is assumed to be transferred either to dry storage or to the Unit 2 pool within 18 months of shutdown.

- Clean all plant areas of loose contamination and process all liquid and solid wastes.
- Conduct radiation surveys of work area contamination and general dose levels; major component, piping, and structure dose levels (including the reactor vessel and its internals); internal piping contamination levels; and activation profiles from primary shield core samples.
- Calculate residual by-product material inventory for plant components, structures and systems, and normalize neutron flux profiles from operations to survey data for development of packaging and shipping requirements and decommissioning safety requirements.
- Determine shipping container requirements for activated materials and procure such containers.
- Develop procedures for occupational exposure control, control and release of liquid and gaseous effluent, control of solid radwaste, site security and emergency programs, and industrial safety.

Following approval of the DP by the NRC, the NRC will issue an order authorizing implementation. The DP may then be implemented by PECO.

3.1.2 Period 2 - Decommissioning Operations and License Termination

The dismantling procedures may begin upon receipt of the dismantling order from the NRC. For the DECON alternative the decommissioning operations involve the following:

- Construct temporary facilities, if necessary, and arrange existing storage facilities to support the dismantling activities. These may include: changing rooms and contaminated laundry facilities for increased work force, protected and open laydown areas to facilitate equipment removal and shipping operations, additional roads to facilitate hauling and transportation, and an access hatch to facilitate entrance into the Reactor Building for large/heavy equipment.

- Lease or procure, and install water cleanup system for removal of cutting residues and crud deposits from the reactor vessel.

- Design and fabricate special shielding and contamination control envelopes, special tooling and remotely operated equipment. Modify the reactor well/spent fuel pool/dryer separator pool to support segmentation activities and prepare rigging for segmentation and removal of piping sections, recirculation pumps and other components, including the reactor vessel and its internals, as required.

- Procure required shipping casks, liners, and Low Specific Activity (LSA) containers from suppliers.

- Conduct decontamination of components and piping systems as required. Remove, package and dispose of piping and components as they are no longer required to support the decommissioning process.

- Segment core support structures and the steam separator and dryer assemblies and package in shielded casks. These operations are performed remotely by cutting equipment within a contamination control envelope (CCE). Ship and bury packaged items which meet 10 CFR 61 Class "C" requirements or less.

- Disassemble, segment and package remaining reactor internals in shielded casks. These internals include: top fuel guide, feedwater and core spray spargers, in-core instrument tubes, fuel support pieces, control rod guide tubes, jet pumps and core support assembly. The operations are conducted underwater using remotely operated tooling and a contamination-control envelope or other contamination barrier(s). Ship and bury packaged items which meet 10 CFR 61 Class "C" requirements or less.

- Package 10 CFR 61 "Greater Than Class C" (GTCC) components into fuel bundle containers for handling and storage with the spent fuel assemblies. Transfer these fuel bundle containers to the dry fuel storage area.

- Segment/section the reactor vessel and package into shielded containers. The operation is performed remotely in air using a contamination control envelope. Sections are placed in containers underwater (for example in the spent fuel pool) or in air with the crane operator protected by a shielded envelope. Ship and bury packaged items.

- After the vessel water level drops below the elevation of the reactor vessel inlet and outlet nozzles during vessel segmentation, remove the reactor recirculation piping and pumps. Package the piping in standard LSA containers; the reactor recirculation pumps are sealed with steel plate so as to serve as their own containers. Ship and bury piping and pumps.

- Remove control rod drive housings and instrumentation tubes from reactor vessel lower head and cut into sections for disposal.

- Remove systems and associated components as they become non-essential to the support of vessel disposition, other decommissioning operations or worker health (e.g., decommissioning waste processing systems, electrical systems, HVAC systems, water systems).

- Remove concrete sacrificial shield including activated/contaminated concrete by controlled demolition. Package and bury radioactive portions.

- Remove steel liner from the drywell, disposing of the activated and contaminated sections as radioactive waste. Remove steel vent pipes connecting the drywell to the suppression chamber, again disposing of the steel as radioactive waste. Dispose of any activated/contaminated drywell concrete; package, ship and bury inventory in standard LSA containers.

- Dismantle/section the suppression chamber steel structure, packaging contaminated segments for disposal; package, ship and bury inventory in standard LSA containers.

- Remove steel liners from the dryer/separator pool, reactor well, and spent fuel pool. Package contaminated material in standard LSA containers, including contaminated pool concrete, for shipping and burial.

- Remove contaminated equipment and material from the fuel storage facility and any other contaminated areas. Use radiation and contamination control techniques until radiation surveys indicate that the structures can be released for unrestricted access and conventional demolition.

- Ship and bury all remaining radioactive materials.

- Conduct final radiation survey to ensure that all radioactive materials have been removed. This survey may coincide with final NRC site inspection.

- Following notification by PECO of completion of the decontamination and disposal of components and materials from the facility, the NRC regional staff conducts an on-site survey to verify that the acceptable activity and contamination levels are satisfied. When the requirements are satisfied, the NRC can terminate the license for either the individual units or the station. The dry fuel storage facility will continue operating under a 10 CFR Part 72 license.

3.1.3 Period 3 - Site Restoration

Following completion of the decommissioning operations, site-restoration activities may begin. This study assumes that all building foundations are removed to three feet below grade. Site areas affected by the dismantling activities are assumed to be cleaned and the plant area graded and landscaped as required. These activities include:

- Demolition of the remaining portions of the primary containment structure and interior portions of the Reactor Building. Internal floors (and walls if above grade) are removed from the lower levels upward, using controlled blasting techniques. Concrete rubble and clean fill produced by demolition activities may be used to backfill below-grade voids. Suitable materials can be used on site for fill; otherwise the rubble is trucked off site for reuse elsewhere.

- Remaining buildings are then removed using conventional demolition techniques for aboveground structures, including the Turbine Building, Radwaste Building, and other site structures.

- Prepare the final dismantling program report.

3.1.4 Post-Period 3 - ISFSI Operations and Demolition

Following completion of the site restoration operations, the Independent Spent Fuel Storage Installation (ISFSI) will continue to operate. During this interval spent fuel shipments will occur. Starting in 2022, spent fuel assemblies will be shipped for a period of approximately 24 years, with the final spent fuel shipment occurring in 2046.

After the final spent fuel shipment to the DOE, the ISFSI physical installation will be decontaminated. Continued radiation exposure from the spent fuel assemblies will cause low-level neutron activation of the interior surfaces of the dry storage modules to levels exceeding current release limits.

Following notification by PECO of completion of the decontamination and disposal of components and materials from the ISFSI facility, the NRC regional staff conducts an on-site survey to verify that the acceptable activity and contamination levels are satisfied. When the requirements are satisfied, the NRC can terminate the Part 72 ISFSI license.

The concrete dry storage modules are demolished and disposed of as clean fill and the area graded and landscaped to conform with the surrounding environment.

3.2 SAFSTOR

The SAFSTOR decommissioning alternative provides a condition that ensures public health and safety from radioactive material remaining at the site without the need for extensive modifications to the facility. During the SAFSTOR period the facility is left intact and all structures are maintained in a sound condition. Systems not required to be operational for support of the spent fuel pool and surveillance purposes during the dormancy period are drained, de-energized, and secured. Minimal cleaning/removal of loose contamination and/or fixation and sealing of remaining contamination are performed. Access to contaminated areas is secured to provide controlled access for inspection and maintenance.

The engineering and planning requirements are similar to those for the DECON alternative, although a shorter time period is expected for these activities due to the more limited work scope. Site preparations are also similar to those for the DECON alternative. However, with the exception of required radiation surveys, the mobilization and preparation of site facilities is less extensive.

3.2.1 Period 1 - SAFSTOR Operations

Prior to commencement of decommissioning operations, PECO will file a Decommissioning Plan (DP) with the NRC. The DP will describe how it will remove all radioactive components and essentially all radioactivity, safely and effectively, from LGS. This request for eventual dismantling of the reactor and termination of the facility's license includes a detailed plan describing the organization and program that will be used during the decommissioning of the facility. The plan will accomplish the required tasks within the ALARA guidelines for protection of personnel from exposure to radioactive contaminants. It will also clearly describe how PECO will continue to protect the health and safety of the public and the environment during the dismantling activities.

Following approval of the DP by the NRC, the NRC issues an order authorizing implementation. The DP may then be implemented by PECO. The DP addresses the spent fuel management plan, preliminary decontamination activities, and the subsequent caretaking program. The document would also provide a general description of the deferred decommissioning activity following the caretaking period. The NRC may amend the operating license to permit "Possession Only" after final plant shutdown. This amended license would remain in effect until final decontamination of the site and its release is complete.

The "Possession Only" license permits ownership and possession of fuel, by-product material and reactor components, but does not permit operation of the reactor. This license status, though permitting significant relief from the technical specifications, still requires adequate surveillance, monitoring and reporting.

After plant shutdown, modified technical specifications are implemented. Spent fuel and in-core source materials are isolated in the spent fuel storage facilities awaiting ultimate disposal or transfer to the ISFSI. These steps may be carried out by plant personnel in accordance with standard operating procedures. The residual inventories of liquid and solid wastes are processed and removed and plant radiation surveys initiated.

The decommissioning activities for the SAFSTOR alternative are as follows:

- Isolate the Reactor Building's fuel handling systems from the power block such that decommissioning operations can commence on the balance of the plant. This activity may be carried out by existing plant personnel in accordance with standard operating technical specifications. Decommissioning operations are assumed to be scheduled around the Reactor Building fuel handling systems, to the greatest extent possible such that the overall project schedule is optimized. Current dry storage cask designs are licensed for spent fuel with a core discharge decay time averaging approximately five years or greater. Decommissioning operations for the fuel storage facilities cannot be expected to begin until all fuel assemblies have been removed from the pool. As spent fuel decays to the point that it meets the heat load criteria of the dry storage casks, it will be transferred to the dry storage facility. It is assumed that all fuel will be available for transfer to dry storage approximately 5 years following its discharge from the reactor core. To optimize the schedule for Unit 1, all fuel is assumed to be transferred either to dry storage or to the Unit 2 pool within 18 months of shutdown.

- Drain/de-energize/secure all non-contaminated systems not required to support decommissioning operations.

- Dispose of contaminated filter elements and resin beds not required for processing wastes from decontamination activities.

- Drain reactor vessel; internals will remain in place.

- Drain/de-energize/secure all contaminated systems. Decontaminate systems as required.
- Prepare lighting and alarm systems whose continued use is required. De-energize and/or secure portions of fire protection, electric power, and HVAC systems whose continued use is not required.
- Clean loose surface contamination from building access pathways.
- Perform radiation survey of plant; post warning signs as appropriate.
- Erect physical barriers and/or secure all access to radioactive or contaminated areas, except as required for controlled access, i.e., inspection and maintenance.
- Spent fuel shipments to DOE will continue throughout Period 1 and into the dormancy period.
- Install security and surveillance monitoring equipment and relocate security fence around secured structures as required.
- Non-radioactive structures, located outside the secured area, can be dismantled at this time. However, this study assumes that demolition would be delayed until after license termination.
- Sections of the site outside of the controlled area may be graded and landscaped as required. Part of this site area may be released for unrestricted use or for restricted use, depending on the terms of the possession-only license.
- Prepare final decommissioning program report for submittal to NRC.

3.2.2 Period 2 - SAFSTOR Dormancy

Activities required during the planned dormancy period, for the SAFSTOR alternative, include a 24-hour guard force, preventive and corrective maintenance on security systems, area lighting, general building maintenance, heating and ventilation of buildings, routine radiological inspections of contaminated buildings, maintenance of structural integrity, and an environmental and radiation monitoring program.

Spent fuel shipments to the DOE repository will continue throughout Period 2 until 2046.

Maintenance and equipment inspection activities are provided by a utility maintenance staff. Their duty is to maintain the structures in a safe condition, provide adequate lighting, heating, and ventilation, and perform periodic preventive maintenance on essential equipment.

An environmental surveillance program is carried out during the dormancy period to ensure that releases of radioactive material to the environment are controlled. Such potential releases are identified and quantified. Appropriate emergency procedures are established and initiated for releases that exceed prescribed limits. The environmental surveillance program will be an abbreviated version of that carried out during normal plant operations.

Primary physical security is provided by the security fence which must be maintained in good condition for the duration of this period. Fire and radiation alarms will be monitored. At the end of the dormancy period for the SAFSTOR alternative, the remaining systems and structures are assumed to be completely dismantled.

3.2.3 Periods 3-5 - Deferred Decommissioning

At the end of the dormancy period, the remaining plant facilities will be decontaminated and dismantled. Essentially, the same operations and methods as those described for the DECON alternative are performed. However, due to the timing of the decommissioning, contractors are hired to supplement the utility's diminished staff resources.

Although the initial radiation levels due to ^{60}Co will decrease significantly during the dormancy period, the internal components of the reactor vessel will still emit sufficiently high radiation dose rates to require remote sectioning underwater due to the presence of long-lived radionuclides such as ^{94}Nb and ^{59}Ni. Therefore, the dismantling procedures described for the DECON alternative would still be employed. Portions of the biological shield will still be radioactive because of the presence of activated trace elements with long half-lives (^{152}Eu and ^{154}Eu) and will require controlled removal, packaging, and burial procedures. It is assumed that radioactive corrosion products on inner surfaces of piping and components will not have decayed to levels that will permit unrestricted use or allow conventional removal. These systems and components are surveyed as they are removed and disposed of in accordance with the existing radioactive release criteria.

With the levels of radioactivity and spectrum of radionuclides expected from forty years of plant operation, no plant process system identified as being contaminated upon final shutdown will become releasable due to the decay period alone, i.e., there is no significant reduction in waste volume in delaying decommissioning. In fact, the SAFSTOR estimate may show a slight increase in the total projected waste volumes, due primarily to initial preparation activities for mothballing LGS as well as from follow-up housekeeping tasks over the caretaking period for the unit.

The delay in decommissioning yields lower working area radiation levels. As such, the difference between the prompt and delayed scenarios is moderated by reduced ALARA controls for the SAFSTOR's lower occupational exposure potential. Because this alternative provides a period of decay for the residual radioactive material, the working area radiation levels are generally lower than with the DECON alternative. Some of the dismantling activities may employ manual techniques rather than remote procedures. Thus, dismantling operations may be simplified for some tasks.

The most significant difference between the DECON and SAFSTOR scenarios, as presented in the cost estimate for LGS, is the larger, owner-controlled area remaining during the period when the plant is in SAFSTOR dormancy. (Plant structures are decontaminated and dismantled in the DECON scenario as soon as practical. Conversely, the site facilities remain intact during the SAFSTOR caretaking period). The activities which take place during the SAFSTOR dormancy period add additional cost to the decommissioning program, negating savings gained in reduced waste disposal surcharges for the decayed, highly radioactive components.

Following PECO's notification to the NRC of the completion of the decontamination activity (comprising the disposition of all material from the site in excess of approved criteria for unrestricted release), the NRC regional staff, and/or its agent will conduct a verification survey of the facility to ensure that residual activity and contamination levels are satisfied. Once the requirements are satisfied, the NRC can terminate the license for the unit.

Site restoration activities may then be performed, similar to those identified for DECON. The site is graded and landscaped. A final decommissioning program report is prepared and the site released for unrestricted use.

4. COST ESTIMATE

A site-specific cost estimate was prepared for LGS to account for the unique features of the site including the NSSS, electric power generation systems, site buildings and structures. The basis of the estimate (including the source of information), methodology, site-specific considerations, assumptions and total costs, are described in this section.

4.1 BASIS OF ESTIMATE

A site-specific cost estimate was developed using LGS drawings and the inventory documents provided by PECO. PECO provided a database (Component Record List) which included the plant systems inventory. These drawings and documents were used to develop the general arrangement of the facility and to determine estimates of building concrete volumes, steel quantities, numbers and sizes of components, and land area of the site restored.

Decommissioning is a labor-intensive effort. Representative labor rates for each craft or salaried worker are essential for the development of a meaningful site-specific decommissioning cost estimate. Consequently, PECO provided the information on the local cost of labor.

Disposition of radioactive waste is a major contributor to the cost of decommissioning. The availability of burial sites is of national concern, with regional compacts being formed to provide adequate burial space for operating and planned reactors. In this study, a base waste burial fee of $298.20 per cubic foot (based upon the disposal charges in effect as of July 1, 1995, at Barnwell, South Carolina) was provided by PECO as a proxy for low-level radioactive waste disposal at a regional site.

4.2 METHODOLOGY

The methodology used to develop the cost estimates follows the basic approach originally presented in the AIF/NESP-036 study report, "Guidelines for Producing Commercial Nuclear Power Plant Decommissioning Cost Estimates" (Ref. 3) and the US DOE "Decommissioning Handbook" (Ref. 4). These references utilize a unit cost factor method for estimating decommissioning activity costs to simplify the estimating calculations. Unit cost factors for concrete removal ($/cubic yard), steel removal ($/ton) and cutting costs ($/in) were developed from the labor cost information provided by PECO. With the item quantity (cubic yards, tons, inches, etc.) developed from plant drawings and inventory documents, the activity-dependent costs are estimated.

The unit cost factors used in this study reflect the latest available information about worker productivity in decommissioning, including the Shippingport Station Decommissioning Project, completed in 1989 as well as from TLG's involvement in the decommissioning planning and engineering for other nuclear facilities such as Shoreham, Rancho Seco, Trojan and Yankee Rowe.

The unit cost factor method provides a demonstrable basis for establishing reliable cost estimates. The detail of activities provided in the unit cost factors for activity time, labor costs (by craft), and equipment and consumable costs, provide assurance that cost elements have not been omitted. These detailed unit cost factors, coupled with the plant-specific inventory of piping, components and structures, provide a high degree of confidence in the reliability of the cost estimates.

The activity duration critical path was used to determine the total decommissioning program schedule. The program schedule is used to determine the period-dependent costs for program management, administration, field engineering, equipment rental, quality assurance and security. PECO provided typical salary and hourly rates for personnel associated with period-dependent costs. The costs for conventional demolition of nonradioactive structures, materials, backfill, landscaping and equipment rental were obtained from the "Building Construction Cost Data" published by R. S. Means (Ref. 5). Examples of unit cost factor development are presented in the AIF/NESP-036 study (Ref. 3). Appendix A presents the detailed development of a typical site-specific unit cost factor. Appendix B summarizes specific factors developed for the LGS analyses.

4.3 CONTINGENCY

The activity- and period-dependent costs are combined to develop the total decommissioning costs. A contingency is then applied. "Contingencies" are defined in the Project and Cost Engineers' Handbook (Ref. 6) as "specific provision for unforeseeable elements of cost within the defined project scope; particularly important where previous experience relating estimates and actual costs has shown that unforeseeable events which will increase costs are likely to occur." The cost elements in this estimate are based upon ideal conditions; therefore, a contingency factor has been applied. In the

"AIF/NESP-036 Guidelines" (Ref. 3), the types of unforeseeable events that are likely to occur in decommissioning are discussed and guidelines are provided for percentage contingency in each category. Application of contingency is assigned on a line item basis for this estimate. It should be noted that contingency, as used in this estimate, does not account for price escalation and inflation in the cost of decommissioning over the remaining operating life of the units.

There is a general misconception on the use and role of contingency within decommissioning cost estimates, sometimes viewed as a "safety factor". Safety factors provide additional security and address situations which may never occur. Contingency funds are expected to be fully expended throughout the program, providing assurance that sufficient funding is available to accomplish the intended tasks. Some of the rationale for, and need to incorporate, contingency within any estimate is offered in the following discussion. An estimate without contingency, or from which contingency has been removed, can disrupt the orderly progression of events and jeopardize the financial success of the project.

One of the most challenging tasks in decommissioning a commercial nuclear station will be the disposition of the reactor vessel and internal components which have become highly radioactive after a lifetime of exposure to radiation produced in the reactor core. The disposition of these highly radioactive components forms the basis for the critical path (schedule) for decommissioning operations. Cost and schedule are inter-dependent and any deviation in schedule, as in a refueling outage, has a significant impact on cost.

Disposition of the reactor vessel internals involves the underwater cutting of the complex components containing millions of curies of radioactive material. Costs are based upon optimum segmentation, handling and packaging scenarios. The schedule is primarily dependent upon the turnaround time for the heavily shielded shipping casks, including preparation, loading and decontamination of the containers for transport. The number of casks required is a function of the pieces generated in the segmentation activity, a value calculated on optimum performance of the tooling employed in cutting the various subassemblies. The risk and uncertainty associated with this task is that the expected optimization may not be achieved, resulting in delays and additional program costs. For this reason, contingency is included to mitigate the consequences of the expected inefficiencies in this complex activity, along with related concerns associated with specialty tooling modifications and repairs, field changes, discontinuities in the coordination of plant services, unexpected conditions, systems failure, water clarity, lighting, computer cutting software corrections, etc. Experience has shown that many of these problem areas have occurred during, and in support of, the reactor vessel segmentation activity. Contingency dollars are an integral part of the total cost to complete this task. Exclusion of this component puts at risk the successful completion of the intended tasks and potentially, follow-on related activities.

The following listing is a composite of some of the activities, assembled from past decommissioning programs, in which contingency dollars were spent to respond to, compensate for, and/or provide adequate funding of decontamination and dismantling tasks:

Incomplete or Changed Conditions:

- Unavailable/incomplete operational history which led to a re-contamination of a work area, as a sealed cubicle incorrectly identified as being non-contaminated, was breached without controls;

- Surface coatings covering contamination which, due to an incomplete characterization, required additional cost and time to remediate;

- Additional decontamination, controlled removal and disposition of previously undetected (although at some sites, suspected) contamination due to enhanced access of formerly inaccessible areas and components;

- Unrecorded construction modifications, facility upgrades, maintenance, enhancements, etc., which precipitated scheduling delays, more costly removal scenarios, additional costs (e.g., for re-engineering, shoring, structural modifications), and compromised worker safety;

Adverse Working Conditions:

- Lower than expected productivity due to heat exhaustion in underground vaults, resulting in a change in the working hours (shifting to cooler periods of the day) and additional manpower;

- Confined space, low-oxygen environments where supplied air was necessary and additional safety precautions prolonged the time required to perform required tasks;

Maintenance, Repairs and Modifications

- Facility refurbishment required to support site operations, including those needed to provide new site services as well as to maintain the integrity of existing structures;
- Damage control, repair and maintenance from bird nesting and fouling of equipment and controls;
- Building modification, i.e., re-supporting of floors to enhance loading capacity for heavily shielded casks;
- Roadway upgrades on site to handle heavier and wider loads; roadway rerouting, excavation and reconstruction;
- Requests for additional safety margins by a vendor;
- Requests to analyze accident scenarios beyond those defined by the removal scenario (requested by the NRC to comply with "total scope of regulation");
- Additional collection of site run-off and processing of such due to disturbance of natural site contours and drainage;
- Concrete coring for removal of embedments and internal conduit, piping and other potentially contaminated material not originally identified;
- Modifications required to respond to higher than expected worker exposure, water clarity, water disassociation and hydrogen generation from high temperature cutting operations;
- Additional waste containers needed to accommodate cutting particulates (fines), inefficient waste geometries and excess material;

Labor

- Turnover of personnel, e.g., craft and health physics. Replacement of labor is costly, involving additional training, badging, medical exams, and associated processing procedures. Recruitment costs are incurred for more experienced personnel and can include relocation and living expense compensation;

- Additional personnel required to comply with NRC mandates and requests;

- Replacement of personnel due to non-qualification and/or incomplete certification (e.g., welders);

Schedule

- Schedule slippage due to a conflict in required resources, i.e., the licensee was forced into a delay until prior (non-licensee) commitments of outside resources were resolved;

- Weather-related delays in the construction of facilities required to support site operations (with compensation for delayed mobilization made to vendor);

- Rejection of materials, requiring refabrication and causing program delays in activities required to be completed prior to initiating decommissioning operations;

Weather

- Frozen crane hydraulics prior to a major lift; and

- Destruction of an exterior asbestos containment enclosure due to violent winds.

Not included within the application of contingency, but equally probable to impact the cost and performance of the decommissioning program are:

- Transition activities and costs: ancillary expenses associated with eliminating up to 80% of the site labor force shortly after the cessation of plant operations. Added cost for worker separation packages throughout the decommissioning program, state mandated retraining and retention incentives for key personnel;

- Delays in approval of the decommissioning plan due to intervention, public participation in local advisory committees, state and local hearings, etc.;

- Regulatory changes, e.g., affecting worker health and safety, site release criteria, waste transportation, and disposal; and

- Policy decisions altering federal and state commitments, e.g., in the ability to accommodate certain waste forms for disposition, or in the timetable for such.

These concerns (with the exception of the first which can be quantified), are typically addressed in a Risk and Uncertainty analysis against which probabilities are assigned and, confidence traded against cost. Other areas addressed in such an analysis would include the probabilities associated with the uncertainties in predicting the costs of goods and services prior to their actual purchase, scope omission and error, escalation, schedule, scope growth, and "Acts of God".

4.4 SITE-SPECIFIC CONSIDERATIONS

There are a number of site-specific considerations that affect the method for dismantling and removal of equipment from the site and the degree of restoration required. The cost impact of the considerations identified below is included in this cost study.

4.4.1 Spent Fuel Disposition

The existing spent fuel pools, with a capacity to store 3921 fuel bundles at Unit 1 and 2832 fuel bundles at Unit 2, are expected to be full before the shutdown date for each unit. This decommissioning estimate assumes storage and dry transfer responsibilities for all fuel bundles in the fuel pool, which is assumed to be full, at shutdown. Following shutdown, the ISFSI will be relicensed as a unique storage facility. Spent fuel will be available for transfer to dry storage approximately 5 years following its discharge from the reactor core. The five years is needed to permit the heat generation rate of the spent fuel assemblies to decay to acceptable levels for transportation and dry storage, typically 1 kilowatt per assembly. An additional 2 months is expected to be needed to complete the transfer of the final core. The decommissioning scenario has been constructed to permit continued operation of the Reactor Building fuel handling facilities at Unit 1 for 18 months following shutdown, and at Unit 2 for 62 months following shutdown. Unit 1 fuel requiring additional decay time beyond the 18-month period is assumed to be transferred to the Unit 2 pool. Once the final spent fuel assemblies have been removed from each individual pool, the spent fuel storage and handling facilities are available for decommissioning.

Current plans are for spent fuel storage to continue after shutdown of LGS until 2046. During this time, shipment of spent fuel from the ISFSI to the U.S. Department of Energy Waste Management System for geologic disposal will be conducted, after which the dry storage facility will be decontaminated and demolished.

4.4.2 Major Component Removal

The reactor pressure vessel and reactor internal components are segmented for disposal in shielded shipping casks. Segmentation and packaging of the internals packages are performed in the dryer separator pool where a turntable and remote cutter will be installed. The vessel is segmented in place using a mast-mounted cutter supported off the lower head and directed from a shielded work platform installed overhead in the reactor well. Shipping cask specifications and DOT regulations dictate segmentation and packaging methodology; all packages designated meet the current physical and radiological limitations and regulations. All cask shipments are to be made in DOT-approved, currently available, truck casks.

Reactor recirculation piping is cut from the reactor vessel once the water level in the vessel (used for personnel shielding during dismantling and cutting operations in and around the vessel) is dropped below the nozzle zone. The piping is boxed and shipped by shielded van. The reactor recirculation pumps and motors are lifted out intact, packaged and transported for disposal.

The main turbine is dismantled using conventional maintenance procedures; the turbine rotors and shafts removed to a laydown area for packaging and transported for disposal. The lower turbine casings are removed from their anchors by controlled demolition. The main condensers are segmented and transported to the laydown area for packaging and disposition as low-level radioactive waste along with the upper and lower turbine casings.

4.4.3 Transportation Methods

For the purposes of the cost estimate, it was assumed that the low-level radioactive waste produced in the decontamination and dismantling of the nuclear units will be moved overland by truck, rail, shielded van, and/or multi-wheeled transporter to the regional burial facility. Transport costs were derived assuming a common destination for PECO waste within the Appalachian Compact.

4.4.4 Low-Level Radioactive Waste Disposal

Burial cost projections for the regional radioactive waste disposal facility were derived using a unit disposal charge of $298.20 per cubic foot. The value was based on 1995 disposal costs at the Barnwell Low-Level Radioactive Waste Management Facility (Barnwell), located in Barnwell, South Carolina, and deemed by PECO as a proxy for a regional site. Surcharges for high curie and weight packages were also calculated using the published 1995 schedule at the Barnwell facility (Ref. 7).

It is assumed that there will be no significant amounts of RCRA (Resource Conservation and Recovery Act) waste, mixed waste or asbestos on site at the time of decommissioning, since it is PECO's goal to have proper planning to minimize or eliminate the generation of hazardous and mixed radioactive wastes.

To the greatest extent practical, non-compactible low-level radioactive waste is recycled to reduce the total volume of radioactive material buried. The recycled waste that meets radioactive material release limits is released as clean scrap, requiring no further cost consideration. Recycled material that does not meet release limits will be shipped and disposed of as radioactive waste. This recycling activity is performed off site by a licensed radioactive waste recovery vendor at a cost of $100 per cubic foot of material.

Compactible DAW (Dry Active Waste), such as booties, glove liners, respirator filter cartridges, shipping containers, radiological controls survey materials, etc. will be assumed to be drummed and compacted to 10% of its original volume.

4.4.5 Site Conditions at Facility Close Out

It is assumed that the site is restored by regrading to conform to the adjacent landscape. Soil matching that of the adjacent landscape is brought on site and placed to allow growth of native vegetation and drainage. The intake structures on site will be demolished and removed, the circulating water piping sealed and abandoned in place. The switchyard and site drainage facilities remain in place.

4.5 ASSUMPTIONS

The following are the major assumptions made in the development of the cost estimates for LGS:

1. Costs are calculated using 1995 dollars. The estimate excludes escalation. No present-value economic analysis is included.

2. LGS Units 1 and 2 are expected to operate until the end of their current license expiration dates. These dates are October 26, 2024, and June 22, 2029, for Units 1 and 2 respectively.

3. Both units are assumed to be identical except for common structures and systems. Common systems and structures are included with the estimate for Unit 2.

4. LGS drawings, equipment and structural specifications, including construction details, were provided by PECO.

5. Employee salary and craft labor rates for site administration, operations, construction and maintenance personnel were provided by PECO for positions identified by TLG.

6. PECO provides for the electrical power required to demolish the plant to be brought on site. These costs are included in the estimate.

7. Material and equipment costs for conventional demolition and/or construction activities were taken from R.S. Means Construction Cost Data. (Ref. 5)

8. Contaminated piping, components and structures other than the reactor vessel and internals will be assumed to meet US DOT limits for LSA material. For transportation calculations, a regional burial facility is assumed to be located within 450 miles of the plant site. Rates for shipping radioactive wastes were provided by Tri-State Motor Transit in published tariffs for this cargo. (Ref. 8).

9. The reactor vessel and internals disposal costs were based on remote in-place segmentation, packaging in shielded casks, and shipping by truck to the burial ground. A maximum normal road weight limit of 80,000 pounds is assumed for all truck shipments with the exception of several overweight cask shipments. Cask shipments may exceed 95,000 pounds, including vessel segment(s), supplementary shielding, cask tie-downs and tractor trailer. The maximum curies per shipment assumed permissible is based upon the license limits of available shielded shipping casks. The number and curie content of vessel segments were selected to meet these limits.

   The number of cask shipments out of the Reactor Building is assumed to average three per week.

10. In the DECON alternative, the NSSS (reactor vessel and reactor coolant system) will be chemically decontaminated using one chemical flush and two water rinses prior to segmentation. Typically, a decontamination factor (DF) of 10 is expected.

11. Reactor vessel and internals packages' conditions:

    Any fuel cladding failure that has occurred or may occur during the lifetime of the plant is assumed:

    a) to have released fission products at sufficiently low levels that the buildup of quantities of long-lived isotopes (e.g. cesium-137, strontium-90, or transuranics) has been prevented from reaching levels exceeding those which permit the major NSSS components to be shipped as LSA waste and burial within the requirements of 10 CFR 61 or the regional burial ground; or

b) to have necessitated systematic decontamination during the operating life of the plant; therefore, the radionuclide levels will be acceptable for transport as LSA waste and burial within the requirements of 10 CFR 61.

12. For purposes of this estimate, the curie contents of the vessel and internals at final shutdown are derived from those listed in NUREG/CR-3474 (Ref. 9). Actual estimates are derived from the Ci/gram values in NUREG/CR-3474 and adjusted for the different mass of LGS components, projected operating life, as well as for different periods of decay. Additional short-lived isotopes are derived from NUREG/CR-0130 (Ref. 10) and NUREG/CR-0672 (Ref. 11) and benchmarked to the long-lived values from NUREG/CR-3474.

13. This study estimates that there will be some radioactive waste generated which is greater than 10 CFR 61 Class C quantities, resulting from disposal of the highly activated sections of the reactor vessel internals. This waste will most likely be disposed of as High-Level Waste in the DOE's deep geological repository unless an alternative solution is approved by the NRC. The cost of disposal, unlike that for the spent fuel, is not covered by DOE's 1 mill/kWhr surcharge, and has been estimated from equivalent disposal costs for spent nuclear fuel.

14. Control elements will be removed and disposed of along with the spent fuel assemblies.

15. The costs associated with the caretaking of spent fuel in the ISFSI are included with the decommissioning cost for Unit 2.

16. This study does not address the cost of the transfer or disposal of spent fuel from the site. This cost is assumed to be covered by the DOE 1 mill/kwhr surcharge.

17. The final reactor core discharge for Unit 2 will remain in wet storage for approximately five years, where it will then be transferred to a pre-existing dry storage facility (ISFSI). Any fuel that cannot be immediately shipped to dry storage following the shutdown of Unit 1 is assumed to be stored in the pool of Unit 2. It is assumed that a type of modular ISFSI system will have been constructed to support plant operations. An incremental number of modules will be constructed to

support decommissioning, the costs for which are included in this estimate.

18. The ISFSI will use a horizontal storage module concrete cask system. The study assumes that DOE will provide Multi-Purpose Canisters (MPC) to be paid for by PECO. PECO will also be responsible for the concrete overpack for these canisters. Only those additional overpacks needed to empty the spent fuel pool at shutdown are reflected within the decommissioning cost, i.e., operational requirements are not addressed. Capital expenditures were based upon a MPC design of 52 fuel bundles per canister.

19. The spent fuel is assumed to be stored for 17 years after Unit 2 shutdown (until 2046) with periodic shipment to the DOE high-level waste repository. The cost for the storage of spent fuel will be included with the cost for decommissioning Unit 2. The decommissioning cost for the ISFSI is identified as a separate line item cost in Appendix C for Unit 2.

20. Scrap generated during decommissioning is not included as a salvage credit line item in this study for two reasons: (1) the scrap value merely offsets the associated site removal and scrap processing costs, and (2) a relatively low value of scrap exists in the market. Scrap processing and site removal costs are not included in the estimate.

21. Decommissioning will take place sufficiently far in the future that all equipment will be worn, obsolete and suitable for scrap as deadweight quantities only. No equipment is salvageable as used equipment.

22. The PECO staffing requirements during decommissioning vary with the level of effort associated with the various phases of the project. Once the decommissioning program commences, only those staff positions which will be necessary to support the decommissioning program are included. There are no costs for staff transition from operations to decommissioning.

23. The DECON cost study assumes that PECO will serve as the Decommissioning Operations Contractor (DOC) for the decommissioning project. As such, PECO will provide sufficient staff to perform the preparatory demolition planning and scheduling, and manage the demolition efforts. Site security, radiological controls, quality assurance

and overall site administration during decommissioning and demolition will also be provided by PECO. The demolition work is performed by PECO, or a demolition subcontractor who will provide adequate staff, labor, equipment, materials and overhead to complete the demolition.

24. Due to the time delay of the proposed deferred alternative (SAFSTOR), PECO's resources are assumed to be augmented by contractor personnel. The DOC will provide sufficient staff to perform the preparatory demolition planning and scheduling and manage the decommissioning efforts. Site security, radiological controls, quality assurance and overall site administration during decommissioning and demolition will be provided by PECO. The demolition work will be performed by the DOC, or a demolition subcontractor who will provide adequate staff, labor, equipment, materials and overhead to complete the demolition.

25. Engineering services for such items as writing activity specifications, detailed procedures, detailed activation analyses, structural modifications, etc. are assumed to be provided by specialty contractors.

26. PECO will remove all items of furniture, tools, mobile equipment such as forklifts, trucks, bulldozers, other similar mobile equipment and other such items of personal property owned by PECO that will be easily removed without the use of special equipment.

27. Existing warehouses will remain for use by PECO and its subcontractors. The warehouses will be dismantled as they are no longer needed to support the decommissioning program.

28. PECO will perform the following activities at no cost or credit to the project:

    - Fuel oil tanks will be emptied. Tanks will be cleaned by flushing or steam cleaning as required prior to disposal.
    - Acid and caustic tanks will be emptied through normal usage.
    - Excess acid or caustic removed to support disposal at the storage container is returned to the vendor.
    - Lubricating and transformer oils will be drained and removed from site by a waste disposal vendor.

29. The decommissioning activities will be performed in accordance with the current regulations which are assumed to be in place at the time of decommissioning.

30. This study follows the principles of ALARA through the use of work duration adjustment factors which incorporate such items as radiological protection instruction, mock-up training, the use of respiratory protection and personnel protective clothing. These items lengthen a task's duration, which increases the costs and lengthens the schedule. ALARA planning is considered in the costs for engineering and planning, and in the development of activity specifications and detailed procedures.

31. This study was performed in accordance with the published study from the Atomic Industrial Forum/National Environmental Studies Project report AIF/NESP-036, "Guidelines for Producing Commercial Nuclear Power Plant Decommissioning Cost Estimates". The contents of those guidelines were prepared under the review of a task force consisting of representatives from utilities, state regulatory commissions, architect/engineering firms, the Federal Energy Regulatory Commission, the NRC, and the National Association of Regulatory Utility Commissioners.

32. Nuclear liability insurance provides coverage for damage or injuries due to radiation exposure from equipment, material, etc. used during decommissioning. Nuclear liability insurance is phased out upon final decontamination of the site. PECO provided current nuclear liability and property insurance premiums which will be factored to reflect lower coverage limits.

33. Only existing site structures and those presently planned will be considered in the dismantling cost.

34. The perimeter fence and in-plant security barriers will be moved as appropriate to conform with the Site Security Plan in force at the various stages in the project.

35. The existing electrical switchyard will remain after the LGS decommissioning in support of the electrical transmission and distribution system.

36. Underground concrete pipe will be collapsed and backfilled. Underground steel pipe will be removed completely, surveyed for contamination, removed from the site and disposed of as clean scrap at no cost or credit to the project.

37. Electrical manholes are backfilled with suitable earthen material and abandoned.

38. All site vestiges are assumed to be removed to a depth of three feet below grade level with the non-contaminated sub-grade foundations remaining in place. Water drain holes will be drilled in each of the foundation basemats to allow for natural drainage.

39. Building foundations will be backfilled with clean demolition debris, and the site will be graded and landscaped. All areas affected by dismantling activities are assumed to be cleaned up, covered with loam and seeded.

4.6 COST ESTIMATE SUMMARY

A summary of the decommissioning costs with annual expenditures is provided in Tables 4.1a, b, c, and d. Table 8.1 also shows the breakdown of the decommissioning costs into the components of decontamination, removal, packaging, transportation, waste disposal, project management (staffing) and other cost categories. The costs were extracted from the detailed reports in Appendix C.

The detailed cost tables (Appendix C) show the detailed listing and costs of major activities for Units 1 and 2, respectively, for the DECON and SAFSTOR decommissioning alternatives. The following must be considered when reviewing the tables in Appendix C:

- "Decon" as used in the headings of these tables, refers to decontamination.
- "Total" as used in the headings of these tables, is the sum of Decon, Remove, Pack, Ship, Bury, and Contingency as well as other miscellaneous items not listed (such as engineering and preparations).

- The subtotal for the major cost categories such as Decon, Remove, Bury, etc. does not include contingency, which is a separate column.

- "Other" includes different types of costs, and the types of costs vary by the associated line item. For instance, in systems removal and structures decontamination, the "Other" cost consists of the off-site recycling costs for low-level radioactive waste. In most of the engineering preparatory activities the "Other" costs is strictly engineering labor hour costs. Other also includes the utility staffing, taxes, insurance, plant energy budgets, and regulatory fees. These items are listed in "Other" since they do not readily fall into one of the other categories.

- "License Termination" includes all costs that contribute to terminating the 10 CFR §50 license and the 10 CFR §72 license for the dry storage scenario. The "Clean" costs are all of the other costs involved which do not directly contribute to termination of the licenses, but are incurred as a result of the decommissioning process. "Clean" costs include the removal of those systems which are not safety-related and the costs to restore the site after license termination. These are also referred to as "radiological" and "non-radiological" costs.

Table 4.1a
DECON ANNUAL DECOMMISSIONING EXPENDITURES
LIMERICK NUCLEAR GENERATING STATION UNIT 1
(Thousands of 1995 Dollars)

Year	Period 1	Period 2 Decommissioning	Period 3 Site Restoration	Totals
2124	$4,934			$4,934
2125	$26,879			$26,879
2126	$8,469	$65,333		$73,802
2127		$95,425		$95,425
2128		$95,782		$95,782
2129		$45,012	$313	$45,326
2130			$593	$593
2131			$593	$593
2132			$594	$594
2133			$593	$593
2134			$593	$593
2135			$16,435	$16,435
	$40,282	$301,551	$27,057	$368,890

Table 4.1b
DECON ANNUAL DECOMMISSIONING EXPENDITURES
LIMERICK NUCLEAR GENERATING STATION UNIT 2
(Thousands of 1995 Dollars)

Year	Period 1	Period 2 Decommissioning	Period 3 Site Restoration	Post Period 3 Fuel Storage	Post Period 3 ISFSI D & D	Totals
2129	$10,344					$10,344
2130	$18,974	$2,660				$21,634
2131		$88,272				$88,272
2132		$88,521				$88,521
2133		$88,283				$88,283
2134		$88,829				$88,829
2135		$12,547	$7,391			$19,938
2136			$4,496	$2,552		$7,048
2137				$5,322		$5,322
2138				$5,322		$5,322
2139				$5,322		$5,322
2140				$5,337		$5,337
2141				$5,322		$5,322
2142				$5,322		$5,322
2143				$5,322		$5,322
2144				$5,337		$5,337
2145				$5,322		$5,322
2146				$2,639	$3,104	$5,743
	$29,318	$369,112	$11,887	$53,121	$3,104	$466,542

TABLE 4.1 c
SAFSTOR ANNUAL DECOMMISSIONING EXPENDITURES
LIMERICK NUCLEAR GENERATING STATION UNIT 1
(Thousands of 1995 Dollars)

Year	Period 1	Period 2	Period 3	Period 4	Period 5	Totals
2024	$5,793					$5,793
2025	$31,558					$31,558
2026	$9,943	$899				$10,842
2027		$1,312				$1,312
2028		$1,315				$1,315
2029		$1,312				$1,312
2030		$1,312				$1,312
2031		$1,312				$1,312
2032		$1,315				$1,315
2033		$1,312				$1,312
2034		$1,312				$1,312
2035		$1,312				$1,312
2036		$1,315				$1,315
2037		$1,312				$1,312
2038		$1,312				$1,312
2039		$1,312				$1,312
2040		$1,315				$1,315
2041		$1,312				$1,312
2042		$1,312				$1,312
2043		$1,312				$1,312
2044		$1,315				$1,315
2045		$1,312				$1,312
2046		$1,312				$1,312
2047		$1,312				$1,312
2048		$1,315				$1,315
2049		$1,312				$1,312
2050		$1,312				$1,312
2051		$1,312				$1,312
2052		$1,315				$1,315
2053		$1,312				$1,312
2054		$1,312				$1,312
2055		$1,312				$1,312
2056		$1,315				$1,315
2057		$1,312				$1,312
2058		$1,312				$1,312
2059		$1,312				$1,312
2060		$1,315				$1,315
2061		$1,312				$1,312
2062		$1,312				$1,312
2063		$1,312				$1,312
2064		$1,315				$1,315
2065		$1,312				$1,312
2066		$1,312				$1,312
2067		$1,312				$1,312
2068		$1,315				$1,315
2069		$1,312				$1,312
2070		$1,312				$1,312
2071		$1,312				$1,312
2072		$1,315				$1,315
2073		$1,312				$1,312
2074		$1,312				$1,312
2075		$1,312				$1,312
2076		$1,315				$1,315
2077		$1,312				$1,312
2078		$1,312				$1,312
2079		$1,312				$1,312
2080		$1,204	$1,427			$2,632
2081			$16,837			$16,837
2082			$6,974	$62,808		$69,782
2083				$105,455		$105,455
2084				$83,661	$1,715	$85,376
2085					$9,342	$9,342
2086					$9,892	$9,892
2087					$4,622	$4,622
	$47,294	$71,679	$25,238	$251,924	$25,571	$421,706

TABLE 4.1 d
SAFSTOR ANNUAL DECOMMISSIONING EXPENDITURES
LIMERICK NUCLEAR GENERATING STATION UNIT 2
(Thousands of 1995 Dollars)

Year	Period 1	Period 2	Period 3	Period 4	Period 5	Totals
2029	$13,320					$13,320
2030	$24,432	$152				$24,584
2031		$5,053				$5,053
2032		$5,067				$5,067
2033		$5,053				$5,053
2034		$4,309				$4,309
2035		$3,012				$3,012
2036		$3,020				$3,020
2037		$3,012				$3,012
2038		$3,012				$3,012
2039		$3,012				$3,012
2040		$3,020				$3,020
2041		$3,012				$3,012
2042		$3,012				$3,012
2043		$3,012				$3,012
2044		$3,020				$3,020
2045		$3,012				$3,012
2046		$3,012				$3,012
2047		$3,012				$3,012
2048		$3,020				$3,020
2049		$3,012				$3,012
2050		$3,012				$3,012
2051		$3,012				$3,012
2052		$3,020				$3,020
2053		$3,012				$3,012
2054		$3,012				$3,012
2055		$3,012				$3,012
2056		$2,522				$2,522
2057		$2,024				$2,024
2058		$2,024				$2,024
2059		$2,024				$2,024
2060		$2,030				$2,030
2061		$2,024				$2,024
2062		$2,024				$2,024
2063		$2,024				$2,024
2064		$2,030				$2,030
2065		$2,024				$2,024
2066		$2,024				$2,024
2067		$2,024				$2,024
2068		$2,030				$2,030
2069		$2,024				$2,024
2070		$2,024				$2,024
2071		$2,024				$2,024
2072		$2,030				$2,030
2073		$2,024				$2,024
2074		$2,024				$2,024
2075		$2,024				$2,024
2076		$2,030				$2,030
2077		$2,024				$2,024
2078		$2,024				$2,024
2079		$2,024				$2,024
2080		$1,980				$1,980
2081		$1,432				$1,432
2082		$235	$9,848			$10,083
2083			$7,851	$39,088		$46,940
2084				$117,265		$117,265
2085				$117,451		$117,451
2086				$25,100	$27,978	$53,078
2087					$21,251	$21,251
	$37,752	$135,684	$17,699	$298,904	$49,229	$539,268

5. SCHEDULE ESTIMATE

The schedule for the decommissioning scenarios considered in this study follows the sequence presented in the AIF/NESP-036 study (Ref. 3) with minor changes to reflect recent experience and revised estimates. In addition, the scheduling has been revised to reflect the spent fuel scenario which is currently planned for LGS.

TLG has prepared a schedule for decommissioning LGS. The assumptions supporting this schedule are listed in Section 5.1. Figure 5.1 presents the schedule of key activities. Note that the activities listed in the schedules do not reflect a one-to-one correspondence with the activities in the cost tables in Appendix C, but reflect dividing some activities for clarity and combining others for convenience. A legend defining the schedule nomenclature and depictions is also included. The schedule was prepared using the "Microsoft Project" computer software (Ref. 12).

5.1 SCHEDULE ESTIMATE ASSUMPTIONS

The schedule estimate reflects the results of a precedence network developed for LGS decommissioning activities, i.e., a PERT (Program Evaluation and Review Technique). The durations used in the precedence network reflect the actual man-hour estimates from the cost tables in Appendix C. The schedule output is then adjusted by stretching certain activities over their slack range; other activities were pushed to the end of their slack period. The following assumptions were made in the development of the decommissioning schedule for LGS.

1. All work except vessel and internals removal activities is performed during an 8-hour workday, 5 days per week with no overtime. There are eleven paid holidays per year.

2. The Reactor Building fuel handling facilities will be isolated and serve as interim wet fuel storage facilities until such time that all spent fuel has been discharged from the spent fuel pool, i.e., within 18 months for Unit 1 and 62 months for Unit 2, from their respective shutdown dates.

3. Vessel and internals removal activities are performed by using separate crews for different activities working on different shifts, with a corresponding backshift charge for the second shift.

4. Multiple crews work parallel activities to the maximum extent possible consistent with optimum efficiency, adequate access for cutting, removal and laydown space, and with the stringent safety measures necessary during demolition of heavy components and structures.

5. For plant systems removal, the systems with the longest removal durations in areas on the critical path are considered to determine the duration of the activity.

6. Following completion of the Unit 1 vessel cutting activity, equipment is relocated to Unit 2.

5.2 PROJECT SCHEDULE

The period-dependent costs presented in the cost tables in Appendix C are based upon the durations developed in the schedules for the DECON and SAFSTOR alternatives. Durations are established between several milestones in each project period; these durations are used to establish a critical path for the entire project. In turn, the critical path duration for each period is used as the basis for determining the total costs for these period-dependent items.

Project timelines for the DECON and SAFSTOR alternatives are included in this section as Figures 5.2 and 5.3, respectively.

FIGURE 5.1
DECON ACTIVITY SCHEDULE

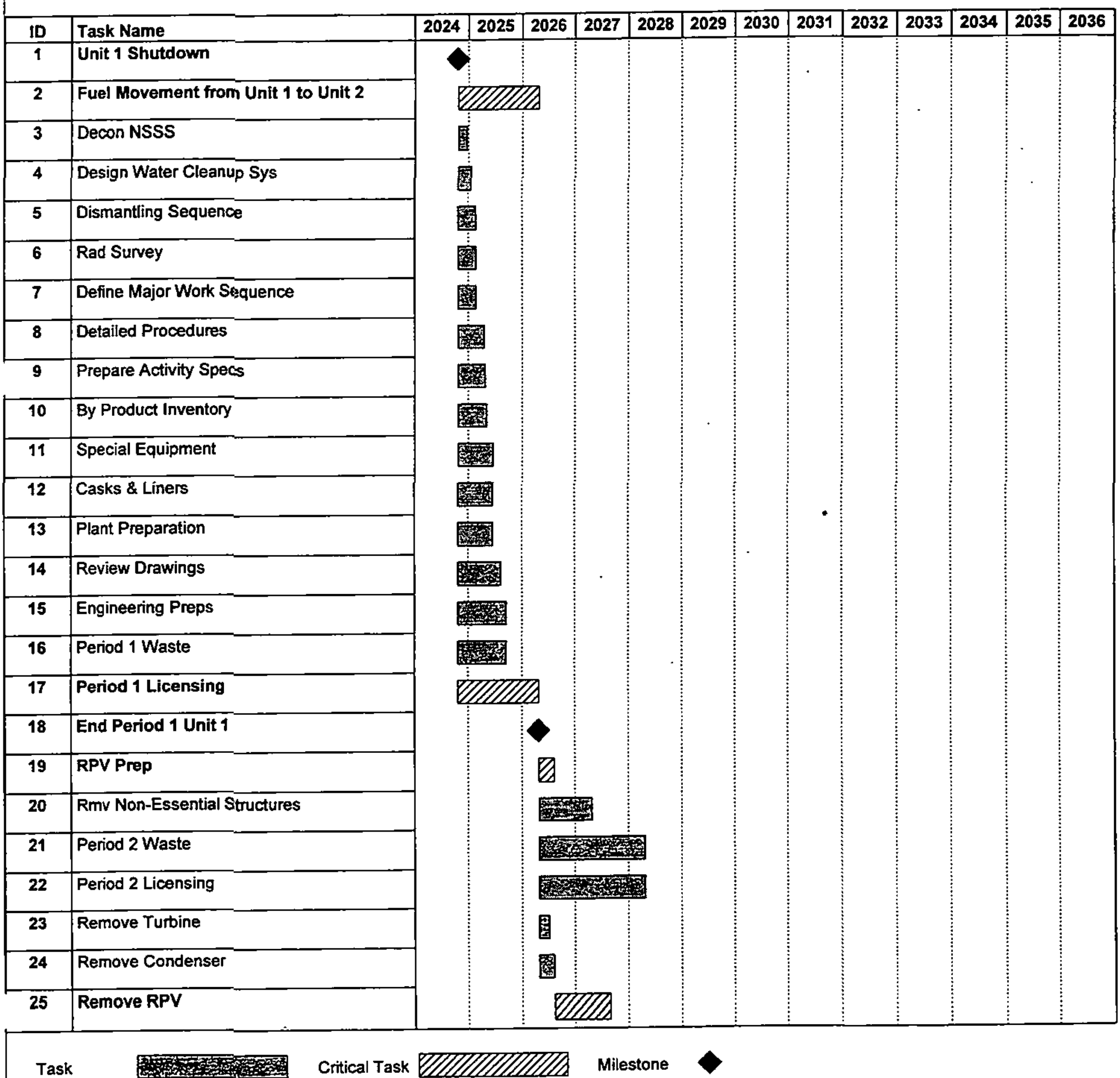


FIGURE 5.1
DECON ACTIVITY SCHEDULE
(continued)

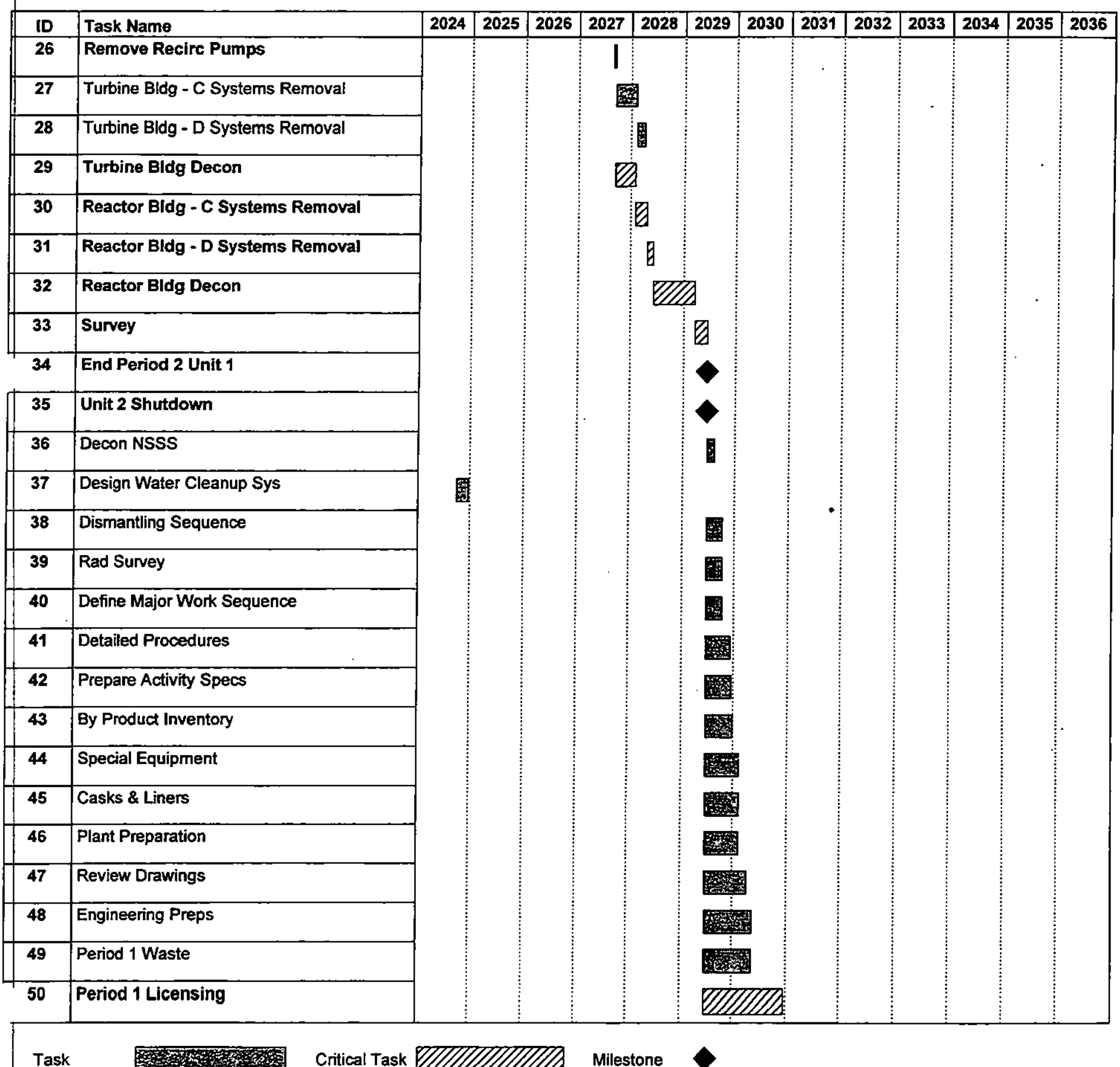
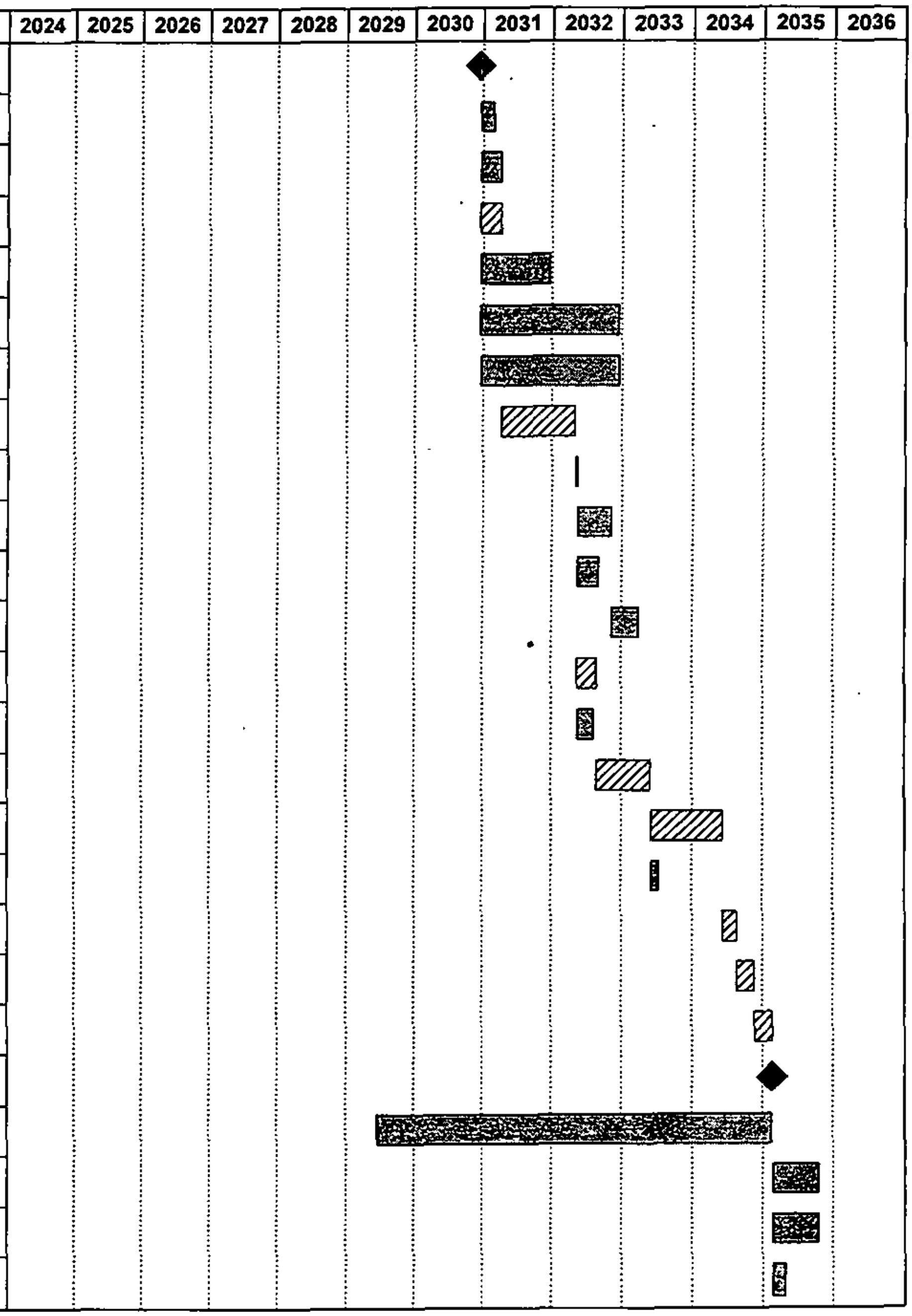


FIGURE 5.1
DECON ACTIVITY SCHEDULE
(continued)

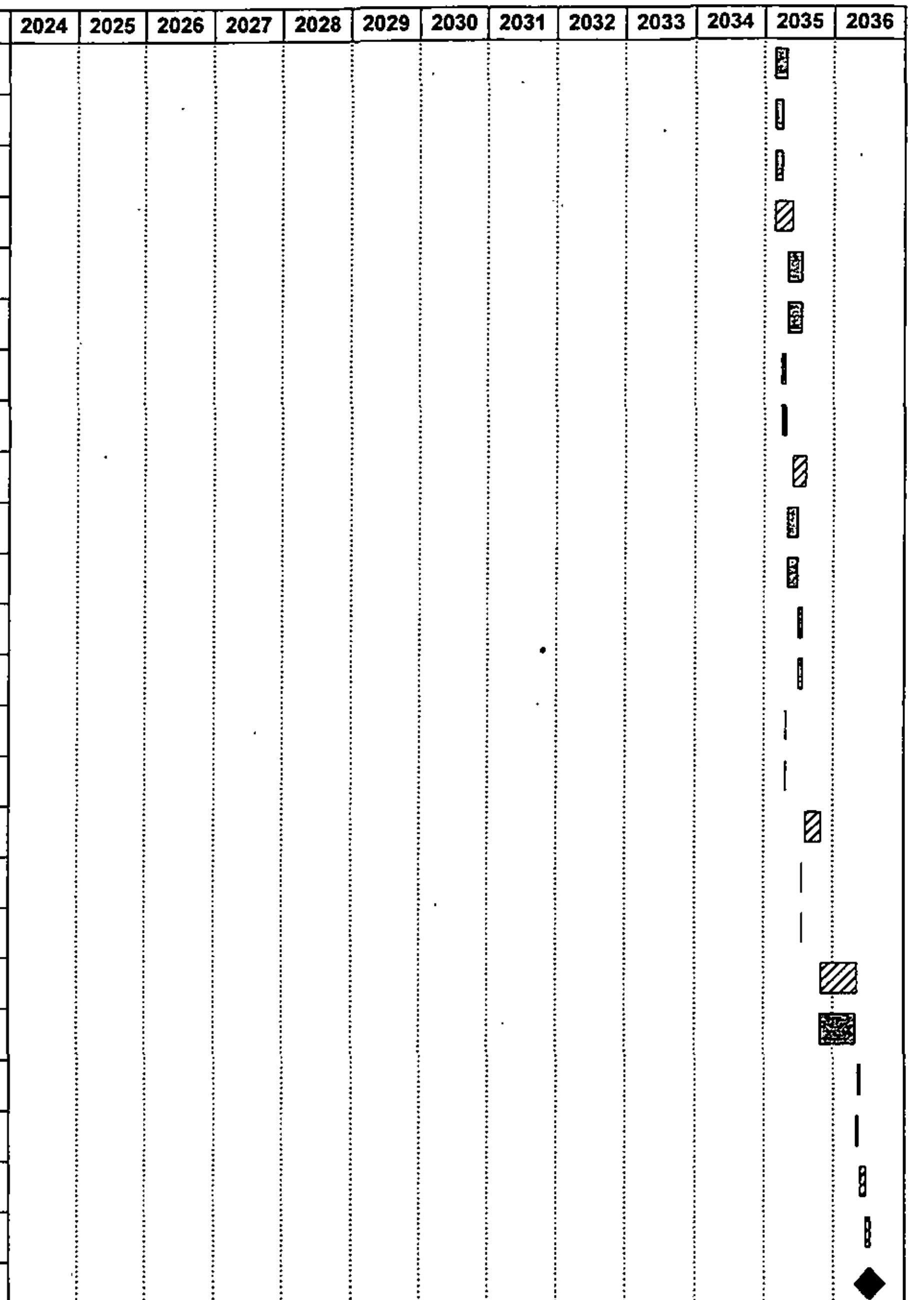
ID	Task Name
51	**End Period 1 Unit 2**
52	Remove Turbine
53	Remove Condenser
54	**RPV Prep**
55	Rmv Non-Essential Structures
56	Period 2 Waste
57	Licensing Period 2
58	**Remove RPV**
59	**Remove Recirc Pumps**
60	Turbine Bldg - C Systems Removal
61	Turbine Bldg - D Systems Removal
62	Turbine Bldg Decon
63	**Reactor Bldg - C Systems Removal**
64	Reactor Bldg - D Systems Removal
65	**Reactor Bldg Decon**
66	**Radwaste Bldg - C Systems Removal**
67	Radwaste Bldg - D Systems Removal
68	**Radwaste Bldg Decon**
69	**Fuel Area Decon**
70	**Survey**
71	**End Period 2 Unit 2**
72	Unit 1 Demolition Delay
73	Reactor Bldg Interior Demolition Unit 1
74	Reactor Bldg Interior Demolition Unit 2
75	Turbine Bldg Interior Demolition Unit 1



Task — Critical Task — Milestone

FIGURE 5.1
DECON ACTIVITY SCHEDULE
(continued)

ID	Task Name
76	Turbine Bldg Interior Demolition Unit 2
77	DG Bldg Interior Demolition Unit1
78	DG Bldg Interior Demolition Unit2
79	**Radwaste Bldg Interior Demolition**
80	Turbine Bldg Exterior Demolition Unit 1
81	Turbine Bldg Exterior Demolition Unit 2
82	DG Bldg Exterior Demolition Unit 1
83	DG Bldg Exterior Demolition Unit 2
84	**Radwaste Bldg Exterior Demolition**
85	Turbine Pedestal Demolition Unit 1
86	Turbine Pedestal Demolition Unit 2
87	Turbine Pedestal Backfill Unit 1
88	Turbine Pedestal Backfill Unit 2
89	DG Bldg Backfill Unit 1
90	DG Bldg Backfill Unit 2
91	**Radwaste Bldg Backfill**
92	Turbine Bldg Backfill Unit 1
93	Turbine Bldg Backfill Unit 2
94	**Unit 1 Reactor Bldg Exterior Demolition**
95	Unit 2 Reactor Bldg Exterior Demolition
96	**Unit 1 Reactor Bldg Backfill**
97	Unit 2 Reactor Bldg Backfill
98	**Remove Project Office**
99	**Landscape Site**
100	**End**



Task | Critical Task | Milestone

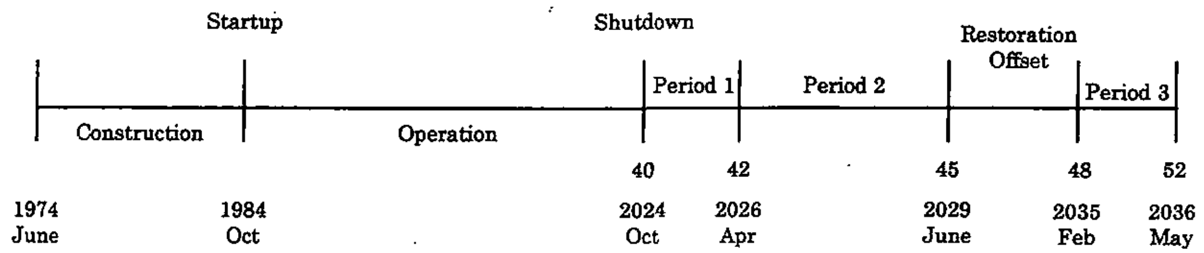
FIGURE 5.1
DECON ACTIVITY SCHEDULE

DEFINITION OF TERMS

TERM	DEFINITION
Group C Systems	Contaminated essential systems.
Group D Systems	Non-contaminated essential systems.
Reactor Bldg	Reactor Building Unit 1 or 2.
Turbine Bldg	Turbine Building Unit 1 or 2.
Radwaste Bldg	Radwaste Building Unit 1 or 2.
RPV	Reactor Pressure Vessel Unit 1 or 2.

FIGURE 5.2
DECON DECOMMISSIONING TIMELINES

UNIT 1



UNIT 2

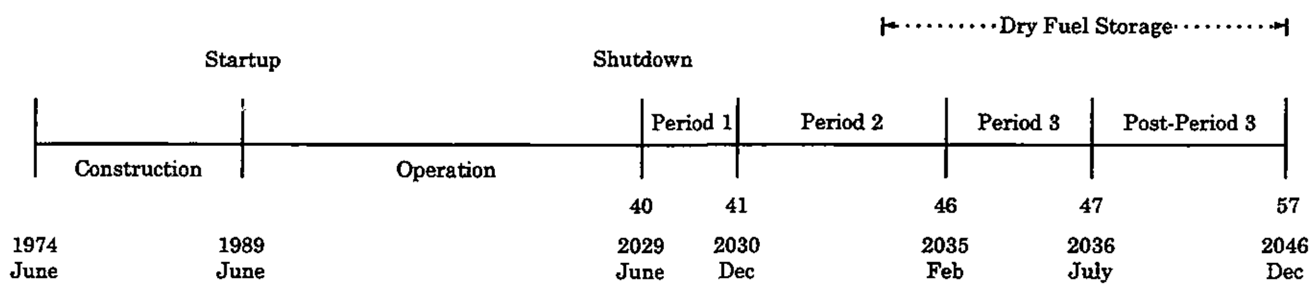
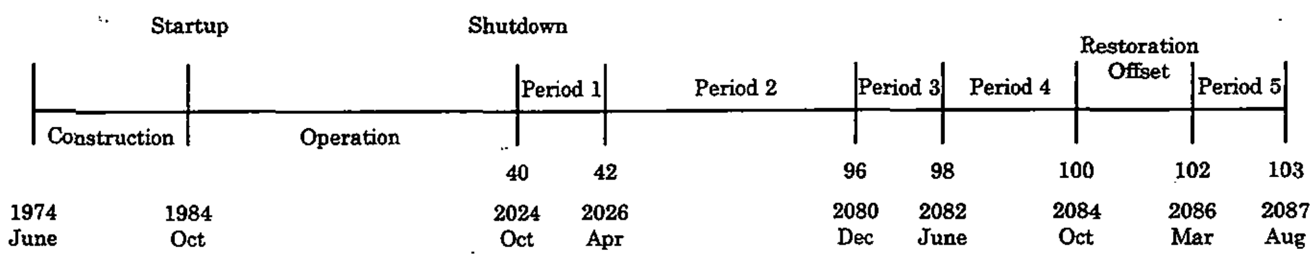
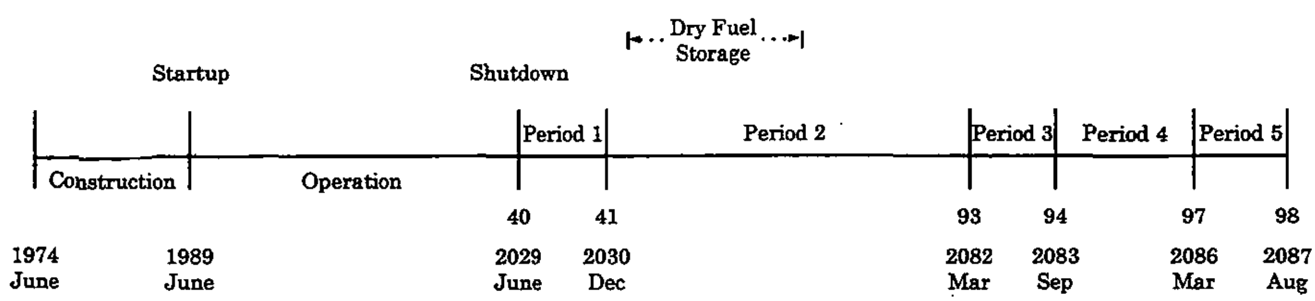


FIGURE 5.3
SAFSTOR DECOMMISSIONING TIMELINES

UNIT 1



UNIT 2



6. RADIOACTIVE WASTES

The ultimate goal of the decommissioning program is the removal of all radioactive material from the site which would restrict its future use. This requires the removal of all radioactive material from the site which is in excess of applicable legal limits.

Under the Atomic Energy Act, the NRC is responsible for protecting the public from sources of ionizing radiation. Title 10 of the Code of Federal Regulations delineates the production, utilization and disposal of radioactive materials and processes. In particular, 10 CFR Part 61 controls the burial of radioactive material; Part 71 defines radioactive material.

The radioactive waste volumes generated during the various decommissioning programs at LGS are shown by line activity in the cost tables in Appendix C. Waste volumes shown in Table 6.1 are quantified consistent with 10 CFR 61 classifications. The waste volumes shown are calculated based on the gross container volume to be shipped and buried in the controlled burial ground. Table 6.1 provides estimated volumes of radioactive waste, by classification, produced by the decommissioning of LGS.

Most of the materials being transported for controlled burial are categorized as LSA material containing Type A quantities as defined in 49 CFR 173-178 (Ref. 13). The containers must be strong tight packages. For this study, commercially available steel containers are presumed to be used for piping, small components and concrete.

The reactor vessel and internals are categorized as large quantity shipments and, accordingly, must be shipped in reusable shielded casks with disposable liners. In this case, the liner volume is taken as the waste volume. No process system containing or handling radioactive substances at shutdown is presumed releasable as non-contaminated scrap metal because of the presence of long-term radionuclides.

The waste volume attributed to site decontamination is primarily generated during Period 2 of DECON. The radioactive waste generated as a result of the decommissioning of LGS is destined for disposal at the future Appalachian Compact Low-Level Waste Disposal facility to be located in Pennsylvania within 450 miles of the site. In this study, the base waste burial fee assumed for decommissioning is $298.20 per cubic foot. This figure is representative of the cost of disposal at the Barnwell facility in South Carolina in 1995. Curie and weight surcharges are applied using the 1995 rate structure in effect at the Barnwell facility (Ref. 7).

The non-compactable (metallic) radioactive waste generated from removal of the plant equipment is assumed to be sent to an off-site vendor for recycling to reduce the final radioactive waste disposal volume. Based upon typical radiological characterizations and industry experience, the inventory of contaminated LGS material was segregated based on the likelihood of volume reduction and decontamination for radiological free release. This reduced burial volume, resulting from reprocessing/recycling radioactive equipment off site, is reflected in the report. The cost of off-site processing of non-compactable metallic waste is estimated to be approximately $100 per cubic foot, and appears in the "other" category in the detailed decommissioning cost tables in Appendix C.

TABLE 6.1

DECOMMISSIONING RADIOACTIVE WASTE BURIAL VOLUMES

	Waste Class[1]	Volume (Cubic feet)[2]
DECON		
Unit 1	A	192,025
	B	31,937
	C	816
	>C	627
Total		**225,405**
Unit 2	A	244,268
	B	34,357
	C	816
	>C	627
Total		**280,068**
SAFSTOR		
Unit 1	A	199,232
	B	10,743
	C	408
	>C	627
Total		**211,010**
Unit 2	A	247,738
	B	11,916
	C	408
	>C	627
Total		**260,689**

1 Waste is classified according to the requirements as delineated in Title 10 of the Code of Federal Regulations, Part 61.55

2 Columns may not add due to rounding.

7. OCCUPATIONAL EXPOSURE

Estimates of occupational radiation exposure were developed by TLG. These estimates are scoping in nature and are performed to provide an upper bound to the exposure limits for comparison with NRC maximum dose limitations.

Radiation doses to decommissioning workers are calculated as the product of the estimated radiation zone work force requirements and the radiation exposure rates estimated for each decommissioning task. The decommissioning occupational exposure estimates are based on the following assumptions:

1. Occupational exposure estimates include only those from the craft labor necessary for decontamination, removal and packaging activities as well as all required health physics personnel exposures in support of these activities. Casual exposures to the plant staff are not included in this estimate.

2. Personnel exposure to radiation is minimized by utilizing shielding and remote handling techniques and avoiding higher radiation fields when personnel presence is not necessary.

3. Local exposure rates near items such as tanks and pipes are reduced by a successful chemical decontamination program prior to work in that area.

4. Careful prompt accounting of accumulated radiation exposure is maintained to rapidly identify tasks causing excessive dose accumulation by workers so that corrective action can be taken.

5. Exposures as the result of spent fuel storage activities are expected to be minimal, and therefore, are not included.

6. Cobalt-60 is the primary contributor to radiation exposure.

It should be noted that the radiation exposure rates used to calculate the exposures shown in Appendix C are based on optimum conditions; factors such as plant age, maintenance and operating history could cause the expected exposure rates at the time of decommissioning to vary significantly. Implementation of the DECON alternative yields the higher occupational radiation exposure because the work is performed soon after shutdown, without the benefit of any extended decay time for the radionuclides on site.

8. RESULTS

Decommissioning technology is well established and the tools and equipment necessary to completely dismantle LGS are available and have been demonstrated. The projected costs to decommission the plant, presuming the use of an integrated station DECON alternative, including the five year and two month operation of the Reactor Building fuel handling equipment as an interim wet fuel storage facility in Unit 2, and post-decommissioning dry fuel storage until 2046, is $835,432,000. This cost includes the complete removal/remediation of all site vestiges. The estimate reflects the site-specific features of LGS and the projected cost of radioactive waste shipping and disposal. An analysis of the major activities contributing to the total cost is shown in Table 8.1.

Burial of radioactive waste represents the majority of the cost to decommission LGS, reflecting the costs associated with the development of new regional waste disposal facilities. The decommissioning staff, along with the removal activity, combine to represent the next largest cost component. This is a direct result of the labor-intensive nature of the decommissioning process. Transportation costs are most sensitive to increases in fuel costs and distances to existing or new burial facilities. Removal costs are dependent on the degree of remotely operated equipment available in the future and the associated higher cost of that equipment versus the savings in labor costs.

This study for LGS provides an estimate for decommissioning the site under current requirements based on present-day costs and available technology. As additional dismantling experience on large reactors becomes available, cost estimates will be modified to reflect this experience. In addition, there are costs associated with decommissioning activities that historically increase at rates significantly greater than inflationary trends. For example, the cost of radioactive waste burial has increased rapidly in the last few years. It is therefore appropriate that this cost estimate be reviewed periodically, and updated/revised as required.

TABLE 8.1
SUMMARY OF DECON DECOMMISSIONING COSTS

Work Category	Costs 95$ (thousands)[1]	Percent of Total Costs[1]
DECON		
Unit 1		
Decontamination	13,492	3.66
Removal	49,459	13.41
Packaging	10,031	2.72
Shipping	3,174	0.86
Burial (off-site)	92,046	24.95
Decommissioning Staffs	43,383	11.76
ISFSI Capital Expenditures	12,400	3.36
Security Guard Supplemental Staffing	5,320	1.44
H.P. Technician Supplemental Staffing	9,885	2.68
LLRW Recycling	42,518	11.53
Other[2]	19,163	5.19
Contingency	68,019	18.44
Subtotal	**368,890**	**100.00**

TABLE 8.1
SUMMARY OF DECON DECOMMISSIONING COSTS
(continued)

Work Category	Costs 95$ (thousands)[1]	Percent of Total Costs[1]
DECON		
Unit 2		
Decontamination	17,730	3.80
Removal	78,039	16.73
Packaging	11,184	2.40
Shipping	4,221	0.90
Burial (off-site)	103,131	22.11
Decommissioning Staffs	64,262	13.77
ISFSI Capital Expenditures	2,000	0.43
Security Guard Supplemental Staffing	7,606	1.63
H.P. Technician Supplemental Staffing	14,895	3.19
LLRW Recycling	42,272	9.06
Other[2]	38,017	8.15
Contingency	83,185	17.83
Subtotal	**466,542**	**100.00**
Station Total (with contingency)	**835,432**	

1 Columns may not add due to rounding.
2 Other includes: engineering & preparations, undistributed costs and energy costs

9. REFERENCES

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(continued)

11. H.D. Oak, et al., "Technology, Safety and Costs of Decommissioning a Reference Boiling Water Reactor Power Station," NUREG/CR-0672 and addenda, Pacific Northwest Laboratory for the Nuclear Regulatory Commission. June 1980.

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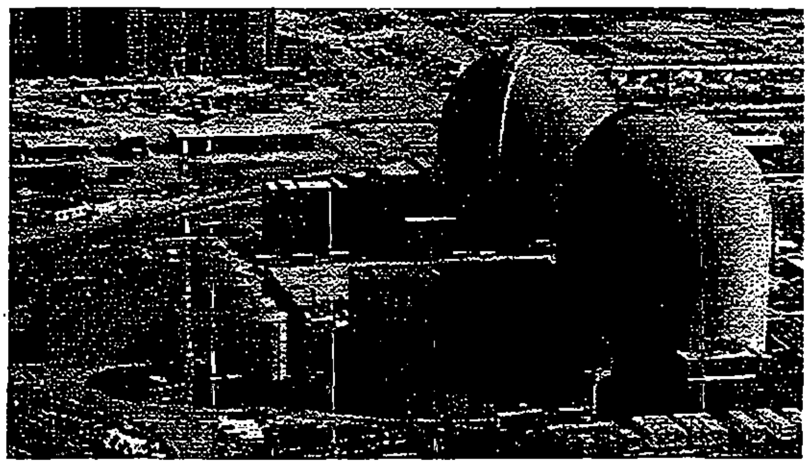
13. U.S. Department of Transportation, Section 49 of the Code of Federal Regulations, "Transportation", Parts 173 through 178.

Document P07-1180-005, Rev. 0

Exhibit TLG-2

DECOMMISSIONING COST ESTIMATE
for the
SALEM GENERATING STATION



prepared for

PUBLIC SERVICE ELECTRIC & GAS COMPANY

September 1996

prepared by

TLG Services, Inc.

Bridgewater, Connecticut

APPROVALS

Project Manager	*William A. Cloutier* (signature) **William A. Cloutier, Jr.**	9-9-96 **Date**
Technical Manager	*Francis W. Seymore* (signature) **Francis W. Seymore**	9/9/96 **Date**
Quality Assurance Manager	*Carolyn A. Palmer* (signature) **Carolyn A. Palmer**	9/9/96 **Date**

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APPENDICES

TABLES AND FIGURES

REVISION LOG

Rev. No.	CRA No.	Date	Item Revised	Reason for Revision
0		9/9/96		Original Issue

EXECUTIVE SUMMARY

This study, prepared for Public Service Electric and Gas (PSE&G) by TLG Services, Inc., evaluates two different decommissioning alternatives for the Salem Generating Station (SGS), following the final cessation of plant operations. The estimated costs for the DECON alternative are $333,441,504 and $347,514,496 (in 1995 dollars) for Unit 1 and Unit 2, respectively. For the SAFSTOR alternative, with deferred decommissioning to be completed within 60 years, the costs are estimated to be $366,614,592 and $428,480,288 for Unit 1 and Unit 2, respectively.

This study provides cost estimates for decommissioning SGS under current requirements and is based upon present-day technology. Using plant drawings and inventory documents and databases, TLG estimated quantities and volumes of equipment and material to be removed during decommissioning. Unit cost factors are applied to the volumes and quantities to develop the activity-dependent costs. The period-dependent costs are then determined from a detailed critical path schedule based on the removal activity durations.

This study includes the following considerations:

> Burial of low-level radioactive waste is assumed to be at a regional site to be designated at a future date by the Northeast Compact. Disposal costs are based on rates in effect as of July 1, 1995, at the Barnwell Low-Level Radioactive Waste Management Facility, as a proxy.
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> Volume reduction and decontamination of low-level radioactive waste, as a means of reducing disposal costs, is assumed to be performed by an off-site radioactive waste recovery vendor.
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> Low-level waste classified as "Greater-Than-Class-C" is packaged for disposal along with the spent nuclear fuel and disposed of at a cost comparable to that envisioned for spent fuel.

Contingency is included in the estimate to address the many uncertainties that exist in a project of this nature. The analysis, prepared on a line item basis, uses a range of contingencies selected to reflect conditions and uncertainties to be present at the time of decommissioning.

In addition to the estimated costs, the report includes program schedules, scrap projections and estimates of occupational radiation exposures and low-level radioactive waste volumes inherent in the proposed decommissioning scenarios.

1. SUMMARY

The Salem Generating Station (Salem) is located on the southern part of Artificial Island on the east bank of the Delaware River in Lower Alloways Creek Township, Salem County, New Jersey. The site is 15 miles south of the Delaware Memorial Bridge, 18 miles south of Wilmington, Delaware, 30 miles southwest of Philadelphia, Pennsylvania, and 7-1/2 miles southwest of Salem, New Jersey. The station is comprised of essentially two identical pressurized water reactors with supporting facilities. Public Service Electric and Gas Company (PSE&G) is part owner and the operator of the two nuclear units.

This study provides the cost, schedule, waste generation/disposition and radiation exposure estimates associated with decommissioning the two Salem units following the conclusion of their operation. Estimates are provided for two alternative decommissioning methods: DECON (prompt removal/dismantling) and SAFSTOR (mothball and delayed dismantling).

DECON is defined by the NRC as "the alternative in which the equipment, structures, and portions of a facility and site containing radioactive contaminants are removed or decontaminated to a level that permits the property to be released for unrestricted use shortly after cessation of operations." DECON consists of the removal of all fuel assemblies and source material, radioactive fission and corrosion products, and all other radioactive materials having activities above Regulatory Guide 1.86, "Termination of Operating Licenses for Nuclear Reactors", NUREG 5512, "Residual Radioactive Contamination from Decommissioning" and other applicable release limits shortly after the cessation of plant operations. The facility operator may then have unrestricted use of the site with no requirement for a Nuclear Regulatory Commission license. This study further assumes that the balance of plant systems and structures are removed to below site grade. The site is assumed to be made available for alternative use.

There are advantages to the DECON alternative. The alternative is less costly, in 1995 dollars, than the scenarios involving extended delays in the station dismantling. (The ultimate cost for any alternative will depend upon future economic factors such as inflation and policy factors, e.g., future NRC regulations and waste policy decisions and actions.) DECON eliminates a potential long-term safety hazard and those individuals familiar with the nuclear facility will still be available to support the dismantling effort. DECON also relieves the utility of long-term obligation and liability for maintenance of the property.

SAFSTOR is defined by the NRC as "the alternative in which the nuclear facility is placed and maintained in a condition that allows the nuclear facility to be safely stored and subsequently decontaminated (deferred decontamination) to levels that permit release for unrestricted use." SAFSTOR consists of placing and maintaining the facility in protective storage once the spent fuel and source material are removed or relocated. Concurrently, the plant staff conducts general plant decontamination activities, radiation surveys, and the processing and removal of any radioactive waste materials remaining from operations. Modified security, surveillance and maintenance plans for the delay period are implemented. Delayed dismantling (decontamination) activities are initiated such that license termination is accomplished within the 60-year time period set by the NRC. As with the DECON alternative, this study further assumes that the remainder of the reactor facility is dismantled and site restoration is performed.

The cost for the SAFSTOR alternative is increased by the cost incurred in maintaining the station in protective storage. However, there are advantages over the DECON alternative. Primarily, the dormancy period provides a period of decay for the residual radioactive material, resulting in lower personnel radiation exposures during dismantling, than are incurred in the DECON alternative. There is also the potential savings (at current prices) in the cost for disposal of the waste volume generated during decommissioning operations due to a reduction in activity levels.

ENTOMB *consists of encasing the radioactive contaminants in a structurally long-*lived material, such as concrete. The entombed structure is appropriately maintained and continued surveillance is carried out until the radioactive material decays to a level permitting unrestricted release of the property. However, this process is restricted in overall duration to 60 years and, therefore, impractical for use at a Part 50 licensee which generates significant amounts of long-lived radioactive material due to neutron activation. ENTOMB as such cannot demonstrate that items such as the reactor vessel and internals will decay to unrestricted release levels within this time frame.

The ENTOMB alternative was not considered in this evaluation, having no significant advantage over the SAFSTOR alternative. The cost of the ENTOMB alternative includes larger up-front capital expenditures, incurs greater levels of occupational exposure to the worker and does not eliminate the necessity for eventual plant decontamination.

While the disposal cost of spent fuel assemblies generated during plant operations is not considered a decommissioning expense, the presence of those assemblies on site does have a bearing on the cost to decommission. This study recognizes that the current wet spent fuel storage facilities at Salem will be active for approximately five years after operations cease at these units. This duration is based upon the current design criteria for dry storage, as well as the Department of Energy's (DOE) minimum acceptance criteria for fuel turnover and transfer to a federal repository. It is assumed that the spent fuel pool inventories at shutdown and the final core loads will be transferred to an on-site Independent Spent Fuel Storage Installation (ISFSI) to await DOE acceptance.

This study provides cost estimates for decommissioning the Salem Station under current requirements based upon present-day costs and available technology. Cost and schedule estimates presented herein are based upon the complete removal of all components and structures within the property lines, as the station is presently configured. Summaries of costs and schedule, for each alternative are provided in Table 1.1. Detailed cost reports for each decommissioning alternative are provided in Appendix C. The schedule and sequence of decommissioning activities are identified in Section 5 of this document.

TABLE 1.1

SALEM GENERATING STATION
COST AND SCHEDULE ESTIMATE SUMMARY

	Cost, 95$ (thousands) [1]	Schedule (months) [1]
DECON (Prompt Removal/Dismantling)		
Unit 1	333,442	286.6 [2]
Unit 2	347,514	284.4 [2]
STATION TOTAL	**680,956**	**328.6**
SAFSTOR (Mothball with Delayed Dismantling)		
Unit 1		
Preparations	63,164	18.0
54.1 year maintenance cost	73,150	649.4
Delayed dismantling	230,301	87.4
Subtotal Unit 1	366,615	754.8
Unit 2		
Preparations	59,810	18.0
51.8 year maintenance cost	116,479	621.8
Delayed dismantling	252,192	71.5
Subtotal Unit 2	428,480	711.2
STATION TOTAL	**795,095**	**755.4**

1. Columns may not add due to rounding.
2. Post-decommissioning dry fuel storage included in these subtotals.

2. INTRODUCTION

This analysis is designed to provide Public Service Electric and Gas Company (PSE&G) with sufficient information to prepare financial planning documents required by the New Jersey State Board of Public Utilities and the U.S. Nuclear Regulatory Commission. It is not a detailed engineering document, but a cost estimate prepared in advance of the detailed engineering preparations which will be necessary to carry out the decommissioning of the Salem site.

2.1 OBJECTIVE OF STUDY

The objective of this study is to prepare an estimate of the cost, schedule, occupational exposure and waste volume generated to decommission Salem including all common and supporting facilities.

The two nuclear units at the Salem site were constructed concurrently, with the construction permits being issued on the same date. For the purposes of this study, the shutdown dates were taken as August 13, 2016, and April 18, 2020, for Units 1 and 2, respectively. This time frame, which reflects 40 years of operating life for each unit, was used as an input for scheduling the decommissioning activities.

2.2 SITE DESCRIPTION

The Salem Station is located on the southern part of Artificial Island on the east bank of the Delaware River in Lower Alloways Creek Township, Salem County, New Jersey. The site is 15 miles south of the Delaware Memorial Bridge, 18 miles south of Wilmington, Delaware, 30 miles southwest of Philadelphia, Pennsylvania, and 7 1/2 miles southwest of Salem, New Jersey.

The Nuclear Steam Supply Systems (NSSS) consist of a pressurized water reactor and a four-loop Reactor Coolant System (RCS). The systems were supplied by the Westinghouse Electric Corporation. The licensed ratings of each of the two units is 3,411 MWt. The warranted gross and approximate net electrical outputs are 1,132 MWe and 1,090 MWe, respectively, for each unit.

The NSSS is housed within a "containment structure", a seismic Category I reinforced concrete dry structure. The containment for each of the Salem units is a steel lined, reinforced concrete cylinder with a hemispherical dome and a flat, reinforced concrete foundation mat. A welded steel liner plate, anchored to the inside face of the containment, serves as a leak-tight membrane.

Heat produced in the reactor is converted to electrical energy by the Steam and Power Conversion System (SPCS). A turbine-generator system converts the thermal energy of steam produced in the steam generators into mechanical shaft power and then into electrical energy. The plant's turbine-generators are each tandem-compound, four-element units. They consist of one high-pressure, double-flow and three low-pressure, double-flow elements driving a direct-coupled generator at 1,800 rpm. The turbines are operated in a closed feedwater cycle which condenses the steam; the heated feedwater is returned to the steam generators. Heat rejected in the main condensers is removed by the Circulating Water System.

The Circulating Water System provides the heat sink required for removal of waste heat in the power plant's thermal cycle. The system has the principal function of removing heat by absorbing this energy in the main condenser. Water is withdrawn from the Delaware River by the circulating water pumps located at the intake structure. After passing through the plant condensers, the discharge is routed back into the Delaware estuary.

2.3 REGULATORY GUIDANCE

The NRC provides decommissioning guidance in the rule "General Requirements for Decommissioning Nuclear Facilities" (Ref. 1) in addition to that previously set forth in Regulatory Guide 1.86 (Ref. 2). This rule defines three decommissioning alternatives acceptable to the NRC, i.e., DECON (prompt removal/dismantling), SAFSTOR (mothball), and ENTOMB (entombment).

DECON (Prompt Removal/Dismantling) is defined by the NRC as "the alternative in which the equipment, structures, and portions of a facility and site containing radioactive contaminants are removed or decontaminated to a level that permits the property to be released for unrestricted use shortly after cessation of operations."

SAFSTOR (Mothball) is defined as "the alternative in which the nuclear facility is placed and maintained in a condition that allows the nuclear facility to be safely stored and subsequently decontaminated (deferred decontamination) to levels that permit release for unrestricted use."

ENTOMB (Entombment) is defined as "the alternative in which radioactive contaminants are encased in a structurally long-lived material, such as concrete; the entombed structure is appropriately maintained and continued surveillance is carried out until the radioactive material decays to a level permitting unrestricted release of the property." However, this process is restricted in overall duration to 60 years and, therefore, limited in application unless it can be shown that a longer duration is necessary to protect the health and safety of the public.

Prior to this rule, no endpoint was identified for either the SAFSTOR or ENTOMB process, i.e., a facility could remain in either state indefinitely. This is no longer the case as the rule places limits on the time allowed to complete the decommissioning process. Consequently, with the new restrictions, the SAFSTOR and ENTOMB options are no longer decommissioning alternatives *in themselves, as neither terminates the license for the site. At the end of the* dormancy period, up to 60 years, both alternatives would still require site decontamination/decommissioning.

3. DECOMMISSIONING ALTERNATIVES

Two specific decommissioning alternatives were examined for the Salem study: DECON and SAFSTOR. The ENTOMB alternative was not considered, having no significant advantage over the SAFSTOR alternative. ENTOMB requires larger up-front capital expenditures, incurs greater levels of occupational exposure to the worker, without eliminating the necessity of eventual plant decontamination.

Although the DECON and SAFSTOR alternatives differ with respect to technique, process, cost, and schedule, both alternatives attain the same result: removal of all radioactive materials from the site and ultimate release of the site for unrestricted and/or alternative use. The dormancy duration selected for use in the SAFSTOR alternative is based on accomplishing license termination within the 60-year time period established by the NRC.

The following sections describe the basic activities necessary for each alternative. Although detailed procedures for each activity required are not provided, and actual sequences of work may vary, these activity descriptions may provide a basis for detailed engineering planning and scheduling at the time of decommissioning.

3.1 DECON

DECON is defined by the NRC as the alternative in which the equipment, structures and portions of a facility and site containing radioactive contaminants are removed or decontaminated to a level which permits the property to be released for unrestricted use shortly after cessation of operations. This study does not address the cost of the removal of spent fuel from the site because such costs are assumed to be covered by the 1 mill/kWhr DOE surcharge. However, the study does consider the constraints that the presence of spent fuel on site may impose on other decommissioning activities. The continued operation of a dry spent fuel storage facility, for maintenance and shipment of the estimated inventory of spent fuel from the Salem site at shutdown, is assumed. In addition to the removal of radioactive material, this study also assumes the removal of the remaining structures from the site, thereby permitting release of the Salem site for alternative use.

3.1.1 Period 1 - Preparations

Prior to the commencement of decommissioning operations, detailed preparations are undertaken to provide a smooth transition from plant operations to site decommissioning activities. These preparations include engineering planning, surveys of plant areas to determine

contamination levels, activation analyses of the reactor vessel and vessel internals, as well as the assembly of a decommissioning management organization. Final planning for activities and writing of activity specifications and detailed work procedures also begin at this time.

Engineering and Planning

Prior to the commencement of decommissioning operations, PSE&G will file an application for termination of the NRC license accompanied by a Decommissioning Plan (DP) with the NRC describing how it will remove all radioactive components and essentially all radioactive material from the Salem site. This request for dismantling of the reactor and termination of the facility's license should include a detailed plan describing the organization and program that will be used during the decommissioning of the facility. The plan will accomplish the required tasks within the As-Low-As-Reasonably-Achievable (ALARA as defined in 10 CFR 20) guidelines for protection of personnel from exposure to radioactive and non-radioactive contaminants. It will also clearly describe how PSE&G (the operating agent for the plant's owners) will continue to protect the health and safety of the public and the environment during the dismantling activity.

Prior to the start of decommissioning operations, work begins on the documentation and planning necessary for both licensing change applications and for accomplishing the work required. The development of a decommissioning organization within the utility is essential to this planning. This development includes identifying the staff requirements and commitment of key personnel.

In preparation for a change in license, regulatory criteria applicable to decommissioning are reviewed. The existing technical specifications are reviewed and modified to reflect decommissioning requirements and to delete non-applicable operating specifications. A DP is prepared during this time.

In addition, an environmental report will be required by the NRC and all applicable records (i.e., as-built or revised drawings and specifications, operating records, and site-specific background data) will be needed to support this submittal.

Much of the work in the development of the DP is also relevant to the development of the detailed engineering plans and procedures. This work includes key activities such as:

- Site preparation plans for decommissioning activities;
- Detailed procedures and sequences for removal and disposal of systems and components;
- Procedures for sectioning and disposing of the reactor vessel and its internals;
- Plans for decontamination of structures and systems;
- Design/procurement and testing of tooling and equipment;
- Identification/selection of specialty contractors;
- Procedures for removal and disposal of radioactive materials; and
- Sequential planning of activities to minimize conflicts with simultaneous activities.

<u>Site Preparations</u>

- Prepare site support and storage facilities as required. This activity is analogous to the preparations undertaken to support the increased craft labor force on site during plant maintenance and refueling outages.
- Isolate the Fuel Handling Building systems from the power block such that decommissioning operations can commence on the balance of the plant. This activity will be carried out by existing plant personnel in accordance with standard operating technical specifications. Decommissioning operations are assumed to be scheduled around the Fuel Handling Building to the greatest extent possible such that the overall project schedule is optimized. Current dry storage cask designs are licensed for spent fuel with a core discharge decay time averaging approximately five years or greater. Therefore, decommissioning operations for the Fuel Handling Building cannot be expected to begin prior to five years after shutdown of each unit. As spent fuel decays to the point that it meets the heat load criteria of the dry storage casks, it will be transferred to the dry fuel storage facility. It is assumed that all fuel is transferred to dry storage within five years and two months of the shutdown date for each unit.

- Clean all plant areas of loose contamination and process all liquid and solid wastes.

- Conduct radiation surveys of work area contamination and general dose levels; major component, piping, and structure dose levels (including the reactor vessel and its internals); internal piping contamination levels; and activation profiles from primary shield core samples.

- Calculate the residual by-product material inventory for plant components, structures and systems, and normalize neutron flux profiles on systems and structural surfaces to benchmark the survey data. This analysis will provide the basis for determining packaging and shipping requirements and decommissioning safety requirements.

- Determine shipping container requirements for activated materials and procure such containers.

- Develop procedures for occupational exposure control, control and release of liquid and gaseous effluent, control of solid radwaste, site security and emergency programs, and industrial safety.

Following approval of the DP by the NRC, the NRC will issue an order authorizing implementation. The DP may then be implemented by PSE&G.

3.1.2 Period 2 - Decommissioning Operations and License Termination

The dismantling procedures may begin upon receipt of the dismantling order from the NRC. For the DECON alternative, the decommissioning operations involve the following:

- Arrange existing storage facilities to support the dismantling activities. These may include: changing rooms and contaminated laundry facilities for increased work force, protected and open laydown areas to facilitate equipment removal and shipping operations.

- Procure and install a water cleanup system for removal of cutting residues and crud deposits from the reactor vessel.

- Design and fabricate (or procure) special shielding and contamination control envelopes, special tooling and remotely operated equipment. Modify the refueling canal to support segmentation activities and prepare rigging for segmentation and removal of piping sections, reactor coolant pumps and other components, including the reactor vessel and its internals.

- Procure required shipping casks, liners, and Low Specific Activity (LSA) containers from suppliers.

- Conduct decontamination of components and piping systems as required. Remove, package and dispose of piping and components as they are no longer required to support the decommissioning process.

- Remove control rod drive housings and instrumentation tubes from reactor vessel head and cut into sections for disposal.

- Reassemble reactor vessel head and flange (following flange separation from vessel) for shipment and disposal as its own container.

- Segment upper and lower core support structures and in-core instrumentation. Package items in shielded casks. These operations are performed remotely by cutting equipment within a contamination control envelope. Ship and dispose of packaged items.

- After the vessel water level drops below the elevation of the reactor vessel inlet and outlet nozzles during vessel segmentation, remove the reactor coolant piping and pumps. Package the piping in standard LSA containers; the reactor coolant pumps are sealed with steel plate so as to serve as their own containers. Ship and bury piping and pumps.

- Disassemble, segment and package remaining reactor internals in shielded casks. These internals include: upper support assembly, support columns and guide tube assembly, upper core plate, upper core barrel, lower core barrel, core baffle, thermal shield, lower core plate, core support columns, core support forging, and lower support structure. The operations are conducted under water using remotely operated tooling and a contamination control envelope or other contamination barrier(s). Ship and bury packaged items which meet 10 CFR 61 Class "C" requirements or less.

- Package 10 CFR 61 "Greater Than Class C" (GTCC) components into fuel bundle containers for handling and storage with the spent fuel assemblies. Transfer these fuel bundle containers to the dry fuel storage area.

- Segment/section the reactor vessel and package into shielded containers. The operation is performed remotely in air using a contamination control envelope. Sections are placed in containers under water (for example in the refueling canal) or in air with the crane operator protected by a shielded envelope. Ship and bury packaged items.

- Remove systems and associated components as they become non-essential to the support of vessel disposition, other decommissioning operations or worker health (e.g., decommissioning waste processing systems, electrical systems, HVAC systems, water systems).

- Remove concrete biological shield including activated/ contaminated concrete by controlled demolition. Package and bury radioactive portions.

- Remove contaminated equipment and material from the Fuel Handling Building and any other contaminated areas once the spent fuel pool has been emptied. Use radiation and contamination control techniques until radiation surveys indicate that the structures can be released for unrestricted access and conventional demolition.

- Ship and bury all remaining radioactive materials.

- Conduct final radiation survey to ensure that all radioactive materials have been removed. This survey may coincide with final NRC site inspection.

- Following notification by PSE&G of completion of the decontamination and disposal of components and materials from the facility, the NRC regional staff conducts an on-site survey to verify that the acceptable activity and contamination levels are satisfied. When the requirements are satisfied, the NRC can terminate the license for either the individual units or the station. The dry fuel storage facility will continue operating under a 10 CFR Part 72 license.

3.1.3 Period 3 - Site Restoration

Following completion of the decommissioning operations, site-restoration activities may begin. All building foundations are assumed to be removed to three feet below grade. Site areas affected by the dismantling activities are assumed to be cleaned and the plant area graded and landscaped as required. The costs reported to perform these activities reflect the following assumptions:

- Demolition of the remaining portions of the primary containment structure and interior portions of the Reactor Building. Internal floors (and walls if above grade) are removed from the lower levels upward, using controlled blasting techniques. Concrete rubble and clean fill produced by demolition activities may be used to backfill below-grade voids. Suitable materials can be used on site for fill; otherwise the rubble is trucked off site for reuse elsewhere.

- Remaining buildings are then removed using conventional demolition techniques for above-ground structures, including the Turbine Building, Auxiliary Building, Fuel Handling Building and other site structures.

- Prepare the final dismantling program report.

3.1.4 Post Period 3 - ISFSI Operations and Demolition

Following completion of the site restoration activities, the Independent Spent Fuel Storage Installation (ISFSI) will continue to operate. During this interval spent fuel shipments will occur. Starting in 2010, spent fuel assemblies are assumed to be shipped for a period of approximately 33 years, with the final spent fuel shipment occurring in year 2043.

After the final spent fuel shipment to the DOE, the ISFSI physical installation will be decontaminated. Continued radiation exposure from the spent fuel assemblies will cause low-level neutron activation of the interior surfaces of the dry storage modules to levels exceeding current release limits.

Following notification by PSE&G of completion of the decontamination and disposal of components and materials from the ISFSI, the NRC regional staff conducts an on-site survey to verify that the acceptable activity and contamination levels are satisfied. When the requirements are satisfied, the NRC can terminate the Part 72 ISFSI license.

The concrete dry storage modules are demolished and disposed of as clean fill, the concrete loading ramps are removed, and the area graded and landscaped to conform with the surrounding environment.

3.2 SAFSTOR

The SAFSTOR decommissioning alternative provides a condition that ensures public health and safety from radioactive material remaining at the site without the need for extensive modifications to the facility. During the SAFSTOR period the facility is left intact and all structures are maintained in a sound condition. Systems not required to be operational for support of the spent fuel pool and surveillance purposes during the dormancy period are drained, de-energized, and secured. Minimal cleaning/removal of loose contamination and/or fixation and sealing of remaining contamination are performed. Access to contaminated areas is secured to provide controlled access for inspection and maintenance.

The engineering and planning requirements are similar to those for the DECON alternative, although a shorter time period is expected for these activities due to the more limited work scope. Site preparations are also similar to those for the DECON alternative. However, with the exception of required radiation surveys, the mobilization and preparation of site facilities is less extensive.

3.2.1 Period 1 - SAFSTOR Operations

Prior to commencement of decommissioning operations, PSE&G will file a Decommissioning Plan (DP) with the NRC. The DP will describe how it will remove all radioactive components and essentially all radioactivity, safely and effectively, from the Salem station. This request for eventual dismantling of the reactor and termination of the facility's license includes a detailed plan describing the organization and program that will be used during the decommissioning of the facility. The plan will accomplish the required tasks within the ALARA guidelines for protection of personnel from exposure to radioactive contaminants. It will also clearly describe how PSE&G will continue to protect the health and safety of the public and the environment during the dismantling activities.

Following approval of the DP by the NRC, the NRC issues an order authorizing implementation. The DP may then be implemented by PSE&G. The DP addresses the spent fuel management plan, preliminary decontamination activities, and the subsequent caretaking program. The document would also provide a general description of the deferred decommissioning activity following the caretaking period. The NRC may amend the operating license to permit "Possession Only" after final plant shutdown. This amended license would remain in effect until final decontamination of the site and its release is complete.

The "Possession Only" license permits ownership and possession of fuel, by-product material and reactor components, but does not permit operation of the reactor. This license status, though permitting significant relief from the technical specifications, still requires adequate surveillance, monitoring and reporting.

After plant shutdown, modified technical specifications are implemented. Spent fuel and in-core source materials are isolated in the Fuel Handling Building awaiting ultimate disposal or transfer to the ISFSI. These steps may be carried out by plant personnel in accordance with standard operating procedures. The residual inventories of liquid and solid wastes are processed and removed and plant radiation surveys initiated.

The decommissioning activities for the SAFSTOR alternative are as follows:

- Isolate the Fuel Handling Building systems from the power block such that decommissioning operations can commence on the balance of the plant. This activity may be carried out by existing plant personnel in accordance with standard operating technical specifications. Decommissioning operations are assumed to be scheduled around the Fuel Handling Building to the greatest extent possible. Current dry storage cask designs are licensed for spent fuel with a core discharge decay time averaging approximately five years or greater. Therefore, the fuel storage facility can be expected to operate for five years after shutdown of each unit. As spent fuel decays to the point that it meets the heat load criteria of the dry storage casks, it will be transferred to the dry storage facility. It is assumed that all fuel is transferred to dry storage within 62 months of the shutdown date for each unit.

- Drain/de-energize/secure all non-contaminated systems not required to support decommissioning operations.
- Dispose of contaminated filter elements and resin beds not required for processing wastes from decontamination activities.
- Drain reactor vessel; internals will remain in place.
- Drain/de-energize/secure all contaminated systems. Decontaminate systems as required.
- Prepare lighting and alarm systems whose continued use is required. De-energize and/or secure portions of fire protection, electric power, and HVAC systems whose continued use is not required.
- Clean loose surface contamination from building access pathways.
- Perform final radiation survey of plant; post warning signs as appropriate.
- Erect physical barriers and/or secure all access to radioactive or contaminated areas, except as required for controlled access, i.e., inspection and maintenance.
- Spent fuel shipments to DOE will continue throughout Period 1 and into the dormancy period.
- Install security and surveillance monitoring equipment and relocate security fence around secured structures as required.
- Non-radioactive structures, located outside of the secured area, can be dismantled at this time. However, this study assumes that demolition would be delayed until after license termination.
- Sections of the site outside of the controlled area may be graded and landscaped as required. Part of this site area may be released for unrestricted use or for restricted use, depending on the terms of the possession-only license.

- Prepare final decommissioning program report for submittal to NRC.

3.2.2 Period 2 - SAFSTOR Dormancy

Activities required during the planned dormancy period, for the SAFSTOR alternative, include a 24-hour guard force, preventive and corrective maintenance on security systems, area lighting, general building maintenance, heating and ventilation of buildings, routine radiological inspections of contaminated buildings, maintenance of structural integrity, and an environmental and radiation monitoring program.

Spent fuel shipments to the DOE repository will continue throughout Period 2 until year 2043.

Maintenance and equipment inspection activities are provided by the utility maintenance staff. Their duty is to maintain the structures in a safe condition, provide adequate lighting, heating, and ventilation, and perform periodic preventive maintenance on essential equipment.

An environmental surveillance program is carried out during the dormancy period to ensure that releases of radioactive material to the environment are controlled. Such potential releases are identified and quantified. Appropriate emergency procedures are established and initiated for releases that exceed prescribed limits. The environmental surveillance program will be an abbreviated version of that carried out during normal plant operations.

Primary physical security is provided by the security fence which must be maintained in good condition for the duration of this period. Fire and radiation alarms will be monitored. At the end of the dormancy period for the SAFSTOR alternative, the remaining systems and structures are completely dismantled.

Although the initial radiation levels due to Co60 will decrease significantly during the dormancy period, the internal components of the reactor vessel will still have sufficiently high radiation dose rates to require remote sectioning under water due to the presence of long-lived radionuclides such as Nb94 and Ni59. Therefore, the dismantling procedures described for the DECON alternative would be employed. Portions of the concrete biological shield will still be radioactive because of the presence of activated trace elements with long half-lives (Eu152 and Eu154) and will require controlled removal, packaging, and burial procedures. It is assumed that radioactive corrosion products on inner surfaces of piping and components will not have decayed to levels that will permit unrestricted use or allow conventional removal. These systems and components are surveyed as they are removed with disposition dependent upon the existing radioactive release criteria.

With the levels of radioactivity and spectrum of radionuclides expected from forty years of plant operation, no plant process system identified as being contaminated upon final shutdown will become releasable due to the decay period, i.e., there is no significant reduction in waste volume in delaying decommissioning.

The delay in decommissioning yields lower working area radiation levels. As such, the differential between the prompt and delayed scenarios is moderated by reduced ALARA controls for the SAFSTOR's lower occupational exposure potential.

The most significant difference (from DECON) in the SAFSTOR scenario costed for Salem is the larger owner-controlled area remaining once the fuel has been transferred to the dry ISFSI. (Plant structures are decontaminated and dismantled in the DECON scenario as soon as practical. Conversely, the site facilities remain intact during the SAFSTOR caretaking period.) The activities which take place during the SAFSTOR dormancy period could add additional cost to the decommissioning program, negating the savings gained in reduced waste disposal surcharges for highly radioactive components.

3.2.3 Period 3 - Preparations

Prior to the commencement of decommissioning operations, detailed preparations are undertaken to provide a smooth transition from dormancy to site decommissioning activities. These preparations include engineering planning, surveys of plant areas to determine contamination levels, activation analyses of the vessel and vessel internals, as well as the assembly of a decommissioning management organization. Final planning for activities and writing of activity specifications and detailed procedures also begin at this time.

Because this alternative provides a period of decay of the residual radioactive material, lower personnel radiation exposures are incurred than with the DECON alternative. Some of the dismantling activities may employ manual techniques rather than remote procedures. Thus, dismantling operations may be simplified.

Much of the work in revising the DP is also relevant to the development of the detailed engineering plans and procedures. This work includes:

- Site preparation plans for decommissioning activities;
- Detailed procedures and sequences for removal of systems and components;
- Procedures for sectioning and disposing of the reactor vessel and its internals;
- Plans for decontamination of structures and systems;
- Design/procurement and testing of specialty tooling and equipment;
- Identification/selection of specialty contractors;
- Procedures for removal and disposal of radioactive materials; and
- Planning and scheduling of tasks to minimize conflicts with simultaneous activities.

3.2.4 Period 4 - Decommissioning Operations and License Termination

For the SAFSTOR alternative the decommissioning operations involve the following:

- Arrange existing storage facilities to support the dismantling activities. These may include: changing rooms and contaminated laundry facilities for increased work force, protected and open laydown areas to facilitate equipment removal and shipping operations.
- Procure and install water cleanup system for removal of cutting residues and crud deposits from the reactor vessel.
- Design and fabricate (or procure) special shielding and contamination control envelopes, special tooling and remotely

operated equipment. Modify the refueling canal to support segmentation activities and prepare rigging for segmentation and removal of piping sections, reactor coolant pumps and other components, including the reactor vessel and its internals.

- Procure required shipping casks, liners, and Low Specific Activity (LSA) containers from suppliers.

- Conduct decontamination of components and piping systems as required. Remove, package and dispose of piping and components as they are no longer required to support the decommissioning process.

- Remove control rod drive housings and instrumentation tubes from reactor vessel head and cut into sections for disposal.

- Reassemble reactor vessel head and flange (following flange separation from vessel) for shipment and disposal as its own container.

- Segment upper and lower core support structures and in-core instrumentation. Package items in shielded casks. These operations are performed remotely by cutting equipment within a contamination control envelope. Ship and dispose of packaged items.

- After the vessel water level drops below the elevation of the reactor vessel inlet and outlet nozzles during vessel segmentation, remove the reactor coolant piping and pumps. Package the piping in standard LSA containers; the reactor coolant pumps are sealed with steel plate so as to serve as their own containers. Ship and bury piping and pumps.

- Disassemble, segment and package remaining reactor internals in shielded casks. These internals include: upper support assembly, support columns and guide tube assembly, upper core plate, upper core barrel, lower core barrel, core baffle, thermal shield, lower core plate, core support columns, core support forging, and lower support structure. The operations are conducted under water using remotely operated tooling and a contamination control envelope or other contamination barrier(s). Ship and bury packaged items which meet 10 CFR 61 Class "C" requirements or less.

- Package 10 CFR 61 "Greater Than Class C" (GTCC) components into fuel bundle containers for transfer to the DOE's geologic repository.

- Segment/section the reactor vessel and package into shielded containers. The operation is performed remotely in air using a contamination control envelope. Sections are placed in containers under water (for example in the spent fuel pool) or in air with the crane operator protected by a shielded envelope. Ship and bury packaged items.

- Remove systems and associated components as they become non-essential to the support of vessel disposition, other decommissioning operations or worker health (e.g., decommissioning waste processing systems, electrical systems, HVAC systems, water systems).

- Remove concrete biological shield including activated/ contaminated concrete by controlled demolition. Package and bury radioactive portions.

- Decontaminate the ISFSI. Continued radiation exposure from the spent fuel assemblies will have produced low-level neutron activation of the interior surfaces of the dry storage modules to levels exceeding current release limits.

- Ship and bury all remaining radioactive materials.

- Conduct final radiation survey to ensure that all radioactive materials have been removed. This survey may coincide with final NRC site inspection.

- Following notification by PSE&G of completion of the decontamination and disposal of components and materials from the facility, the NRC regional staff conducts an on-site survey to verify that the acceptable activity and contamination levels are satisfied. When the requirements are satisfied, the NRC can terminate the license for either the individual units or the station.

3.2.5 Period 5 - Site Restoration

Following completion of the decommissioning operations, site-restoration activities may begin. All building foundations are assumed to be removed to three feet below grade. Site areas affected by the dismantling activities are assumed to be cleaned and the plant area graded and landscaped as required. The costs reported to perform these activities reflect the following assumptions:

- Demolition of the remaining portions of the containment structure and interior portions of the Reactor Building. Internal floors (and walls if above grade) are removed from the lower levels upward, using controlled blasting techniques. Concrete rubble and clean fill produced by demolition activities may be used to backfill below-grade voids. Suitable materials can be used on site for fill; otherwise the rubble is trucked off site for reuse elsewhere.

- Remaining buildings are then removed using conventional demolition techniques for aboveground structures, including the Turbine Building, Fuel Handling Building, Auxiliary Building, and other site structures.

- Prepare the final dismantling program report.

4. COST ESTIMATE

A site-specific cost estimate was prepared for the Salem Generating Station to account for the unique features of the site including the NSSS, electric power generation systems, site buildings and structures. The basis of the estimate (including the source of information) methodology, site-specific considerations, assumptions and total costs, are described in this section.

4.1 BASIS OF ESTIMATE

A site-specific cost estimate was developed using Salem drawings and the inventory documents provided by PSE&G. These drawings and documents were used to develop the general arrangement of the facility and to determine estimates of building concrete volumes, steel quantities, numbers and sizes of components, and land area of the site to be restored.

Decommissioning is a labor-intensive effort. Representative labor rates for each craft or salaried worker are essential for the development of a meaningful site-specific decommissioning cost estimate. Consequently, PSE&G provided the information on the local cost of labor.

Disposition of radioactive waste is a major contributor to the cost for decommissioning. The availability of burial sites is of national concern, with regional compacts being formed to provide adequate burial space for operating and planned reactors. In this study, a base waste burial fee of $298.20 per cubic foot was assumed. New Jersey is a member of the Northeast Compact which has not published any rate structure for the yet-to-be constructed facility. This figure is representative of estimates for new facilities and consistent with radioactive waste disposal charges in place as of July 1995 at the Chem Nuclear Systems, Inc., Barnwell LLW Management Facility (Barnwell) in South Carolina. Surcharges for high-curie and high-weight packages are also based upon this schedule.

4.2 METHODOLOGY

The methodology used to develop the cost estimates follows the basic approach originally presented in the AIF/NESP-036 study report, "Guidelines for Producing Commercial Nuclear Power Plant Decommissioning Cost Estimates" (Ref. 3) and the US DOE "Decommissioning Handbook" (Ref. 4). These references utilize a unit cost factor method for estimating decommissioning activity costs to simplify the estimating calculations. Unit cost factors for concrete removal ($/cubic yard), steel removal ($/ton) and cutting costs ($/in) were developed from the labor cost information provided by PSE&G. With the item quantity (cubic yards, tons, inches, etc.) developed from plant drawings and inventory documents, the activity-dependent costs are estimated.

The unit cost factors used in this study reflect the latest available information about worker productivity in decommissioning, including the Shippingport Station Decommissioning Project, completed in 1989, as well as from TLG's involvement in the decommissioning planning and engineering for the Shoreham, Yankee Rowe, Trojan, Rancho Seco, Pathfinder and Cintichem reactor facilities.

The activity duration critical path was used to determine the total decommissioning program schedule. The program schedule is used to determine the period-dependent costs for program management, administration, field engineering, equipment rental, quality assurance and security. PSE&G provided typical salary and hourly rates for personnel associated with period-dependent costs. The costs for conventional demolition of nonradioactive structures, materials, backfill, landscaping and equipment rental were obtained from the "Building Construction Cost Data" published by R. S. Means (Ref. 5). Examples of unit cost factor development are presented in the AIF/NESP-036 study (Ref. 3). Appendix A presents the detailed development of a typical site-specific unit cost factor. Appendix B summarizes specific factors developed for the Salem analyses.

The activity- and period-dependent costs are combined to develop the total decommissioning costs. A contingency is then applied. "Contingencies" are defined in the American Association of Cost Engineers Cost Engineers' Notebook (Ref. 6) as "specific provision for unforeseeable elements of cost within the defined project scope; particularly important where previous experience relating estimates and actual costs has shown that unforeseeable events which will increase costs are likely to occur." The cost elements in this estimate are based upon ideal conditions; therefore, a contingency factor has been applied. As with any major project, examples of items which could occur that have not been accounted for in this estimate are changes in the regulatory requirements, the effects of craft labor strikes, bad weather halting or slowing down waste shipments to the burial grounds, equipment/tool breakage, changes in the anticipated plant shutdown conditions, etc. In the "Guidelines" study (Ref. 3), the types of unforeseeable events that are likely to occur in decommissioning are discussed and guidelines are provided for percentage contingency in each category. Application of contingency is assigned on a line item basis for this estimate. It should be noted that contingency, as used in this estimate, does not account for price escalation and inflation in the cost of decommissioning over the remaining operating life of the unit.

The unit cost factor method provides a demonstrable basis for establishing reliable cost estimates. The detail of activities provided in the unit cost factors for activity time, labor costs (by craft), and equipment and consumable costs, provides assurance that cost elements have not been omitted. These detailed unit cost factors, coupled with the plant-specific inventory of piping, components and structures, provide a high degree of confidence in the reliability of the cost estimates.

4.3 SITE-SPECIFIC CONSIDERATIONS

There are a number of site-specific considerations that affect the method for dismantling and removal of equipment from the site and the degree of restoration required. The cost impact of the considerations identified below is included in this cost study.

4.3.1 Spent Fuel Disposition

The existing spent fuel pools, with capacity to store 1,632 fuel bundles each, are expected to be full at the time of shutdown for each unit. PSE&G is currently involved in phase 3 licensing efforts at the Mescalero facility in New Mexico. It is assumed for this study, that the Mescalero facility will be licensed and operating prior to plant shutdown. The facility will have provided Salem with sufficient turnover of spent fuel assemblies such that additional on-site storage space will not be required to support plant operations. After plant shutdown, the continued cost of wet storage for the full fuel pool inventory will be incurred until the final full core load of fuel has decayed for at least 60 months from reactor core discharge date. The five years are needed to permit the heat generation rate of the spent fuel assemblies to decay to acceptable levels for transportation and dry storage, typically 1 kilowatt per assembly. The decommissioning scenario has been constructed to permit continued operation of the Fuel Handling Building for each unit for this five-year period. Once the final core discharge of spent fuel assemblies has been placed in dry storage, the Fuel Handling Building spent fuel storage and handling facilities are available for decommissioning.

Current plans are for spent fuel storage to continue after shutdown of Salem until the year 2043. During this time, shipment of spent fuel from the dry ISFSI to the U.S. Department of Energy Waste Management System for geologic disposal will be conducted, after which the dry storage facility will be decontaminated and demolished.

4.3.2 Major Component Removal

The reactor pressure vessel and reactor internal components are segmented for disposal in shielded shipping casks. Segmentation and packaging of the internals' packages are performed in the refueling canal where a turntable and remote cutter will be installed. The vessel is segmented in place using a mast-mounted cutter supported off the lower head and directed from a shielded work platform installed overhead in the canal. Shipping cask specifications and DOT regulations dictate segmentation and packaging methodology; all packages designated meet the current physical and radiological limitations and regulations. All cask shipments are to be made in US DOT-approved, currently available, truck casks.

4.3.3 Steam Generators and Other NSSS Components

The size and weight of the steam generators, their configuration in the Reactor Building, as well as the limited access in the Reactor Building itself place restrictions on the removal of these components. Modifications to the Reactor Building are necessary for component extraction due to the fact that the only large access to the building is the existing equipment hatch located approximately 30 feet above grade. The removal of the generators through this hatch requires that the units be positioned horizontally, which becomes impossible due to physical impediments within the structure.

Determination of the removal strategy requires several different considerations including: modifications to the Reactor Building for removal of the generators; rigging needed to maneuver and remove the generators from the structure; and the component preparations needed to transport the generators to a disposal site.

A potential method for removal (and the one used as a basis in this estimate) is through an opening created in the building large enough for the extraction of the generators. This opening would be approximately forty feet square and at grade level. Creating this opening will provide the room needed for extraction of the generators and for the rigging equipment required for their removal. Removal of sections of the steam generator cubicle walls, adjoining floor slabs and grating would also have to be accomplished to allow the generators to be maneuvered through the opening.

The opening in the Reactor Building would be created using a diamond wire saw to section the containment wall into large blocks for removal. Once the building is opened, grating within the work area will be decontaminated and removed. A trolley crane will be set up for removal of the generators, portions of the steam generator cubicle walls and portions of floor slabs. A 15-foot section of the cubicle wall will be removed to allow for the maneuvering of the generators within the building. Large cubicle wall sections are lowered out of the Reactor Building using the trolley crane where they can be decontaminated, segmented, and prepared for ultimate disposal.

The generators are rigged for removal, disconnected from the surrounding piping and supports and maneuvered into the open area and lowered onto a dolly. The dolly will allow the lower end of the steam generator to rotate through the construction opening as it is being lowered. Once the steam generator has been lowered to the horizontal position, it will be filled with low-density cellular concrete for stabilization of the internal contamination. Nozzles and other openings will be welded closed. The generator will be then be lifted onto a multi-wheeled transporter and moved to an on-site storage area to await transport to the disposal facility. The remaining steam generators will be removed using the same technique. Once the generator removal is complete, a portion of the construction hatch will be closed using concrete blocks. A smaller opening will be covered with a temporarily sealed barrier to allow for access during future decommissioning.

Once at the storage area, two-inch thick carbon steel plate will be welded to the outside surface of each generator for shielding during transport. The generators will then be loaded onto multi-wheeled transporters and moved to the Barge Loading Facility where they will be shipped to the Northeast Compact's waste disposal facility by a combination of barge and overland transport.

The size and weight of the generator packages was a concern in evaluating transportation alternatives. As such, discussions were held with Lampson, Inc., (rigging) on the moving of the generators. Lampson has experience moving large nuclear components and was able to supply pricing based on the specific generator dimensions and weight. TLG was also able to apply experience gained in the Large Component Removal Program at the Trojan Nuclear Plant, where Lampson was a subcontractor.

The pressurizer will be removed and prepared as its own package for burial in the same fashion as the steam generators.

Reactor coolant piping is cut from the reactor vessel once the water level in the vessel (used for personnel shielding during dismantling and cutting operations in and around the vessel) is dropped below the nozzle zone. The piping is boxed and shipped by shielded van. The reactor coolant pumps and motors are lifted out intact, packaged and transported together with the steam generators for disposal.

4.3.4 Transportation Methods

For the purposes of cost estimation, it was assumed that the NSSS components are moved by a combination of ocean-going barge, overland transport and/or rail to the regional burial facility.

4.3.5 Low-Level Radioactive Waste Disposal

Burial cost projections for the regional radioactive waste disposal facility were based on radioactive waste disposal charges in place as of July 1995 at the Chem Nuclear Systems, Inc., Barnwell LLW Management Facility (Barnwell) in South Carolina. Surcharges for high-curie and high-weight packages are also based upon this schedule (Ref. 7).

It is assumed that there will be no significant amounts of RCRA waste, mixed waste or asbestos on site at the time of decommissioning, since it is PSE&G's goal to have proper planning to minimize or eliminate the generation of hazardous and mixed radioactive wastes.

To the greatest extent practical, non-compactable low-level radioactive waste is recycled to reduce the total volume of radioactive material buried. The recycled waste that meets radioactive material release limits is released as clean scrap, requiring no further cost consideration. Recycled material that does not meet release limits will be shipped and disposed of as radioactive waste. This recycling activity is performed off site by a licensed radioactive waste recovery vendor.

Compactable DAW, such as booties, glove liners, respirator filter cartridges, shipping containers, radiological controls survey materials, etc. will be assumed to be drummed and compacted to 10% of their original volume.

4.3.6 Site Conditions at Facility Close Out

It is assumed that the site is restored by regrading to conform to the adjacent landscape. Soil matching that of the adjacent landscape is brought on site and placed to allow growth of native vegetation and drainage. The intake structure on site will be demolished and removed and the circulating water piping will be sealed and abandoned in place. The switchyard and site drainage facilities remain in place.

4.4 ASSUMPTIONS

The following are the major assumptions made in the development of the cost estimates for Salem.

1. Costs are calculated using 1995 dollars. The estimate excludes escalation. No present-value economic analysis is included.

2. Salem Unit 1 is expected to operate until the end of its current license expiration date, August 13, 2016.

3. Salem Unit 2 is expected to operate until the end of its current license expiration date, April 18, 2020.

4. All shared or common site vestiges are included with the estimate for Unit 2.

5. Salem drawings, equipment and structural specifications, including construction details, were provided by PSE&G.

6. Employee salary and craft labor rates for site administration, operations, construction and maintenance personnel were provided by PSE&G for positions identified by TLG.

7. PSE&G provides for the electrical power required to demolish the plant to be brought on site. These costs are included in the estimate.

8. Material and equipment costs for conventional demolition and/or construction activities were taken from R.S. Means Construction Cost Data. (Ref. 5)

9. Contaminated piping, components and structures other than the reactor vessel and internals will be assumed to meet US DOT limits for LSA material. For transportation calculations, a regional burial facility is

assumed to be located within 100 miles of the plant site. Rates for shipping radioactive wastes were provided by Tri-State Motor Transit in published tariffs for this cargo. (Ref. 8).

10. The reactor vessel and internals' disposal costs were based on remote in-place segmentation, packaging in shielded casks, and shipping by truck to the burial ground. A maximum normal road weight limit of 80,000 pounds is assumed for all truck shipments with the exception of several overweight cask shipments. Cask shipments may exceed 95,000 pounds, including vessel segment(s), supplementary shielding, cask tie-downs and tractor trailer. The maximum curies per shipment assumed permissible is based upon the license limits of available shielded shipping casks. The number and curie content of vessel segments were selected to meet these limits.

    The number of cask shipments out of the Reactor Building is assumed to average one and one half per week.

11. In the DECON alternative, the NSSS (reactor vessel and reactor coolant system) will be chemically decontaminated using one chemical flush and two water rinses prior to segmentation. Typically, a decontamination factor (DF) of 10 is expected.

12. Reactor vessel and internals packages' conditions:

    Any fuel cladding failure that has occurred or may occur during the lifetime of the plant is assumed:

    a) to have released fission products at sufficiently low levels that the buildup of quantities of long-lived isotopes (e.g. cesium-137, strontium-90, or transuranics) has been prevented from reaching levels exceeding those which permit the major NSSS components to be shipped as LSA waste and buried within the requirements of 10 CFR 61 or the regional burial ground; or

    b) to have necessitated systematic decontamination during the operating life of the plant; therefore, the radionuclide levels will be acceptable for transport as LSA waste and burial within the requirements of 10 CFR 61.

13. For purposes of this cost estimate, the curie contents of the vessel and internals at final shutdown are derived from those listed in NUREG/CR-3474 (Ref. 9). These estimates (derived from the Ci/gram values in

NUREG/CR-3474) are adjusted for the different mass of Salem components, projected operating life, as well as for different periods of decay. Additional short-lived isotopes will be derived from NUREG/CR-0130 (Ref. 10) and NUREG/CR-0672 (Ref. 11) and benchmarked to the long-lived values from NUREG/CR-3474.

14. This study estimates that there will be some radioactive waste generated which is greater than 10 CFR 61 Class C quantities, resulting from disposal of the highly activated sections of the reactor vessel internals. This waste will most likely be disposed of as high-level waste in the DOE's deep geological repository unless an alternative solution is approved by the NRC. The cost of disposal, unlike that for the spent fuel, is not covered by DOE's 1 mill/kWhr surcharge, and has been estimated from equivalent disposal costs for spent nuclear fuel.

15. Control element assemblies will be removed and disposed of along with the spent fuel assemblies.

16. The costs associated with the caretaking of spent fuel in the ISFSI are included within the decommissioning cost.

17. This study does not address the cost of the removal or disposal of spent fuel from the site. This cost is assumed to be covered by the DOE 1 mill/kwhr surcharge.

18. The final reactor core discharge will remain in the spent fuel pool for approximately five years, where it will then be transferred to a dry storage facility (ISFSI). It is assumed that a modular type ISFSI will be constructed to support decommissioning of the nuclear unit. Dry fuel storage modules will be constructed to support decommissioning of the Fuel Handling Building, the costs for which are included in this estimate.

19. The ISFSI will use a horizontal concrete storage module system. The study assumes dual purpose (storage and transport) canisters to be paid for by PSE&G. PSE&G will also be responsible for the concrete storage modules for these canisters. Only those modules needed to empty the spent fuel pool at shutdown, are reflected within the decommissioning cost, i.e., operational requirements are not addressed. These costs are assumed to be covered by the operating plant through the existing licensing agreement with the Mescalero Apaches in New Mexico. Capital expenditures were based upon a canister design of 24 fuel bundles per canister.

20. The spent fuel is assumed to be stored for 23 years after shutdown of Unit 2 (until 2043) with periodic shipment to the DOE high-level waste repository. The cost for the storage of spent fuel will be included with the cost for decommissioning. The decommissioning cost for the ISFSI is identified as a separate line item cost in Appendix C.

21. Scrap generated during decommissioning is not included as a salvage credit line item in this study for two reasons: (1) the scrap value merely offsets the associated site removal and scrap processing costs, and (2) a relatively low value of scrap exists in the market. Scrap processing and site removal costs are not included in the estimate.

22. Decommissioning will take place sufficiently far in the future that all equipment will be worn, obsolete and suitable for scrap as deadweight quantities only. No equipment is salvageable as used equipment.

23. The PSE&G staffing requirements during decommissioning vary with the level of effort associated with the various phases of the project. Once the decommissioning program commences, only those staff positions which will be necessary to support the decommissioning program are included. There are no costs for staff transition from operations to decommissioning.

24. This study assumes that PSE&G will serve as the Decommissioning Operations Contractor (DOC) for the decommissioning project. As such, PSE&G will provide sufficient staff to perform the preparatory demolition planning and scheduling, and manage the demolition efforts. Site security, radiological controls, quality assurance and overall site administration during decommissioning and demolition will also be provided by PSE&G. The demolition work is performed by PSE&G, or a demolition subcontractor who will provide adequate staff, labor, equipment, materials and overhead to complete the demolition.

25. Engineering services for such items as writing activity specifications, detailed procedures, detailed activation analyses, structural modifications, etc. are assumed to be provided by PSE&G.

26. PSE&G will remove all items of furniture, tools, mobile equipment such as forklifts, trucks, bulldozers, other similar mobile equipment and other such items owned by PSE&G that will be easily removed without the use of special equipment.

27. Existing warehouses will remain for use by PSE&G and its subcontractors. The warehouses will be dismantled as they are no longer needed to support the decommissioning program.

28. There will be no significant amount of hazardous or toxic materials on site at shutdown. It is assumed that disposal of this material will be ongoing as part of the environmental monitoring and remediation activities at the station. PSE&G will perform the following activities at no cost or credit to the project:

    - Fuel oil tanks will be emptied. Tanks will be cleaned by flushing or steam cleaning as required prior to disposal.

    - Acid and caustic tanks will be emptied through normal usage.

    - Excess acid, caustic, and all chemicals listed (at shutdown) in the New Jersey "Right to Know Report" will be removed and the storage container returned to the vendor. It is assumed that these chemicals will have some value, therefore, the cost for their removal will be compensated through their subsequent sale.

    - Lubricating and transformer oils will be drained and removed from site by a waste disposal vendor.

29. The decommissioning activities will be performed in accordance with the current regulations which are assumed to be in place at the time of decommissioning, including the Industrial Site Recovery Act (ISRA) which is mandatory under current New Jersey State Regulations.

30. This study follows the principles of ALARA through the use of work duration adjustment factors which incorporate such items as radiological protection instruction, mock-up training, the use of respiratory protection and personnel protective clothing. These items lengthen a task's duration, which increases the costs and lengthens the schedule. ALARA planning is considered in the costs for engineering and planning, and in the development of activity specifications and detailed procedures.

31. This study was performed in accordance with the published study from the Atomic Industrial Forum/National Environmental Studies Project report AIF/NESP-036, "Guidelines for Producing Commercial Nuclear Power Plant Decommissioning Cost Estimates". The contents of those guidelines were prepared under the review of a task force consisting of

representatives from utilities, state regulatory commissions, architect/engineering firms, the Federal Energy Regulatory Commission, the NRC, and the National Association of Regulatory Utility Commissioners.

32. Nuclear liability insurance provides coverage for damage or injuries due to radiation exposure from equipment, material, etc. used during decommissioning. Nuclear liability insurance is phased out upon final decontamination of the site. PSE&G provided current nuclear liability and property insurance premiums which were factored to reflect lower coverage limits and return of premiums during decommissioning activities.

33. Only existing site structures and those presently planned will be considered in the dismantling cost.

34. The perimeter fence and in-plant security barriers will be moved as appropriate to conform with the Site Security Plan in force at the various stages in the project.

35. The existing electrical switchyard will remain after the Salem decommissioning in support of the electrical transmission and distribution system.

36. Underground concrete pipe is assumed to be collapsed and backfilled if it is located less than 10 feet below grade. Underground steel pipe, if located less than 10 feet below grade, is assumed to be removed completely, surveyed for contamination, removed from the site and disposed of as clean scrap. Piping located greater than 10 feet below grade will be sealed with concrete plugs and abandoned in place.

37. Electrical manholes are assumed to be backfilled with suitable earthen material and abandoned.

38. All site buildings are assumed to be removed to a depth three feet below grade. Water drain holes are assumed to be drilled in all remaining below-grade foundations and basemats to provide for natural drainage.

39. All remaining site vestiges are assumed to be removed to a depth of three feet below grade level with the non-contaminated sub-grade foundations remaining in place. Water drain holes are assumed to be drilled in each of the foundation basemats to allow for natural drainage.

This degree of site restoration will constitute compliance with the CAFRA document dated July 9, 1976.

40. Building foundations are assumed to be backfilled with clean demolition debris, and the site graded and landscaped. All areas affected by dismantling activities are assumed to be cleaned up, covered with loam and seeded.

41. All road and parking area base material is assumed to remain in place. Road and parking areas with asphalt are assumed to be broken up and disposed of at the nearest New Jersey state-licensed landfill. All gravel road and parking areas are assumed to remain in place with the area covered with fill and loam and seeded.

42. Upon completion of the dismantling operations, the site is assumed to be returned to the condition that existed prior to installation of the reactor facility.

43. The site will be returned to unrestricted use after the NRC approval to terminate the possession-only license is received.

44. All property tax payments will cease upon shutdown of each unit.

4.5 COST ESTIMATE SUMMARY

A summary of the decommissioning costs with annual expenditures is provided in Tables 4.1a-4.1d. Table 8.1 also shows the breakdown of the decommissioning costs into the components of decontamination, removal, packaging, transportation, waste disposal, project management (staffing) and other cost categories. The costs were extracted from the detailed reports in Appendix C.

The detailed cost tables (Appendix C) show the detailed listing and costs of major activities for Salem for the DECON and SAFSTOR decommissioning alternatives. Note that "Decon" as used in the headings of these tables, refers to decontamination. It should be noted that "Total" as used in the heading of tables, is the sum of Decon, Remove, Pack, Ship and Bury, as well as other miscellaneous items not listed (such as engineering and preparations). Staff relocation expenses are those costs associated with moving specialty contractor personnel to the site, either for per diem allowance or for moving expenses.

4.6 DECOMMISSIONING vs. SITE RESTORATION

The total projected station cost of decommissioning Salem for the DECON alternative is $680,956,000. The majority of this cost is directly attributable to the engineering and planning and the actual disposition of the residual radioactive material. It should be noted, however, that a direct accounting of only these costs is not entirely accurate in portraying the actual cost of "decommissioning" as defined by the NRC. Consideration must also be given to the method of executing the decommissioning process. The following paragraphs describe, in general, the activities which are both necessary to complete the decommissioning process and which extend beyond the disposition of the radioactively contaminated inventory.

Nuclear power plants are designed to contain the radioactive material inherent in the normal operation of the facility. Accordingly, radioactive and potentially radioactive systems are located in shielded labyrinths, tunnels and pipe chases. This inaccessibility, while essential during operation, serves to impede decommissioning activities. Consequently, disposition of these components requires that, in many situations, additional access (and working space) be developed. This access is achieved by dismantling structures and components along the intended path of egress and in the immediate working area. In most instances, this material is non-radioactive and therefore not normally perceived as a necessary constituent in facility decontamination. However, failure to establish adequate working room will increase the residence times for decontamination and dismantling activities resulting in increases in the cost and incurred occupational exposure.

The costs associated with the removal of non-contaminated and other releasable materials in support of the decommissioning process are commonly referred to as cascading costs. Cascading costs are identified in evaluating the dismantling processes involved in decommissioning Salem and are included with the license termination costs delineated in Appendix C. Consequently, for the utility to meet the intent of the NRC's definition of decommissioning, ("...release of the property for unrestricted use and termination of license") a cost of $602,740,896 would be required to terminate the facility's license(s), or approximately 89% of the total cost. The remaining costs would be required for site restoration as described in Section 3.

TABLE 4.1a
SUMMARY OF DECON DECOMMISSIONING COSTS
Salem Generating Station Unit 1
(1995 Dollars)

Year	Period 1 Preparations	Period 2 Decommissioning	Period 3 Site Restoration	Post Period 3 Dry Fuel Storage	Totals
2016	$15,812,091				$15,812,091
2017	$40,932,008				$40,932,008
2018	$4,694,285	$46,165,320			$50,859,604
2019		$51,881,068			$51,881,068
2020		$50,726,684			$50,726,684
2021		$50,209,591			$50,209,591
2022		$30,263,984	$1,755,177		$32,019,161
2023			$4,652,769		$4,652,769
2024			$4,665,516		$4,665,516
2025			$4,652,769		$4,652,769
2026			$5,961,993		$5,961,993
2027			$4,679,705	$272,170	$4,951,876
2028				$967,130	$967,130
2029				$964,487	$964,487
2030				$964,487	$964,487
2031				$964,487	$964,487
2032				$967,130	$967,130
2033				$964,487	$964,487
2034				$917,278	$917,278
2035				$740,703	$740,703
2036				$742,733	$742,733
2037				$740,703	$740,703
2038				$740,703	$740,703
2039				$740,703	$740,703
2040				$5,701,337	$5,701,337
	$61,438,384	$229,246,648	$26,367,930	$16,388,542	$333,441,504

TABLE 4.1b
SUMMARY OF DECON DECOMMISSIONING COSTS
Salem Generating Station Unit 2
(1995 Dollars)

Year	Period 1 Preparations	Period 2 Decommissioning	Period 3 Site Restoration	Post Period 3 Dry Fuel Storage	Totals
2020	$24,493,523				$24,493,523
2021	$27,518,189	$10,864,459			$38,382,648
2022		$52,775,187			$52,775,187
2023		$52,177,162			$52,177,162
2024		$51,647,234			$51,647,234
2025		$53,304,690			$53,304,690
2026		$16,408,080	$18,370,983		$34,779,063
2027			$20,196,613	$224,607	$20,421,219
2028				$967,130	$967,130
2029				$964,487	$964,487
2030				$964,487	$964,487
2031				$964,487	$964,487
2032				$967,130	$967,130
2033				$964,487	$964,487
2034				$916,804	$916,804
2035				$738,457	$738,457
2036				$740,480	$740,480
2037				$738,457	$738,457
2038				$738,457	$738,457
2039				$738,457	$738,457
2040				$740,480	$740,480
2041				$738,457	$738,457
2042				$738,457	$738,457
2043				$6,913,055	$6,913,055
	$52,011,712	$237,176,812	$38,567,596	$19,758,376	$347,514,496

TABLE 4.1c
SUMMARY OF SAFSTOR DECOMMISSIONING COSTS
Salem Generating Station Unit 1
(1995 Dollars)

Year	Period 1 Dormancy Prep	Period 2 Dormancy	Period 3 Preparations	Period 4 Decommissioning	Period 5 Site Restoration	Totals
2016	$16,256,114					$16,256,114
2017	$42,081,429					$42,081,429
2018	$4,826,106	$4,577,271				$9,403,377
2019		$5,170,217				$5,170,217
2020		$4,268,472				$4,268,472
2021		$3,326,450				$3,326,450
2022		$1,374,188				$1,374,188
2023		$1,374,188				$1,374,188
2024		$1,377,953				$1,377,953
2025		$1,374,188				$1,374,188
2026		$1,353,262				$1,353,262
2027		$1,345,365				$1,345,365
2028		$1,349,051				$1,349,051
2029		$1,345,365				$1,345,365
2030		$1,345,365				$1,345,365
2031		$1,345,365				$1,345,365
2032		$1,349,051				$1,349,051
2033		$1,345,365				$1,345,365
2034		$1,345,365				$1,345,365
2035		$1,345,365				$1,345,365
2036		$1,349,051				$1,349,051
2037		$1,345,365				$1,345,365
2038		$1,345,365				$1,345,365
2039		$1,345,365				$1,345,365
2040		$1,159,533				$1,159,533
2041		$969,419				$969,419
2042		$969,419				$969,419
2043		$969,419				$969,419
2044		$972,075				$972,075
2045		$969,419				$969,419
2046		$969,419				$969,419
2047		$969,419				$969,419
2048		$972,075				$972,075
2049		$969,419				$969,419
2050		$969,419				$969,419
2051		$969,419				$969,419
2052		$972,075				$972,075
2053		$969,419				$969,419
2054		$969,419				$969,419
2055		$969,419				$969,419
2056		$972,075				$972,075
2057		$969,419				$969,419
2058		$969,419				$969,419
2059		$969,419				$969,419
2060		$972,075				$972,075
2061		$969,419				$969,419
2062		$969,419				$969,419
2063		$969,419				$969,419
2064		$972,075				$972,075
2065		$969,419				$969,419
2066		$969,419				$969,419
2067		$969,419				$969,419
2068		$972,075				$972,075
2069		$969,419				$969,419
2070		$969,419				$969,419
2071		$969,419				$969,419
2072		$222,605	$16,232,855			$16,455,460
2073			$15,282,981	$16,798,780		$32,081,761
2074				$61,731,536		$61,731,536
2075				$57,280,195		$57,280,195
2076				$35,125,868	$95,040	$35,220,907
2077					$246,025	$246,025
2078					$17,540,351	$17,540,351
2079					$9,967,603	$9,967,603
	$63,163,648	$73,149,712	$31,515,836	$170,936,378	$27,849,018	$366,614,592

TABLE 4.1d
SUMMARY OF SAFSTOR DECOMMISSIONING COSTS
Salem Generating Station Unit 2
(1995 Dollars)

Year	Period 1 Dormancy Prep	Period 2 Dormancy	Period 3 Preparations	Period 4 Decommissioning	Period 5 Site Restoration	Totals
2020	$28,165,724					$28,165,724
2021	$31,643,864	$1,114,403				$32,758,266
2022		$5,413,321				$5,413,321
2023		$5,413,321				$5,413,321
2024		$5,428,152				$5,428,152
2025		$4,184,559				$4,184,559
2026		$2,075,416				$2,075,416
2027		$1,674,938				$1,674,938
2028		$1,679,527				$1,679,527
2029		$1,674,938				$1,674,938
2030		$1,674,938				$1,674,938
2031		$1,674,938				$1,674,938
2032		$1,679,527				$1,679,527
2033		$1,674,838				$1,674,938
2034		$1,674,938				$1,674,938
2035		$1,674,938				$1,674,938
2036		$1,679,527				$1,679,527
2037		$1,674,938				$1,674,938
2038		$1,674,938				$1,674,938
2039		$1,674,938				$1,674,938
2040		$2,459,996				$2,459,996
2041		$3,223,150				$3,223,150
2042		$3,223,150				$3,223,150
2043		$2,628,651				$2,628,651
2044		$2,049,444				$2,049,444
2045		$2,043,844				$2,043,844
2046		$2,043,844				$2,043,844
2047		$2,043,844				$2,043,844
2048		$2,049,444				$2,049,444
2049		$2,043,844				$2,043,844
2050		$2,043,844				$2,043,844
2051		$2,043,844				$2,043,844
2052		$2,049,444				$2,049,444
2053		$2,043,844				$2,043,844
2054		$2,043,844				$2,043,844
2055		$2,043,844				$2,043,844
2056		$2,049,444				$2,049,444
2057		$2,043,844				$2,043,844
2058		$2,043,844				$2,043,844
2059		$2,043,844				$2,043,844
2060		$2,049,444				$2,049,444
2061		$2,043,844				$2,043,844
2062		$2,043,844				$2,043,844
2063		$2,043,844				$2,043,844
2064		$2,049,444				$2,049,444
2065		$2,043,844				$2,043,844
2066		$2,043,844				$2,043,844
2067		$2,043,844				$2,043,844
2068		$2,049,444				$2,049,444
2069		$2,043,844				$2,043,844
2070		$2,043,844				$2,043,844
2071		$2,043,844				$2,043,844
2072		$1,473,589				$1,473,589
2073		$786,271	$5,424,625			$6,210,896
2074			$13,743,425			$13,743,425
2075			$1,460,642	$55,854,738		$57,315,380
2076				$62,852,172		$62,852,172
2077				$63,673,045		$63,673,045
2078				$6,122,626	$26,562,973	$32,685,599
2079					$16,497,679	$16,497,679
	$59,809,588	$116,478,776	$20,628,692	$188,502,580	$43,060,652	$428,480,288

5. SCHEDULE ESTIMATE

The schedules for the integrated decommissioning scenarios considered in this study follow the sequence presented in the AIF/NESP-036 study (Ref. 3) with minor changes to reflect recent experience and revised estimates. In addition, the scheduling has been revised to reflect the spent fuel scenario which is currently planned for Salem.

TLG has prepared a schedule for decommissioning Salem. The assumptions supporting this schedule are listed in Section 5.1. Figure 5.1 presents the schedule of key activities. Note that the activities listed in the schedules do not reflect a one-to-one correspondence with the activities in the cost tables in Appendix C, but reflect dividing some activities for clarity and combining others for convenience. The schedule was prepared using the "Microsoft Project" computer software (Ref. 12).

5.1 SCHEDULE ESTIMATE ASSUMPTIONS

The schedule estimate reflects the results of a precedence network developed for the Salem decommissioning activities, i.e., a PERT (Program Evaluation and Review Technique). The durations used in the precedence network reflect the actual man-hour estimates from the cost tables in Appendix C. The schedule output is then adjusted by stretching certain activities over their slack range; other activities were pushed to the end of their slack period. The following assumptions were made in the development of the decommissioning schedule for Salem:

1. All work except vessel and internals removal activities is performed during an 8-hour workday, 5 days per week with no overtime. There are eleven paid holidays per year.

2. The Fuel Handling Buildings will be isolated and serve as interim wet fuel storage facilities until such time that all spent fuel has been discharged from the spent fuel pools, i.e., within five years and two months from shutdown of each nuclear unit.

3. Vessel and internals removal activities are performed by using separate crews for different activities working on different shifts, with a corresponding backshift charge for the second shift.

4. Multiple crews work parallel activities to the maximum extent possible consistent with optimum efficiency, adequate access for cutting, removal

and laydown space, and with the stringent safety measures necessary during demolition of heavy components and structures.

5. For plant systems removal, the systems with the longest removal durations in areas on the critical path are considered to determine the duration of the activity.

5.2 PROJECT SCHEDULE

The period-dependent costs presented in the cost tables in Appendix C are based upon the durations developed in the schedule for the DECON alternative. Durations are established between several milestones in each project period; these durations are used to establish a critical path for the entire project. In turn, the critical path duration for each period is used as the basis for determining the total costs for these period-dependent items.

Project timelines are included in this section as Figure 5.2a and 5.2b. Milestone dates are based on a 40-year plant operating life from the issuance of the operating license.

FIGURE 5.1
DECON ACTIVITY SCHEDULE

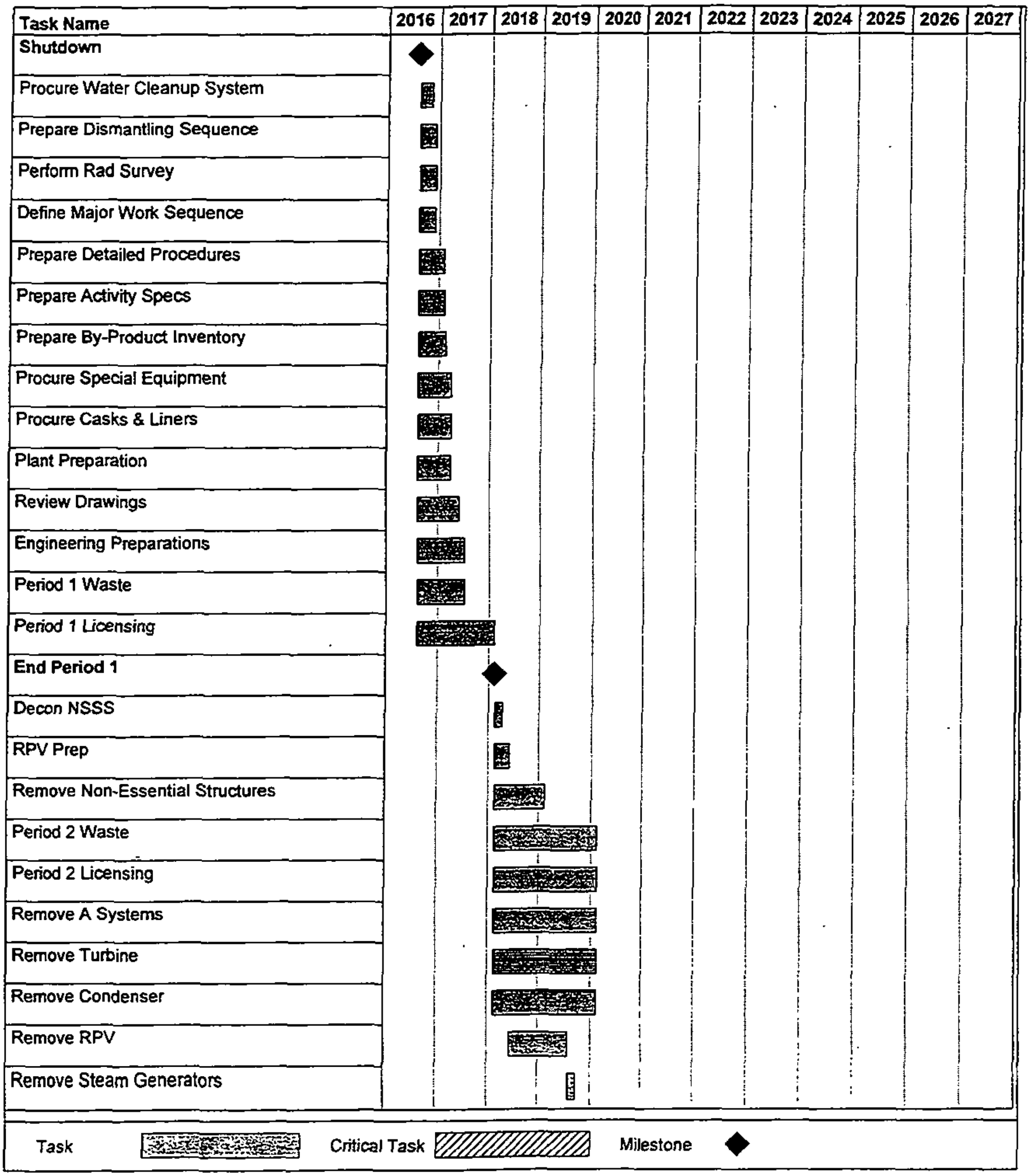


FIGURE 5.1
DECON ACTIVITY SCHEDULE
(continued)

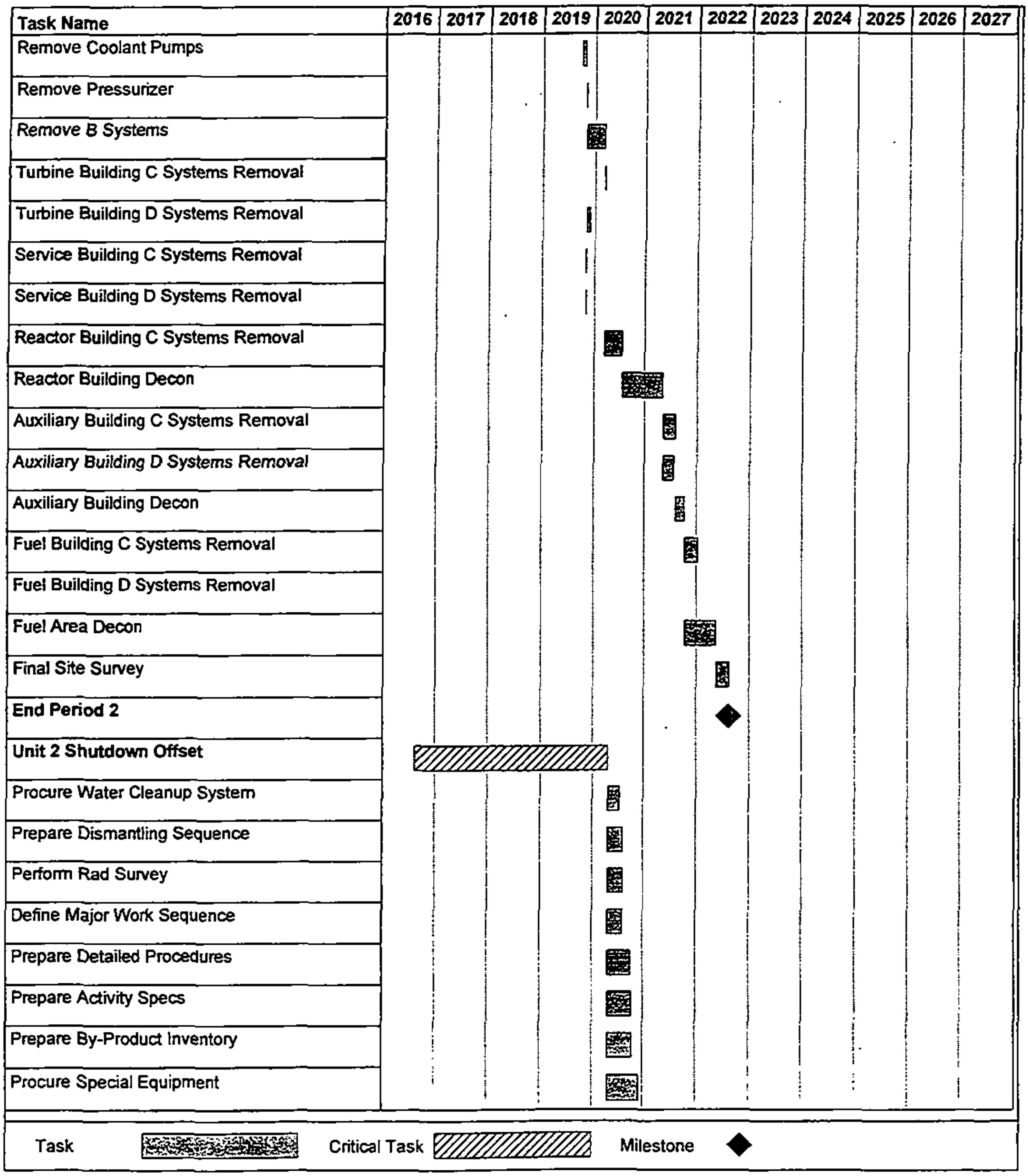


FIGURE 5.1
DECON ACTIVITY SCHEDULE
(continued)

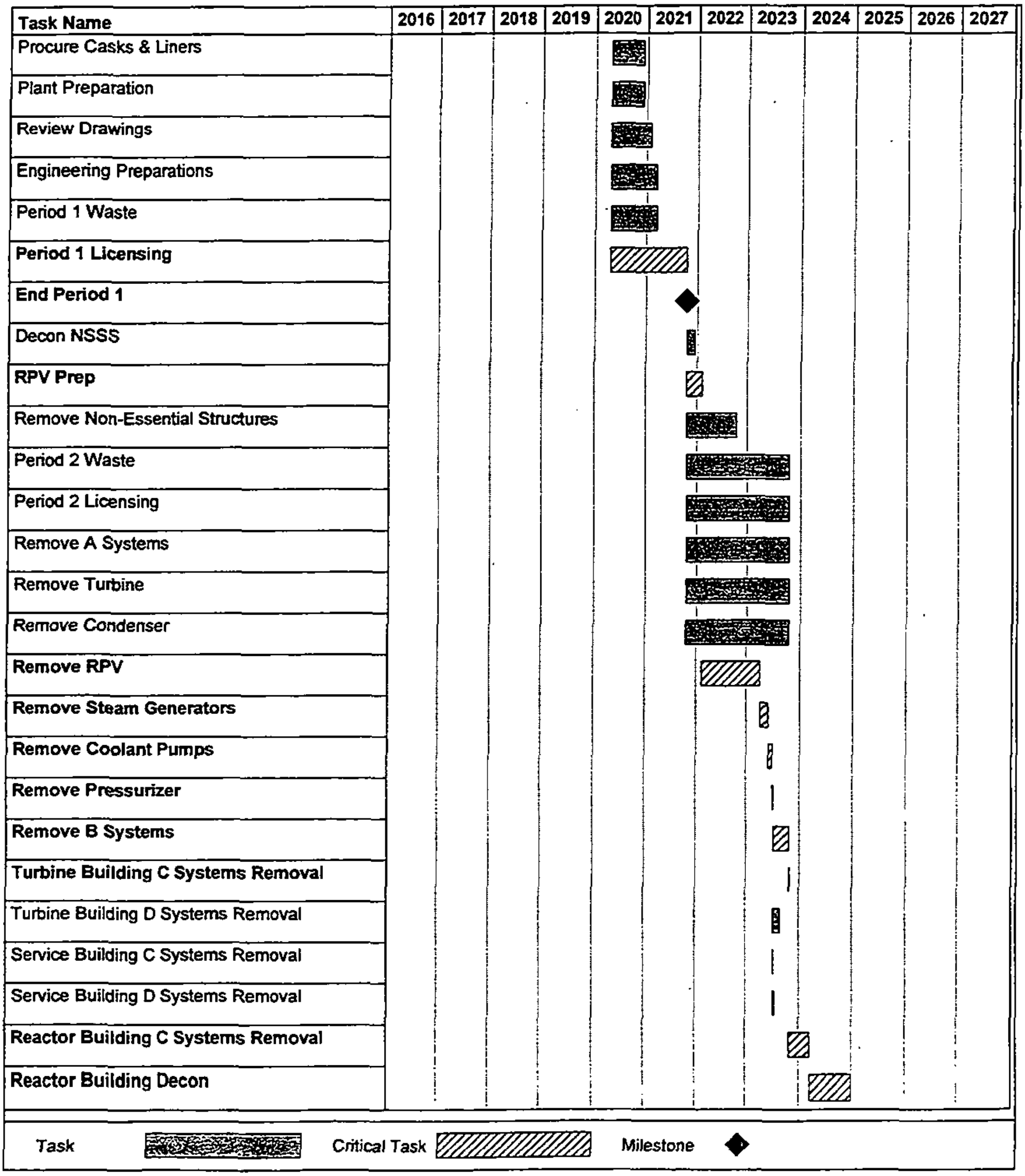


FIGURE 5.1
DECON ACTIVITY SCHEDULE
(continued)

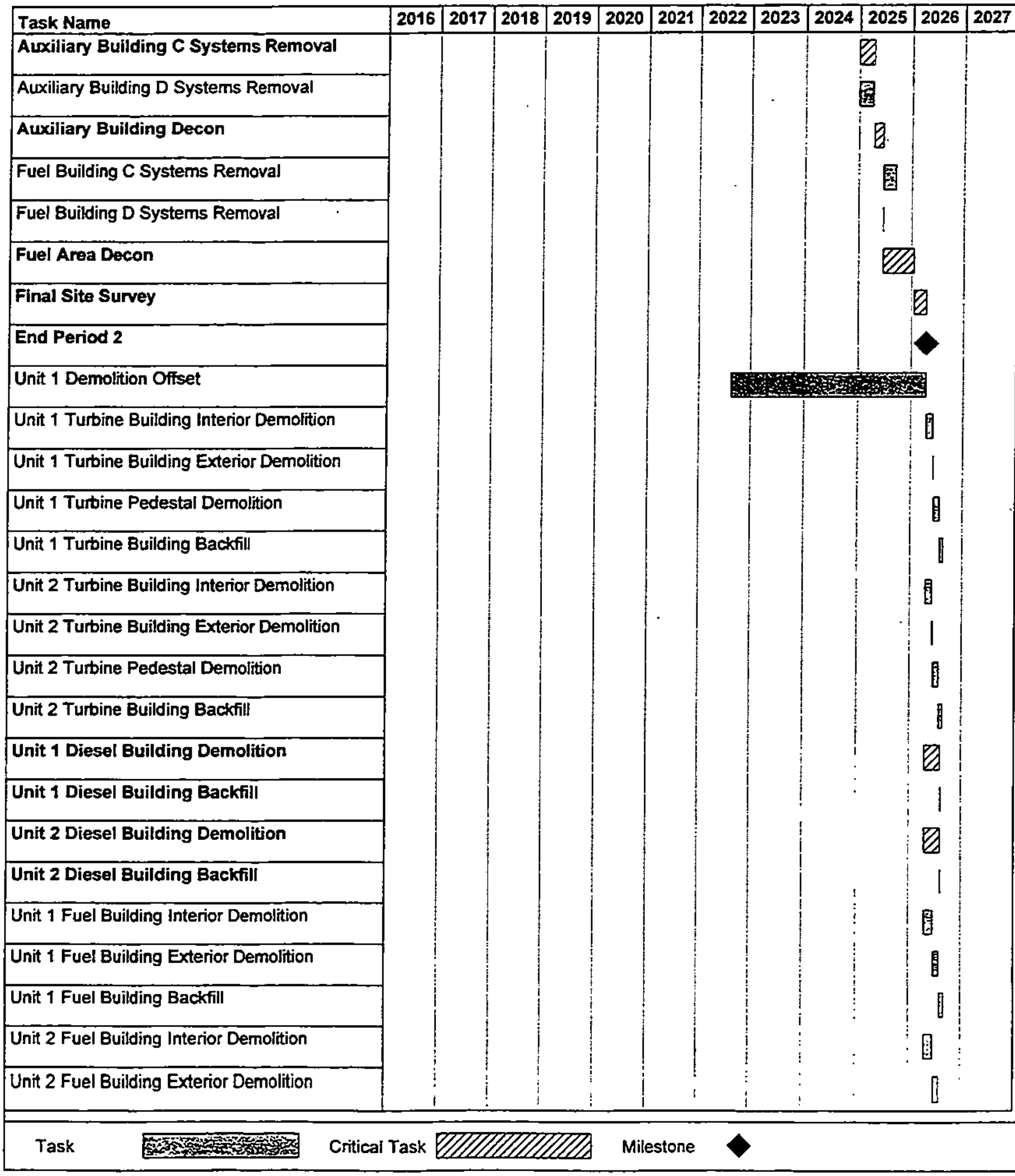


FIGURE 5.1
DECON ACTIVITY SCHEDULE
(continued)

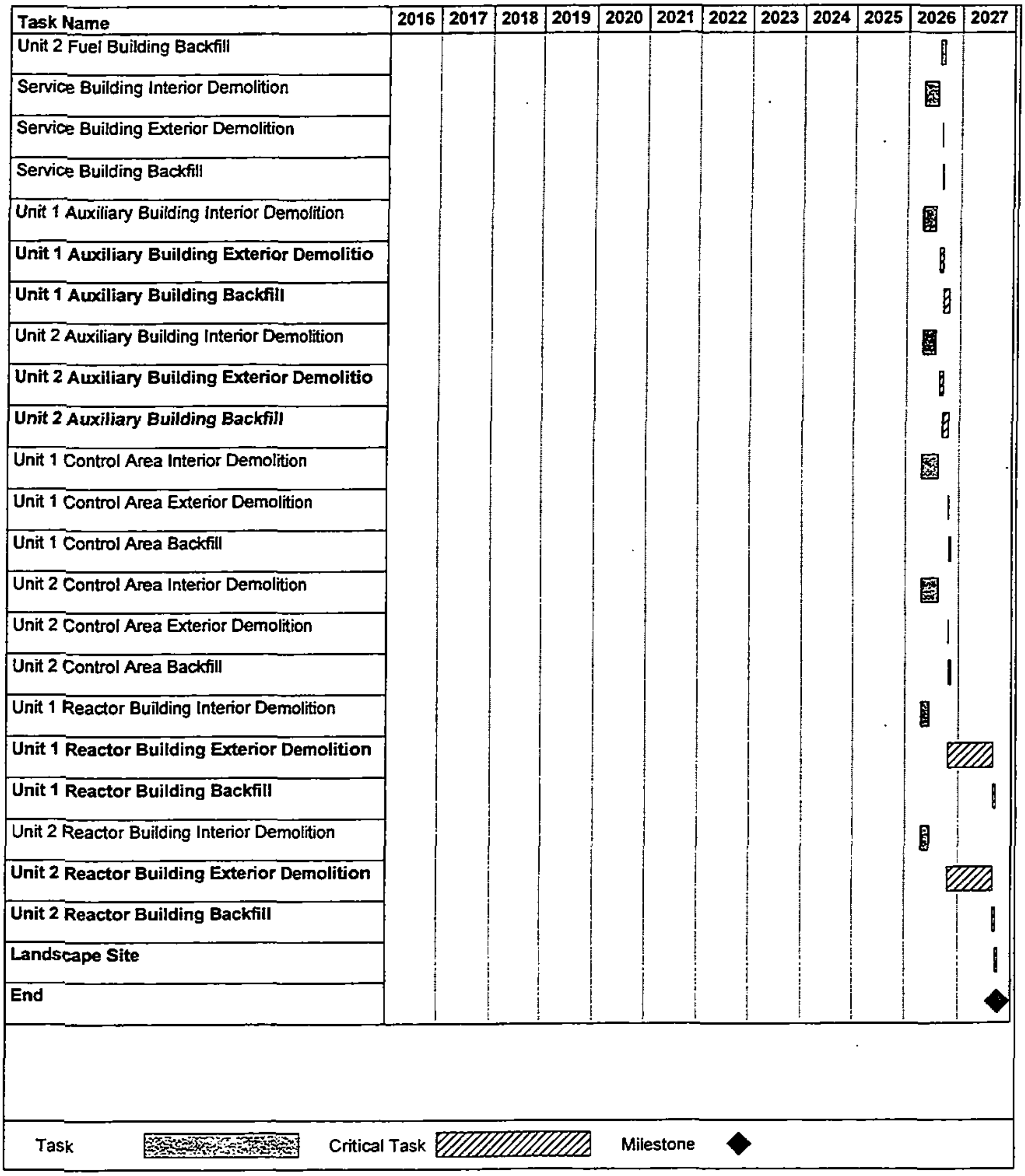
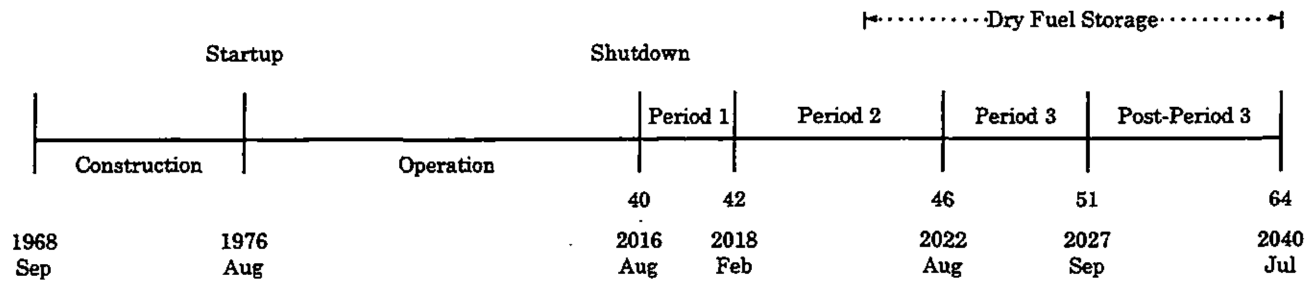


FIGURE 5.2a
DECON DECOMMISSIONING TIMELINES
(not to scale)

UNIT 1



UNIT 2

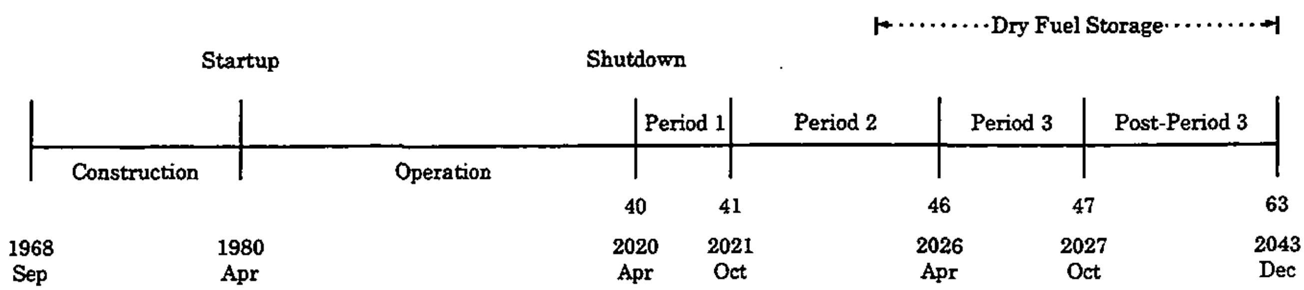
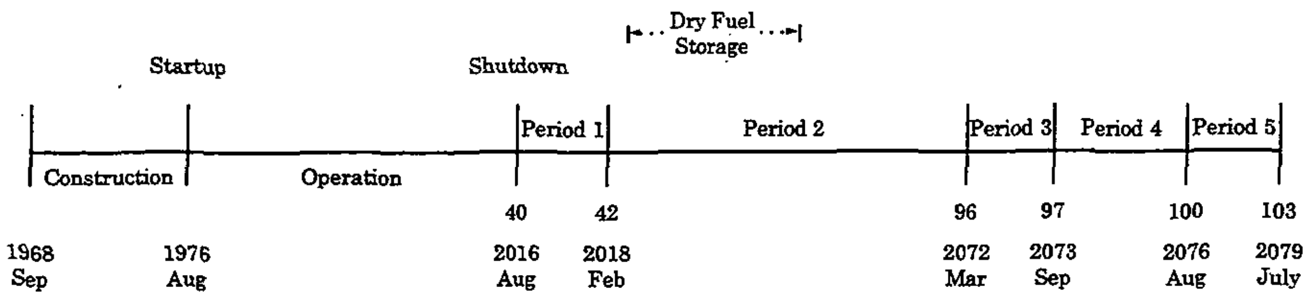
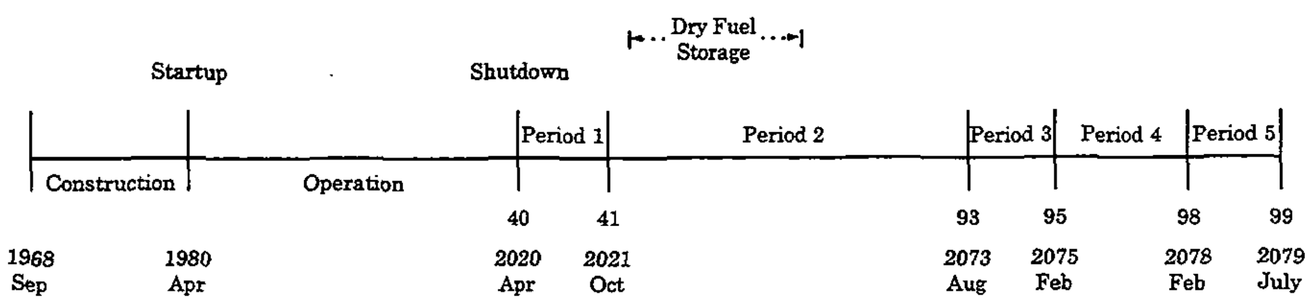


FIGURE 5.2b
SAFSTOR DECOMMISSIONING TIMELINES
(not to scale)

UNIT 1



UNIT 2



6. RADIOACTIVE WASTES

The ultimate goal of the decommissioning program is the removal of all radioactive material from the site which would restrict its future use. This requires the removal of all radioactive material from the site which is in excess of applicable legal limits.

Under the Atomic Energy Act, the NRC is responsible for protecting the public from sources of ionizing radiation. Title 10 of the Code of Federal Regulations delineates the production, utilization and disposal of radioactive materials and processes. In particular, 10 CFR Part 61 controls the burial of radioactive material; Part 71 defines radioactive material.

The radioactive waste volumes generated during the various decommissioning programs at Salem are shown by line activity in the cost tables in Appendix C. Waste volumes shown in Table 6.1 are quantified consistent with 10 CFR 61 classifications. The waste volumes shown are calculated based on the gross container volume to be shipped and buried in the controlled burial ground. Table 6.1 provides estimated volumes of radioactive waste, by classification, produced by the decommissioning of Salem.

Most of the materials being transported for controlled burial are categorized as LSA material containing Type A quantities as defined in 49 CFR 173-178 (Ref. 13). The containers must be strong, tight packages. For this study, commercially available steel containers are presumed to be used for piping, small components and concrete.

The reactor vessel and internals are categorized as large quantity shipments and, accordingly, must be shipped in reusable shielded casks with disposable liners. In this case, the liner volume is taken as the waste volume. No process system containing or handling radioactive substances at shutdown is presumed releasable as non-contaminated scrap metal because of the presence of long-term radionuclides.

The waste volume attributed to site decontamination is primarily generated during Period 2 of DECON. The radioactive waste generated as a result of the decommissioning of Salem is destined for disposal at the future Northeast Compact Low-Level Waste Disposal Facility to be located in New Jersey within 100 miles of the site. In this study, the base waste burial fee assumed for decommissioning is $298.20 per cubic foot. This figure was obtained from the rate structure in place as of July 1995 at the Chem Nuclear Systems, Inc., Barnwell LLW Management Facility (Barnwell) in South Carolina. Curie and weight surcharges are also applied using this rate structure.

The non-compatible (metallic) radioactive waste generated from removal of the plant equipment is assumed to be sent to an off-site vendor for recycling to reduce the final radioactive waste disposal volume. Based upon typical radiological characterizations and industry experience, the inventory of contaminated Salem material was segregated based on the likelihood of volume reduction and decontamination for radiological free release. This reduced burial volume, resulting from reprocessing/recycling radioactive equipment off site, is reflected in the report. The cost of off-site processing of non-compatible metallic waste is estimated to be approximately $100 per cubic foot, and appears in the "other" category in the detailed decommissioning cost tables in Appendix C.

TABLE 6.1

DECOMMISSIONING RADIOACTIVE WASTE BURIAL VOLUMES

	Waste Class [1]	Volume [2] (Cubic feet)
DECON		
Unit 1	A	110,294
	B	12,318
	C	476
	>C	564
Total		**123,652**
Unit 2	A	110,302
	B	12,361
	C	476
	>C	564
Total		**123,703**
SAFSTOR		
Unit 1	A	114,943
	B	5,966
	C	476
	>C	564
Total		**121,949**
Unit 2	A	114,960
	B	6,003
	C	476
	>C	564
Total		**122,003**

1. Waste is classified according to the requirements as delineated in Title 10 of the Code of Federal Regulations, Part 61.55
2. Columns may not add due to rounding.

7. OCCUPATIONAL EXPOSURE

Estimates of occupational radiation exposure were developed by TLG. These estimates are scoping in nature and are performed to provide an upper bound to the exposure limits for comparison with NRC maximum dose limitations.

Radiation doses to decommissioning workers are calculated as the product of the estimated radiation zone work force requirements and the radiation exposure rates estimated for each decommissioning task. The decommissioning occupational exposure estimates are based on the following assumptions:

1. Occupational exposure estimates include only those from the craft labor necessary for decontamination, removal and packaging activities, as well as all required health physics personnel exposures in support of these activities. Casual exposures to the plant staff are not included in this estimate.

2. Personnel exposure to radiation is minimized by utilizing shielding and remote handling techniques and avoiding higher radiation fields when personnel presence is not necessary.

3. Local exposure rates near items such as tanks and pipes are reduced by a successful chemical decontamination program prior to work in that area.

4. Careful prompt accounting of accumulated radiation exposure is maintained to rapidly identify tasks causing excessive dose accumulation by workers so that corrective action can be taken.

5. Exposures as the result of spent fuel storage activities are expected to be minimal, and therefore, are not included.

6. Cobalt-60 is the primary contributor to radiation exposure.

It should be noted that the radiation exposure rates used to calculate the exposures shown in Appendix C are based on optimum conditions; factors such as plant age, maintenance and operating history could cause the expected exposure rates at the time of decommissioning to vary significantly. Implementation of the DECON alternative yields the higher occupational radiation exposure because the work is performed soon after shutdown, without the benefit of any extended decay time for the radionuclides on site.

8. RESULTS

Decommissioning technology is well established and the tools and equipment necessary to completely dismantle Salem are available and have been demonstrated. The projected cost to decommission the station, presuming the use of the DECON alternative, including the five year and two month operation of the Fuel Handling Buildings as interim wet fuel storage facilities, and post-decommissioning dry fuel storage until 2043, is $680,956,000. This cost includes the complete removal/remediation of all site vestiges. The estimate reflects the site-specific features of Salem and the projected cost of radioactive waste shipping and disposal. An analysis of the major activities contributing to the total cost is shown in Table 8.1.

The decommissioning and utility staffs along with the removal activity combine to represent the majority of the cost to decommission Salem. This is a direct result of the labor-intensive nature of the decommissioning process. Burial is the next largest cost component reflecting increasing waste burial charges and weight and curie surcharges. Transportation costs are most sensitive to increases in fuel costs and distances to existing or new burial facilities. Removal costs are dependent on the degree of remotely operated equipment available in the future and the associated higher cost of that equipment versus the savings in labor costs.

This study for Salem provides an estimate for decommissioning the site under current requirements based on present-day costs and available technology. As additional dismantling experience on large reactors becomes available, cost estimates will be modified to reflect this experience. In addition, there are costs associated with decommissioning activities that historically increase at rates significantly greater than inflationary trends. For example, the cost of radioactive waste burial has increased rapidly in the last few years. It is therefore appropriate that this cost estimate be reviewed periodically, and updated/revised as required.

TABLE 8.1

SUMMARY OF DECON DECOMMISSIONING COSTS

Work Category	Costs 95$ (thousands) [1]	Percent of Total Costs [1]
Unit 1		
Decontamination	11,453	3.43
Removal	53,430	16.02
Packaging	7,172	2.15
Shipping	6,823	2.05
Burial (off-site)	71,879	21.56
Decommissioning Staffs	107,113	32.12
Other [2]	75,570	22.66
Subtotal	**333,442**	**100.00**
Unit 2		
Decontamination	11,656	3.35
Removal	64,998	18.70
Packaging	7,178	2.07
Shipping	6,808	1.96
Burial (off-site)	71,957	20.71
Decommissioning Staffs	112,567	32.39
Other [2]	72,349	20.82
Subtotal	**347,514**	**100.00**
STATION TOTAL (with contingency)	**680,956**	

1. Columns may not add due to rounding.
2. Other includes: engineering & preparations, undistributed costs and off-site LLRW recycling costs.

9. REFERENCES

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4. W.J. Manion and T.S. LaGuardia, "Decommissioning Handbook", U.S. Department of Energy, DOE/EV/10128-1, November 1980.

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6. Cost Engineers' Notebook: American Association of Cost Engineers, AA-4.000, pg 3 of 22, Rev. 2 (January 1978) (Updated periodically).

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9. J.C. Evans et al., "Long-Lived Activation Products in Reactor Materials" NUREG/CR-3474, Pacific Northwest Laboratory for the Nuclear Regulatory Commission. August 1984.

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11. H.D. Oak, et al., "Technology, Safety and Costs of Decommissioning a Reference Boiling Water Reactor Power Station," NUREG/CR-0672 and addenda, Pacific Northwest Laboratory for the Nuclear Regulatory Commission. June 1980.

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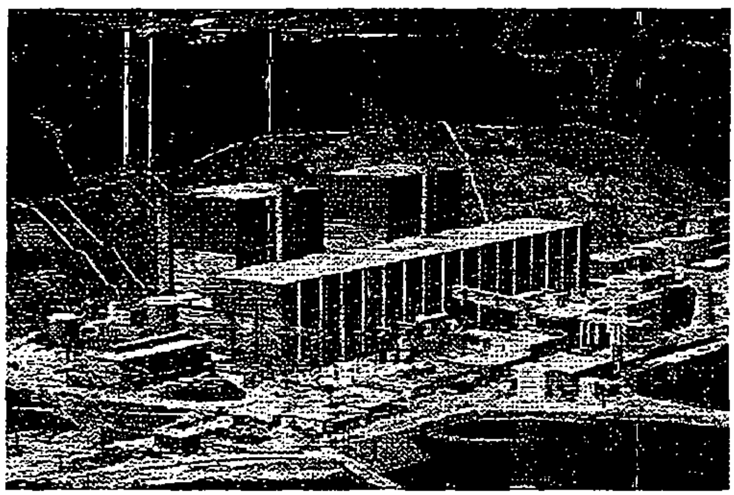
13. U.S. Department of Transportation, Section 49 of the Code of Federal Regulations, "Transportation", Parts 173 through 178.

Document P07-1180-003, Rev. 0

Exhibit TLG-3

DECOMMISSIONING COST ESTIMATE
for the
PEACH BOTTOM ATOMIC POWER STATION
UNITS 2 AND 3



prepared for

PUBLIC SERVICE ELECTRIC & GAS COMPANY

September 1996

prepared by

TLG Services, Inc.

Bridgewater, Connecticut

APPROVALS

Project Manager	William A. Cloutier, Jr.	9-9-96 Date
Technical Manager	Francis W. Seymore	9/9/96 Date
Quality Assurance Manager	Carolyn A. Palmer	9/9/96 Date

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APPENDICES

TABLES AND FIGURES

REVISION LOG

Rev. No.	CRA No.	Date	Item Revised	Reason for Revision
0		9/9/96		Original Issue

EXECUTIVE SUMMARY

This study, prepared for Public Service Electric and Gas (PSE&G) by TLG Services, Inc., evaluates two different decommissioning alternatives for the Peach Bottom Atomic Power Station Units 2 & 3 (PBAPS), following the final cessation of plant operations. The estimated costs for the DECON alternative are $358,190,176 and $473,196,320 for Unit 2 and Unit 3, respectively (in 1995 dollars). For the SAFSTOR alternative, with deferred decommissioning to be completed within 60 years, the costs are estimated to be $392,237,632 and $546,944,064 for Unit 2 and Unit 3, respectively.

This study provides cost estimates for decommissioning PBAPS under current requirements and is based upon present-day technology. Using plant drawings and inventory documents and databases, TLG estimated quantities and volumes of equipment and material to be removed during decommissioning. Unit cost factors are applied to the volumes and quantities to develop the activity-dependent costs. The period-dependent costs are then determined from a detailed critical path schedule based on the removal activity durations.

This study includes the following considerations:

Burial of low-level radioactive waste is assumed to be at a regional site to be designated at a future date by the Appalachian Compact. Disposal costs are based on rates in effect as of July 1, 1995, at the Barnwell Low-Level Radioactive Waste Management Facility, as a proxy.

Volume reduction and decontamination of low-level radioactive waste, as a means of reducing disposal costs, is assumed to be performed by an off-site radioactive waste recovery vendor.

Low-level waste classified as "Greater-Than-Class-C" is packaged for disposal along with the spent nuclear fuel and disposed of at a cost comparable to that envisioned for spent fuel.

Contingency is included in the estimate to address the many uncertainties that exist in a project of this nature. The analysis, prepared on a line item basis, uses a range of contingencies selected to reflect conditions and uncertainties to be present at the time of decommissioning.

In addition to the estimated costs, the report includes program schedules, scrap projections and estimates of occupational radiation exposures and low-level radioactive waste volumes inherent in the proposed decommissioning scenarios.

1. SUMMARY

The Peach Bottom Atomic Power Station (PBAPS) is located in southeastern Pennsylvania on the westerly shore of Conowingo Pond at the mouth of Rock Run Creek. The site encompasses portions of Peach Bottom Township, York County, Drumore Township, Lancaster County, and Fulton Township, Lancaster County. The station is about 38 miles north-northeast of Baltimore, Maryland, and 63 miles west-southwest of Philadelphia, Pennsylvania. This study addresses the decommissioning of PBAPS Units 2 and 3 which are essentially identical boiling water reactors with supporting facilities. PECO Energy Company (PECO) is the primary owner and operator of the two nuclear units. In addition to cost, schedule, waste generation/disposition, and occupational exposure are also evaluated. The study is based upon the DECON (prompt removal/dismantling) and SAFSTOR (mothball with delayed dismantling) decommissioning alternatives.

DECON is defined by the NRC as "the alternative in which the equipment, structures, and portions of a facility and site containing radioactive contaminants are removed or decontaminated to a level that permits the property to be released for unrestricted use shortly after the cessation of operations." DECON of a power reactor consists of the removal and disposal of all fuel assemblies and source material, radioactive fission and corrosion products, and all other radioactive materials having activities above Regulatory Guide 1.86, "Termination of Operating Licenses for Nuclear Reactors", NUREG 5512, "Residual Radioactive Contamination from Decommissioning" and other applicable release limits shortly after the cessation of plant operations. The facility operator may then have unrestricted use of the site with no requirement for a Nuclear Regulatory Commission license. This scenario is equivalent to the DECON mode as described in the rule on decommissioning issued by the NRC, "General Requirements for Decommissioning Nuclear Facilities." The balance of plant systems and structures are removed to below site grade. The site is then made available for alternative use.

There are advantages to the DECON alternative. The alternative is less costly, in 1995 dollars, than the scenarios involving extended delays in the station dismantling. (The ultimate cost for any alternative will depend upon future economic factors such as inflation and policy factors, e.g., future NRC regulations and waste policy decisions and actions.) DECON eliminates a potential long-term safety hazard and those individuals familiar with the nuclear facility will still be available to support the dismantling effort. DECON also relieves the utility of long-term obligation and liability for maintenance of the property.

SAFSTOR is defined by the NRC as "the alternative in which the nuclear facility is placed and maintained in a condition that allows the nuclear facility to be safely stored and subsequently decontaminated (deferred decontamination) to levels that permit release for unrestricted use." SAFSTOR consists of placing and maintaining the facility in protective storage once the spent fuel and source material are removed, disposed of or relocated. Concurrently, the plant staff conducts general plant decontamination activities, radiation surveys, and the processing and removal of any radioactive waste materials remaining from operations. Modified security, surveillance and maintenance plans for the delay period are implemented. Delayed dismantling (decontamination) activities are initiated such that license termination is accomplished within the 60-year time period set by the NRC. As with the DECON alternative, this study further assumes that the remainder of the reactor facility is dismantled and site restoration is performed.

The cost for the SAFSTOR alternative is increased by the cost incurred in maintaining the station in protective storage. However, there are advantages over the DECON alternative. Primarily, the dormancy period provides a period of decay for the residual radioactive material, resulting in lower personnel radiation exposures during dismantling, than are incurred in the DECON alternative. There is also the potential savings (at current prices) in the cost for disposal of the waste volume generated during decommissioning operations due to a reduction in activity levels.

ENTOMB consists of encasing the radioactive contaminants in a structurally long-lived material, such as concrete. The entombed structure is appropriately maintained and continued surveillance is carried out until the radioactive material decays to a level permitting unrestricted release of the property. However, this process is restricted in overall duration to 60 years and, therefore, impractical for use at a Part 50 licensee which generates significant amounts of long-lived radioactive material due to neutron activation. ENTOMB as such cannot demonstrate that items such as the reactor vessel and internals will decay to unrestricted release levels within this time frame.

The ENTOMB alternative was not considered in this evaluation, having no significant advantage over the SAFSTOR alternative. The cost of the ENTOMB alternative includes larger up-front capital expenditures, incurs greater levels of occupational exposure to the worker and does not eliminate the necessity for eventual plant decontamination.

While the disposal cost of spent fuel assemblies generated during plant operations is not considered a decommissioning expense, the presence of those assemblies on site does have a bearing on the cost to decommission. This study recognizes that the current wet spent fuel storage facilities at PBAPS Units 2 and 3 will be active for approximately five years after operations cease at these units. This duration is based upon the current design criteria for dry storage as well as the Department of Energy's (DOE) minimum acceptance criteria for fuel turnover and transfer to a federal repository. It is assumed that the spent fuel pool inventory at shutdown and the final core load will be transferred to an on-site Independent Spent Fuel Storage Installation (ISFSI) to await DOE acceptance.

This study provides cost estimates for decommissioning PBAPS under current requirements based upon present-day costs and available technology. Cost and schedule estimates presented herein are based upon the complete removal of all components and structures within the property lines, as the station is presently configured. A summary of costs and schedule, for each alternative, are provided in Table 1.1. Detailed cost reports for each decommissioning alternative and nuclear unit are provided in Appendix C. The schedule and sequence of decommissioning activities are identified in Section 5 of this document.

TABLE 1.1

PEACH BOTTOM ATOMIC POWER STATION UNITS 2 AND 3 COST AND SCHEDULE ESTIMATE SUMMARY

	Cost, 95$ (thousands) [1]	Schedule (months) [1]
DECON (Prompt Removal/Dismantling)		
Unit 2	358,190	104.4
Unit 3	473,196	330.0 [2]
STATION TOTAL	**831,386**	**340.8**
SAFSTOR (Mothball with Delayed Dismantling)		
Unit 2		
Preparations	48,486	18.0
54.0 year maintenance cost	63,761	647.8
Delayed dismantling	279,990	88.9
Subtotal Unit 2	392,238	754.7
Unit 3		
Preparations	52,669	18.0
54.3 year maintenance cost	138,906	652.0
Delayed dismantling	355,368	75.5
Subtotal Unit 3	546,944	745.5
STATION TOTAL	**939,182**	**756.3**

1. Columns may not add due to rounding.
2. Post-decommissioning dry fuel storage included in this subtotal.

2. INTRODUCTION

This analysis is designed to provide Public Service Electric and Gas Company (PSE&G) with sufficient information to prepare financial planning documents required by the New Jersey State Board of Public Utilities and the U.S. Nuclear Regulatory Commission. It is not a detailed engineering document, but a cost estimate prepared in advance of the detailed engineering preparations which will be necessary to carry out the decommissioning of Units 2 and 3 at the Peach Bottom site.

2.1 OBJECTIVE OF STUDY

The objective of this study is to prepare an estimate of the cost, schedule, occupational exposure and waste volume generated to decommission PBAPS including all common and supporting facilities. The study considered the integration of the two-unit dismantling, as discussed below.

Operating licenses were issued on August 8, 1973, for Unit 2 and July 2, 1974, for Unit 3. For the purposes of this study, the shutdown dates were taken as August 8, 2013, for Unit 2 and July 2, 2014, for Unit 3. This time frame was used as an input for scheduling the remediation activities.

2.2 SITE DESCRIPTION

PBAPS is located about 38 miles north-northeast of Baltimore, Maryland, and 63 miles west-southwest of Philadelphia, Pennsylvania. The station is comprised of two essentially identical boiling water reactors with supporting facilities.

The Nuclear Steam Supply Systems (NSSS) consist of a boiling water reactor system designed by General Electric. The Reactor Recirculation System is comprised of the reactor vessel and two recirculation pump loops external to the reactor vessel which provide the driving flow of water to the reactor vessel jet pumps. Each external loop contains one high-capacity, motor-driven recirculation pump and two motor-operated gate valves for pump maintenance. The recirculation loops are a part of the nuclear system process barrier and are located inside the containment structure. The design reactor thermal power level is 3,293 Megawatts thermal (Mwt). The corresponding net electrical output is approximately 1,126 Megawatts electric (MWe).

The containment system at PBAPS is comprised of a primary containment and a secondary containment. Primary containment is a Mark I type containment. It is comprised of a steel, light-bulb shaped pressure vessel (drywell) with a steel torus-shaped pressure chamber below, encircling the drywell. The drywell and the suppression chamber are connected by vents. The drywell is anchored into a reinforced concrete envelope. The torus-shaped suppression chamber is housed in a dedicated room. Secondary containment is comprised of the reactor building, in conjunction with the HVAC and standby gas treatment system.

Heat produced in the reactor is converted to electrical energy by the power conversion system. A turbine-generator system converts the thermal energy of steam produced in the reactor into mechanical shaft power and then into electrical energy. The turbine consists of a high-pressure, double-flow turbine element, and three double-flow, low-pressure turbine elements aligned in tandem. The generator is driven at 1,800 rpm and rated at 1,280 MVA. The exhaust steam from the turbine is condensed and deaerated in the main condenser. The heat rejected to the main condenser is removed by the circulating water system.

The circulating water system provides the heat sink required for removal of waste heat in the power plant's thermal cycle. The system has the principal function of removing heat by absorbing this energy in the main condenser. Water is withdrawn from the Susquehanna River via the intake tunnels by the circulating water pumps. After passing through the plant condensers, the discharge is routed through five mechanical draft cooling towers then back to the river.

2.3 REGULATORY GUIDANCE

The NRC provides decommissioning guidance in the rule "General Requirements for Decommissioning Nuclear Facilities" (Ref. 1) in addition to that previously set forth in Regulatory Guide 1.86 (Ref. 2). This rule defines three decommissioning alternatives acceptable to the NRC, i.e., DECON (prompt removal/dismantling), SAFSTOR (mothball), and ENTOMB (entombment).

<u>DECON (Prompt Removal/Dismantling)</u> is defined by the NRC as "the alternative in which the equipment, structures, and portions of a facility and site containing radioactive contaminants are removed and disposed of or decontaminated to a level that permits the property to be released for unrestricted use shortly after cessation of operations."

<u>SAFSTOR (Mothball)</u> is defined by the NRC as "the alternative in which the nuclear facility is placed and maintained in a condition that allows the nuclear

facility to be safely stored and subsequently decontaminated (deferred decontamination) to levels that permit release for unrestricted use."

ENTOMB (Entombment) is defined by the NRC as "the alternative in which radioactive contaminants are encased in a structurally long-lived material, such as concrete; the entombed structure is appropriately maintained and continued surveillance is carried out until the radioactive material decays to a level permitting unrestricted release of the property." However, this process is restricted in overall duration to 60 years and, therefore, limited in application unless it can be shown that a longer duration is necessary to protect the health and safety of the public.

Prior to this rule, no endpoint was identified for either the SAFSTOR or ENTOMB process, i.e., a facility could remain in either state indefinitely. This is no longer the case as the rule places limits on the time allowed to complete the decommissioning process. Consequently, with the new restrictions, the SAFSTOR and ENTOMB options are no longer decommissioning alternatives in themselves, as neither terminates the license for the site. At the end of the dormancy period (up to 60 years), both alternatives would still require site decontamination/decommissioning.

3. DECOMMISSIONING ALTERNATIVES

Two specific decommissioning alternatives were examined for the PBAPS study: DECON and SAFSTOR. The ENTOMB alternative was not considered, having no significant advantage over the SAFSTOR alternative. ENTOMB requires larger up-front capital expenditures and incurs greater levels of occupational exposure to the worker without eliminating the necessity of eventual plant decontamination.

Although the DECON and SAFSTOR alternatives share similar methodology, they differ with respect to technique, process, cost, and schedule. Both alternatives attain the same result: removal of all radioactive materials from the site and ultimate release of the site for unrestricted and/or alternative use. The dormancy duration selected for use in the SAFSTOR alternative is based on accomplishing license termination within the 60-year time period established by the NRC.

The following sections describe the basic activities necessary for each alternative. Although detailed procedures for each activity required are not provided, and actual sequences of work may vary, these activity descriptions may provide a basis for detailed engineering planning and scheduling at the time of decommissioning.

3.1 DECON

DECON is defined by the NRC as the alternative in which the equipment, structures, and portions of a facility and site containing radioactive contaminants are removed and disposed of or decontaminated to a level that permits the property to be released for unrestricted use shortly after cessation of operations. This study does not address the cost of the removal of spent fuel from the site because such costs are assumed to be covered by the 1 mill/kWhr DOE surcharge. However, the study does consider the constraints that the presence of spent fuel on site may impose on other decommissioning activities. The continued operation of a dry spent fuel storage facility, for maintenance and shipment of the estimated inventory of spent fuel from the PBAPS site at shutdown, is assumed. In addition to the removal of radioactive material, this study also assumes the removal of the remaining structures from the site, thereby permitting release of the PBAPS site for alternative use.

3.1.1 Period 1 - Preparations

Prior to the commencement of decommissioning operations, detailed preparations are undertaken to provide a smooth transition from plant operations to site decommissioning activities. These preparations include engineering planning, surveys of plant areas to determine

contamination levels, activation analyses of the vessel and vessel internals, as well as the assembly of a decommissioning management organization. Final planning for activities and writing of activity specifications and detailed work procedures also begin at this time.

Engineering and Planning

Prior to the commencement of decommissioning operations, PECO will file an application for termination of the NRC license accompanied by a Decommissioning Plan (DP) with the NRC describing how it will remove all radioactive components and essentially all radioactive material from PBAPS. This request for dismantling of the reactor and termination of the facility's license should include a detailed plan describing the organization and program that will be used during the decommissioning of the facility. The plan will accomplish the required tasks within the As-Low-As-Reasonably-Achievable (ALARA as defined in 10 CFR 20) guidelines for protection of personnel from exposure to radioactive and non-radioactive contaminants. It will also clearly describe how PECO (the operating agent for the plant's owners) will continue to protect the health and safety of the public and the environment during the dismantling activity.

Prior to the start of decommissioning operations, work begins on the documentation and planning necessary for both licensing change applications and for accomplishing the work required. The development of a decommissioning organization within the utility is essential to this planning. This development includes identifying the staff requirements and commitment of key personnel.

In preparation for a change in license, regulatory criteria applicable to decommissioning are reviewed. The existing technical specifications are reviewed and modified to reflect decommissioning requirements and to delete non-applicable operating specifications. A DP is prepared during this time.

In addition, an environmental report will be required by the NRC and all applicable records (i.e., as-built or revised drawings and specifications, operating records, and site-specific background data) will be needed to support this submittal.

Much of the work in the development of the DP is also relevant to the development of the detailed engineering plans and procedures. This work may include key activities such as:

- Site preparation plans for decommissioning activities;
- Detailed procedures and sequences for removal and disposal of systems and components;
- Procedures for sectioning and disposing of the reactor vessel and its internals;
- Plans for decontamination of structures and systems;
- Design/procurement and testing of tooling and equipment;
- Identification/selection of specialty contractors;
- Procedures for removal and disposal of radioactive materials; and
- Sequential planning of activities to minimize conflicts with simultaneous activities.

Site Preparations

- Prepare site support and storage facilities as required. This activity is analogous to the preparations undertaken to support the increased craft labor force on site during plant maintenance and refueling outages
- Isolate the Reactor Buildings' fuel handling systems from the power block such that decommissioning operations can commence on the balance of the plant. This activity may be carried out by existing plant personnel in accordance with standard operating technical specifications. Decommissioning operations are assumed to be scheduled around the Reactor Building fuel handling systems to the greatest extent possible, such that the overall project schedule is optimized. Current dry storage cask designs are licensed for spent fuel with a core discharge decay time averaging approximately five years or greater. Therefore, decommissioning operations for the fuel storage facilities cannot be expected to begin prior to five years after the shutdown of each unit. As spent fuel decays to the point that it meets the heat load criteria of the dry storage casks, it will be transferred to the dry storage facility. It is assumed that all fuel is transferred to dry

storage within five years and two months of the shutdown date for each unit, respectively.

- Clean all plant areas of loose contamination and process all liquid and solid wastes.

- Conduct radiation surveys of work area contamination and general dose levels; major component, piping, and structure dose levels (including the reactor vessel and its internals); internal piping contamination levels; and activation profiles from primary shield core samples.

- Calculate the residual by-product material inventory for plant components, structures and systems, and normalize neutron flux profiles on systems and structural surfaces to benchmark the survey data. This analysis will provide the basis for determining packaging and shipping requirements and decommissioning safety requirements.

- Determine shipping container requirements for activated materials and procure such containers.

- Develop procedures for occupational exposure control, control and release of liquid and gaseous effluent, control of solid radwaste, site security and emergency programs, and industrial safety.

Following approval of the DP by the NRC, the NRC will issue an order authorizing implementation. The DP may then be implemented by PECO.

3.1.2 Period 2 - Decommissioning Operations and License Termination

The dismantling procedures may begin upon receipt of the dismantling order from the NRC. For the DECON alternative, the decommissioning operations involve the following:

- Arrange existing storage facilities to support the dismantling activities. These may include: changing rooms and contaminated laundry facilities for increased work force, protected and open laydown areas to facilitate equipment removal and shipping operations.

- Procure and install a water cleanup system for removal of cutting residues and crud deposits from the reactor vessel.

- Design and fabricate (or procure) special shielding and contamination control envelopes, special tooling and remotely operated equipment. Modify the reactor well/spent fuel pool/dryer separator pool to support segmentation activities and prepare rigging for segmentation and removal of piping sections, recirculation pumps and other components, including the reactor vessel and its internals.

- Procure required shipping casks, liners, and Low Specific Activity (LSA) containers from suppliers.

- Conduct decontamination of components and piping systems as required. Remove, package and dispose of piping and components as they are no longer required to support the decommissioning process.

- Remove control rod drive housings and instrumentation tubes from reactor vessel lower head and cut into sections for disposal.

- Segment core support structures and the steam separator and dryer assemblies and package in shielded casks. These operations are performed remotely by cutting equipment within a contamination control envelope (CCE). Ship and bury packaged items which meet 10 CFR 61 Class "C" requirements or less.

- After the vessel water level drops below the elevation of the reactor vessel inlet and outlet nozzles during vessel segmentation, remove the reactor recirculation piping and pumps. Package the piping in standard LSA containers; the reactor recirculation pumps are sealed with steel plate so as to serve as their own containers. Ship and bury piping and pumps.

- Disassemble, segment and package remaining reactor internals in shielded casks. These internals include: top fuel guide, feedwater and core spray spargers, in-core instrument tubes, fuel support pieces, control rod guide tubes, jet pumps and core support assembly. The operations are conducted under water using remotely operated tooling and a contamination control envelope or other contamination barrier(s). Ship and bury packaged items which meet 10 CFR 61 Class "C" requirements or less.

- Package 10 CFR 61 "Greater Than Class C" (GTCC) components into fuel bundle containers for handling and storage with the spent fuel assemblies. Transfer these fuel bundle containers to the dry fuel storage area.

- Segment/section the reactor vessel and package into shielded containers. The operation is performed remotely in air using a contamination control envelope. Sections are placed in containers under water (for example in the spent fuel pool) or in air with the crane operator protected by a shielded envelope. Ship and bury packaged items.

- Remove systems and associated components as they become non-essential to the support of vessel disposition, other decommissioning operations or worker health (e.g., decommissioning waste processing systems, electrical systems, HVAC systems, water systems).

- Remove concrete sacrificial shield including activated /contaminated concrete by controlled demolition. Package and bury radioactive portions.

- Remove steel liner from the drywell, disposing of the activated and contaminated sections as radioactive waste. Remove steel vent pipes connecting the drywell to the suppression chamber, again disposing of the steel as radioactive waste. Dispose of any activated/contaminated drywell concrete; package, ship and bury inventory in standard LSA containers.

- Dismantle/section the suppression chamber steel structure, packaging contaminated segments for disposal; package, ship and bury inventory in standard LSA containers.

- Remove steel liners from the dryer/ separator pool, reactor well, and spent fuel pool. Package contaminated material in standard LSA containers, including contaminated pool concrete, for shipping and burial.

- Remove contaminated equipment and material from the fuel storage facility and any other contaminated areas once the spent fuel pool has been emptied. Use radiation and contamination control techniques until radiation surveys indicate that the structures can be released for unrestricted access and conventional demolition.

- Ship and bury all remaining radioactive materials.

- Conduct final radiation survey to ensure that all radioactive materials have been removed. This survey may coincide with final NRC site inspection.

- Following notification by PECO of completion of the decontamination and disposal of components and materials from the facility, the NRC regional staff conducts an on-site survey to verify that the acceptable activity and contamination levels are satisfied. When the requirements are satisfied, the NRC can terminate the license for either the individual units or the station. The dry fuel storage facility will continue operating under a 10 CFR Part 72 license.

3.1.3 Period 3 - Site Restoration

Following completion of the decommissioning operations, site-restoration activities may begin. All building foundations are assumed to be removed to three feet below grade. Site areas affected by the dismantling activities are assumed to be cleaned and the plant area graded and landscaped as required. The costs reported to perform these activities reflect the following assumptions:

- Demolition of the remaining portions of the primary containment structure and interior portions of the Reactor Building. Internal floors (and walls if above grade) are removed from the lower levels upward, using controlled blasting techniques. Concrete rubble and clean fill produced by demolition activities may be used to backfill below-grade voids. Suitable materials can be used on site for fill; otherwise the rubble is trucked off site for reuse elsewhere.

- Remaining buildings are then removed using conventional demolition techniques for above-ground structures, including the Turbine Building, Radwaste Building, and other site structures.

- Prepare the final dismantling program report.

3.1.4 Post Period 3 - ISFSI Operations and Demolition

Following completion of the site restoration operations, the Independent Spent Fuel Storage Installation (ISFSI) will continue to operate. During this interval spent fuel shipments will occur. Starting in 2010, spent fuel assemblies are assumed to be shipped for a period of approximately 31 years, with the final spent fuel shipment occurring in 2041.

After the final spent fuel shipment to the DOE, the ISFSI physical installation will be decontaminated. Continued radiation exposure from the spent fuel assemblies will cause low-level neutron activation of the interior surfaces of the dry storage modules to levels exceeding current release limits.

Following notification by PECO of completion of the decontamination and disposal of components and materials from the ISFSI, the NRC regional staff conducts an on-site survey to verify that the acceptable activity and contamination levels are satisfied. When the requirements are satisfied, the NRC can terminate the Part 72 ISFSI license.

The concrete dry storage modules are demolished and disposed of as clean fill, the concrete loading ramps are removed, and the area graded and landscaped to conform with the surrounding environment.

3.2 SAFSTOR

The SAFSTOR decommissioning alternative provides a condition that ensures public health and safety from radioactive material remaining at the site without the need for extensive modifications to the facility. During the SAFSTOR period the facility is left intact and all structures are maintained in a sound condition. Systems not required to be operational for support of the spent fuel pool and surveillance purposes during the dormancy period are drained, de-energized, and secured. Minimal cleaning/removal of loose contamination and/or fixation and sealing of remaining contamination are performed. Access to contaminated areas is secured to provide controlled access for inspection and maintenance.

The engineering and planning requirements are similar to those for the DECON alternative, although a shorter time period is expected for these activities due to the more limited work scope. Site preparations are also similar to those for the DECON alternative. However, with the exception of required radiation surveys, the mobilization and preparation of site facilities is less extensive.

3.2.1 Period 1 - SAFSTOR Operations

Prior to commencement of decommissioning operations, PECO will file a Decommissioning Plan (DP) with the NRC. The DP will describe how it will remove all radioactive components and essentially all radioactivity, safely and effectively, from PBAPS. This request for eventual dismantling of the reactor and termination of the facility's license includes a detailed plan describing the organization and program that will be used during the decommissioning of the facility. The plan will accomplish the required tasks within the ALARA guidelines for protection of personnel from exposure to radioactive contaminants. It will also clearly describe how PECO will continue to protect the health and safety of the public and the environment during the dismantling activities.

Following approval of the DP by the NRC, the NRC issues an order authorizing implementation. The DP may then be implemented by PECO. The DP addresses the spent fuel management plan, preliminary decontamination activities, and the subsequent caretaking program. The document would also provide a general description of the deferred decommissioning activity following the caretaking period. The NRC may amend the operating license to permit "Possession Only" after final plant shutdown. This amended license would remain in effect until final decontamination of the site and its release is complete.

The "Possession Only" license permits ownership and possession of fuel, by-product material and reactor components, but does not permit operation of the reactor. This license status, though permitting significant relief from the technical specifications, still requires adequate surveillance, monitoring and reporting.

After plant shutdown, modified technical specifications are implemented. Spent fuel and in-core source materials are isolated in the spent fuel storage facilities awaiting ultimate disposal or transfer to the ISFSI. These steps may be carried out by plant personnel in accordance with standard operating procedures. The residual inventories of liquid and solid wastes are processed and removed and plant radiation surveys initiated.

The decommissioning activities for the SAFSTOR alternative are as follows:

- Isolate the Reactor Buildings' fuel handling systems from the power block such that decommissioning operations can commence on the balance of the plant. This activity may be carried out by existing plant personnel in accordance with standard operating technical specifications. Decommissioning operations are assumed to be scheduled around the Reactor Building fuel handling systems, to the greatest extent possible. Current dry storage cask designs are licensed for spent fuel with a core discharge decay time averaging approximately five years or greater. Therefore, the fuel storage facilities can be expected to operate for five years after shutdown of each unit. As spent fuel decays to the point that it meets the heat load criteria of the dry storage casks, it will be transferred to the dry storage facility. It is assumed that all fuel is transferred to dry storage within 62 months of the shutdown date for each unit.

- Drain/de-energize/secure all non-contaminated systems not required to support decommissioning operations.

- Dispose of contaminated filter elements and resin beds not required for processing wastes from decontamination activities.

- Drain reactor vessel; internals will remain in place.

- Drain/de-energize/secure all contaminated systems. Decontaminate systems as required.

- Prepare lighting and alarm systems whose continued use is required. De-energize and/or secure portions of fire protection, electric power, and HVAC systems whose continued use is not required.

- Clean loose surface contamination from building access pathways.

- Perform final radiation survey of plant; post warning signs as appropriate.

- Erect physical barriers and/or secure all access to radioactive or contaminated areas, except as required for controlled access, i.e., inspection and maintenance.

- Spent fuel shipments to DOE will continue throughout Period 1 and into the dormancy period.
- Install security and surveillance monitoring equipment and relocate security fence around secured structures as required.
- Non-radioactive structures, located outside the secured area, can be dismantled at this time. However, this study assumes that demolition would be delayed until after license termination.
- Sections of the site outside of the controlled area may be graded and landscaped as required. Part of this site area may be released for unrestricted use or for restricted use, depending on the terms of the possession-only license.
- Prepare final decommissioning program report for submittal to NRC.

3.2.2 Period 2 - SAFSTOR Dormancy

Activities required during the planned dormancy period, for the SAFSTOR alternative, include a 24-hour guard force, preventive and corrective maintenance on security systems, area lighting, general building maintenance, heating and ventilation of buildings, routine radiological inspections of contaminated buildings, maintenance of structural integrity, and an environmental and radiation monitoring program.

Spent fuel shipments to the DOE repository will continue throughout Period 2 until 2041.

Maintenance and equipment inspection activities are provided by the utility maintenance staff. Their duty is to maintain the structures in a safe condition, provide adequate lighting, heating, and ventilation, and perform periodic preventive maintenance on essential equipment.

An environmental surveillance program is carried out during the dormancy period to ensure that releases of radioactive material to the environment are controlled. Such potential releases are identified and quantified. Appropriate emergency procedures are established and initiated for releases that exceed prescribed limits. The environmental surveillance program will be an abbreviated version of that carried out during normal plant operations.

Primary physical security is provided by the security fence which must be maintained in good condition for the duration of this period. Fire and radiation alarms will be monitored. At the end of the dormancy period for the SAFSTOR alternative, the remaining systems and structures are completely dismantled.

Although the initial radiation levels due to Co60 will decrease significantly during the dormancy period, the internal components of the reactor vessel will still have sufficiently high radiation dose rates to require remote sectioning under water due to the presence of long-lived radionuclides such as Nb94 and Ni59. Therefore, the dismantling procedures described for the DECON alternative would be employed. Portions of the concrete shield will still be radioactive because of the presence of activated trace elements with long half-lives (Eu152 and Eu154) and will require controlled removal, packaging, and burial procedures. It is assumed that radioactive corrosion products on inner surfaces of piping and components will not have decayed to levels that will permit unrestricted use or allow conventional removal. These systems and components are surveyed as they are removed with disposition dependent upon the existing radioactive release criteria.

With the levels of radioactivity and spectrum of radionuclides expected from forty years of plant operation, no plant process system identified as being contaminated upon final shutdown will become releasable due to the decay period, i.e., there is no significant reduction in waste volume in delaying decommissioning.

The delay in decommissioning yields lower working area radiation levels. As such, the differential between the prompt and delayed scenarios is moderated by reduced ALARA controls for the SAFSTOR's lower occupational exposure potential.

The most significant difference (from DECON) in the SAFSTOR scenario costed for PBAPS is the larger owner controlled area remaining once the fuel has been transferred to the dry ISFSI. (Plant structures are decontaminated and dismantled in the DECON scenario as soon as practical. Conversely, the site facilities remain intact during the SAFSTOR caretaking period.) The activities which take place during the SAFSTOR dormancy period could add additional cost to the decommissioning program, negating the savings gained in reduced waste disposal surcharges for highly radioactive components.

3.2.3 Period 3 - Preparations

Prior to the commencement of decommissioning operations, detailed preparations are undertaken to provide a smooth transition from dormancy to site decommissioning activities. These preparations include engineering planning, surveys of plant areas to determine contamination levels, activation analyses of the vessel and vessel internals, as well as the assembly of a decommissioning management organization. Final planning for activities and writing of activity specifications and detailed procedures also begin at this time.

Because this alternative provides a period of decay of the residual radioactive material, lower personnel radiation exposures are incurred than with the DECON alternative. Some of the dismantling activities may employ manual techniques rather than remote procedures. Thus, dismantling operations may be simplified.

Much of the work in revising the DP is also relevant to the development of the detailed engineering plans and procedures. This work includes:

- Site preparation plans for decommissioning activities;
- Detailed procedures and sequences for removal of systems and components;
- Procedures for sectioning and disposing of the reactor vessel and its internals;
- Plans for decontamination of structures and systems;
- Design/procurement and testing of specialty tooling and equipment;
- Identification/selection of specialty contractors;
- Procedures for removal and disposal of radioactive materials; and
- Planning and scheduling of tasks to minimize conflicts with simultaneous activities.

3.2.4 Period 4 - Decommissioning Operations and License Termination

For the SAFSTOR alternative the decommissioning operations involve the following:

- Arrange existing storage facilities to support the dismantling activities. These may include: changing rooms and contaminated laundry facilities for increased work force, protected and open laydown areas to facilitate equipment removal and shipping operations.

- Procure and install a water cleanup system for removal of cutting residues and crud deposits from the reactor vessel.

- Design and fabricate (or procure) special shielding and contamination control envelopes, special tooling and remotely operated equipment. Modify the reactor well/spent fuel pool/dryer separator pool to support segmentation activities and prepare rigging for segmentation and removal of piping sections, recirculation pumps and other components, including the reactor vessel and its internals.

- Procure required shipping casks, liners, and Low Specific Activity (LSA) containers from suppliers.

- Conduct decontamination of components and piping systems as required. Remove, package and dispose of piping and components as they are no longer required to support the decommissioning process.

- Remove control rod drive housings and instrumentation tubes from reactor vessel lower head and cut into sections for disposal.

- Segment core support structures and the steam separator and dryer assemblies and package in shielded casks. These operations are performed remotely by cutting equipment within a contamination control envelope. Ship and bury packaged items which meet 10 CFR 61 Class "C" requirements or less.

- After the vessel water level drops below the elevation of the reactor vessel inlet and outlet nozzles during vessel segmentation, remove the reactor recirculation piping and pumps. Package the piping in standard LSA containers; the reactor recirculation pumps are sealed with steel plate so as to serve as their own containers. Ship and bury piping and pumps.

- Disassemble, segment and package remaining reactor internals in shielded casks. These internals include: top fuel guide, feedwater and core spray spargers, in-core instrument tubes, fuel support pieces, control rod guide tubes, jet pumps and core support assembly. The operations are conducted under water using remotely operated tooling and a contamination control envelope or other contamination barrier(s). Ship and bury packaged items which meet 10 CFR 61 Class "C" requirements or less.

- Package 10 CFR 61 "Greater Than Class C" (GTCC) components into fuel bundle containers for transfer to the DOE's geologic repository.

- Segment/section the reactor vessel and package into shielded containers. The operation is performed remotely in air using a contamination control envelope. Sections are placed in containers under water (for example in the spent fuel pool) or in air with the crane operator protected by a shielded envelope. Ship and bury packaged items.

- Remove systems and associated components as they become non-essential to the support of vessel disposition, other decommissioning operations or worker health (e.g., decommissioning waste processing systems, electrical systems, HVAC systems, water systems).

- Remove concrete sacrificial shield including activated/ contaminated concrete by controlled demolition. Package and bury radioactive portions.

- Remove steel liner from the drywell, disposing of the activated and contaminated sections as radioactive waste. Remove steel vent pipes connecting the drywell to the suppression chamber, again disposing of the steel as radioactive waste. Dispose of any activated/contaminated drywell concrete; package, ship and bury inventory in standard LSA containers.

- Dismantle/section the suppression chamber steel structure, packaging contaminated segments for disposal; package, ship and bury inventory in standard LSA containers.

- Remove steel liners from the dryer/separator pool, reactor well, and spent fuel pool. Package contaminated material in standard LSA containers, including contaminated pool concrete, for shipping and burial.

- Decontaminate the ISFSI. Continued radiation exposure from the spent fuel assemblies will have produced low-level neutron activation of the interior surfaces of the dry storage modules to levels exceeding current release limits.

- Ship and bury all remaining radioactive materials.

- Conduct final radiation survey to ensure that all radioactive materials have been removed. This survey may coincide with final NRC site inspection.

- Following notification by PECO of completion of the decontamination and disposal of components and materials from the facility, the NRC regional staff conducts an on-site survey to verify that the acceptable activity and contamination levels are satisfied. When the requirements are satisfied, the NRC can terminate the license for either the individual units or the station.

3.2.5 Period 5 - Site Restoration

Following completion of the decommissioning operations, site-restoration activities may begin. All building foundations are assumed to be removed to three feet below grade. Site areas affected by the dismantling activities are assumed to be cleaned and the plant area graded and landscaped as required. The costs reported to perform these activities reflect the following assumptions:

- Demolition of the remaining portions of the primary containment structure and interior portions of the Reactor Building. Internal floors (and walls if above grade) are removed from the lower levels upward, using controlled blasting techniques. Concrete rubble and clean fill produced by demolition activities may be used to backfill below-grade voids. Suitable materials can be used on site for fill; otherwise the rubble is trucked off site for reuse elsewhere.

- Remaining buildings are then removed using conventional demolition techniques for above ground structures, including the Turbine Building, Radwaste Building, and other site structures.

- Prepare the final dismantling program report.

4. COST ESTIMATE

A site-specific cost estimate was prepared for PBAPS to account for the unique features of the site including the NSSS, electric power generation systems, site buildings and structures. The basis of the estimate (including the source of information) methodology, site-specific considerations, assumptions and total costs, are described in this section.

4.1 BASIS OF ESTIMATE

A site-specific cost estimate was developed using PBAPS drawings and the inventory documents provided by PECO. PECO provided a database (Component Record List) which included the plant systems inventory. These drawings and documents were used to develop the general arrangement of the facility and to determine estimates of building concrete volumes, steel quantities, numbers and sizes of components, and land area to be restored.

Decommissioning is a labor-intensive effort. Representative labor rates for each craft or salaried worker are essential for the development of a meaningful site-specific decommissioning cost estimate. Consequently, PECO provided the information on the local cost of labor.

Disposition of radioactive waste is a major contributor to the cost for decommissioning. The availability of burial sites is of national concern, with regional compacts being formed to provide adequate burial space for operating and planned reactors. In this study, a base waste burial fee of $298.20 per cubic foot was assumed. Pennsylvania is a member of the Appalachian Compact which has not published any rate structure for the yet-to-be constructed facility. This figure is representative of estimates for new facilities and consistent with radioactive waste disposal charges in place as of July 1995 at the Chem-Nuclear Systems, Inc., Barnwell LLW Management Facility (Barnwell) in South Carolina. Surcharges for high-curie and high-weight packages are also based upon this schedule.

4.2 METHODOLOGY

The methodology used to develop the cost estimates follows the basic approach originally presented in the AIF/NESP-036 study report, "Guidelines for Producing Commercial Nuclear Power Plant Decommissioning Cost Estimates" (Ref. 3) and the US DOE "Decommissioning Handbook" (Ref. 4). These references utilize a unit cost factor method for estimating decommissioning activity costs to simplify the estimating calculations. Unit cost factors for concrete removal ($/cubic yard), steel removal ($/ton) and cutting costs ($/in) were developed from the labor cost information provided by PECO. With the item quantity (cubic yards, tons, inches, etc.) developed from plant drawings and inventory documents, the activity-dependent costs are estimated.

The unit cost factors used in this study reflect the latest available information about worker productivity in decommissioning, including the Shippingport Station Decommissioning Project, completed in 1989, as well as from TLG's involvement in the decommissioning planning and engineering for the Shoreham, Yankee Rowe, Trojan, Rancho Seco, Pathfinder and Cintichem reactor facilities.

The activity duration *critical* path was used to determine the total decommissioning program schedule. The program schedule is used to determine the period-dependent costs for program management, administration, field engineering, equipment rental, quality assurance and security. PECO provided typical salary and hourly rates for personnel associated with period-dependent costs. The costs for conventional demolition of nonradioactive structures, materials, backfill, landscaping and equipment rental were obtained from the "Building Construction Cost Data" published by R. S. Means (Ref. 5). Examples of unit cost factor development are presented in the AIF/NESP-036 study (Ref. 3). Appendix A presents the detailed development of a typical site-specific unit cost factor. Appendix B summarizes specific factors developed for the PBAPS analyses.

The activity-dependent and period-dependent costs are combined to develop the total decommissioning costs. A contingency is then applied. "Contingencies" are defined in the American Association of Cost Engineers Cost Engineers' Notebook (Ref. 6) as "specific provision for unforeseeable elements of cost within the defined project scope; particularly important where previous experience relating estimates and actual costs has shown that unforeseeable events which will increase costs are likely to occur." The cost elements in this estimate are based upon ideal conditions; therefore, a contingency factor has been applied. As with any major project, examples of items which could occur that have not been accounted for in this estimate are changes in the regulatory requirements, the effects of craft labor strikes, bad weather halting or slowing down waste shipments to the burial grounds, equipment/tool breakage, changes in the anticipated plant shutdown conditions, etc. In the "Guidelines" study (Ref. 3), the types of unforeseeable events that are likely to occur in decommissioning are discussed and guidelines are provided for percentage contingency in each category. Application of contingency is assigned on a line item basis for this estimate. It should be noted that contingency, as used in this estimate, does not account for price escalation and inflation in the cost of decommissioning over the remaining operating life of the units.

The unit cost factor method provides a demonstrable basis for establishing reliable cost estimates. The detail of activities provided in the unit cost factors for activity time, labor costs (by craft), and equipment and consumable costs, provides assurance that cost elements have not been omitted. These detailed unit cost factors, coupled with the plant-specific inventory of piping, components and structures, provide a high degree of confidence in the reliability of the cost estimates.

4.3 SITE-SPECIFIC CONSIDERATIONS

There are a number of site-specific considerations that affect the method for dismantling and removal of equipment from the site and the degree of restoration required. The cost impact of the considerations identified below is included in this cost study.

4.3.1 Spent Fuel Disposition

The existing spent fuel pools, with a capacity to store 3,814 fuel bundles each, are expected to be full before the shutdown date for each unit. The estimate for each unit includes the continued cost of wet storage for the fuel until each core discharge has decayed for at least 60 months from the discharge date. The five years are needed to permit the heat generation rate of the spent fuel assemblies to decay to acceptable levels for transportation and dry storage, typically 1 kilowatt per assembly. The decommissioning scenario has been constructed to permit continued operation of the Reactor Building fuel handling facilities for each unit. Once the final core discharge of spent fuel assemblies has been placed in dry storage, each unit's spent fuel storage and handling facilities are available for decommissioning.

Current plans are for spent fuel storage to continue after shutdown of PBAPS until 2041. During this time, shipment of spent fuel from the dry ISFSI to the U.S. Department of Energy Waste Management System for geologic disposal will be conducted, after which the dry storage facility will be decontaminated and demolished.

4.3.2 Major Component Removal

The reactor pressure vessel and reactor internal components are segmented for disposal in shielded shipping casks. Segmentation and packaging of the internals' packages are performed in the dryer/ separator pool where a turntable and remote cutter will be installed. The vessel is segmented in place using a mast-mounted cutter supported off the lower head and directed from a shielded work platform installed overhead in the reactor well. Shipping cask specifications and DOT regulations dictate segmentation and packaging methodology; all packages designated meet the current physical and radiological limitations and regulations. All cask shipments are to be made in US DOT-approved, currently available, truck casks.

Reactor recirculation piping is cut from the reactor vessel once the water level in the vessel (used for personnel shielding during dismantling and cutting operations in and around the vessel) is dropped below the nozzle zone. The piping is boxed and shipped by shielded van. The reactor recirculation pumps and motors are lifted out intact, packaged and transported for disposal.

The main turbine is dismantled using conventional maintenance procedures; the turbine rotors and shafts are removed to a laydown area for packaging and transported for disposal. The lower turbine casings are removed from their anchors by controlled demolition. The main condensers are segmented and transported to the laydown area for packaging and disposition as low-level radioactive waste along with the upper and lower turbine casings.

4.3.3 Transportation Methods

For the purposes of cost estimation, it was assumed that the NSSS components are moved by a combination of overland transport and rail to the regional burial facility.

4.3.4 Low-Level Radioactive Waste Disposal

Burial cost projections for the regional radioactive waste disposal facility were based on radioactive waste disposal charges in place as of July 1995 at the Chem-Nuclear Systems, Inc., Barnwell LLW Management Facility (Barnwell) in South Carolina. Surcharges for high-curie and weight packages were also applied using this schedule (Ref. 7).

It is assumed that there will be no significant amounts of RCRA waste, mixed waste or asbestos on site at the time of decommissioning, since it is PECO's goal to have proper planning to minimize or eliminate the generation of hazardous and mixed radioactive wastes.

To the greatest extent practical, non-compactible low-level radioactive waste is recycled to reduce the total volume of radioactive material buried. The recycled waste that meets radioactive material release limits is released as clean scrap, requiring no further cost consideration. Recycled material that does not meet release limits will be shipped and disposed of as radioactive waste. This recycling activity is performed off site by a licensed radioactive waste recovery vendor.

Compactable DAW, such as booties, glove liners, respirator filter cartridges, shipping containers, radiological controls survey materials, etc. will be assumed to be drummed and compacted to 10% of their original volume.

4.3.5 Site Conditions at Facility Close Out

It is assumed that the site is restored by regrading to conform to the adjacent landscape. Soil matching that of the adjacent landscape is brought on site and placed to allow growth of native vegetation and drainage. The intake structures on site will be demolished and removed and the circulating water piping will be sealed and abandoned in place. The switchyard and site drainage facilities remain in place.

4.4 ASSUMPTIONS

The following are the major assumptions made in the development of the cost estimates for PBAPS.

1. Costs are calculated using 1995 dollars. The estimate excludes escalation. No present-value economic analysis is included.

2. PBAPS Units 2 and 3 are expected to operate until the end of their current license expiration dates. These dates are August 8, 2013, and July 2, 2014, for Units 2 and 3 respectively.

3. Both units are assumed to be identical except for common structures and systems. Common systems and structures are included with the estimate for Unit 3.

4. PBAPS drawings, equipment and structural specifications, including construction details, were provided by PECO.

5. Employee salary and craft labor rates for site administration, operations, construction and maintenance personnel were provided by PECO for positions identified by TLG.

6. PECO provides for the electrical power required to demolish the plant to be brought on site. These costs are included in the estimate.

7. Material and equipment costs for conventional demolition and/or construction activities were taken from R.S. Means Construction Cost Data. (Ref. 5)

8. Contaminated piping, components and structures other than the reactor vessel and internals will be assumed to meet US DOT limits for LSA material. For transportation calculations, a regional burial facility is assumed to be located within 350 miles of the plant site. Rates for shipping radioactive wastes were provided by Tri-State Motor Transit in published tariffs for this cargo. (Ref. 8).

9. The reactor vessel and internals' disposal costs were based on remote in-place segmentation, packaging in shielded casks, and shipping by truck to the burial ground. A maximum normal road weight limit of 80,000 pounds is assumed for all truck shipments with the exception of several overweight cask shipments. Cask shipments may exceed 95,000 pounds, including vessel segment(s), supplementary shielding, cask tie-downs and tractor trailer. The maximum curies per shipment assumed permissible is based upon the license limits of available shielded shipping casks. The number and curie content of vessel segments were selected to meet these limits.

   The number of cask shipments out of the Reactor Building is assumed to average three per week.

10. In the DECON alternative, the NSSS (reactor vessel and reactor coolant system) will be chemically decontaminated using one chemical flush and two water rinses prior to segmentation. Typically, a decontamination factor (DF) of 10 is expected.

11. Reactor vessel and internals packages' conditions:

    Any fuel cladding failure that has occurred or may occur during the lifetime of the plant is assumed:

a) to have released fission products at sufficiently low levels that the buildup of quantities of long-lived isotopes (e.g. cesium-137, strontium-90, or transuranics) has been prevented from reaching levels exceeding those which permit the major NSSS components to be shipped as LSA waste and buried within the requirements of 10 CFR 61 or the regional burial ground; or

b) to have necessitated systematic decontamination during the operating life of the plant; therefore, the radionuclide levels will be acceptable for transport as LSA waste and burial within the requirements of 10 CFR 61.

12. For purposes of this cost estimate, the curie contents of the vessel and internals at final shutdown are derived from those listed in NUREG/CR-3474 (Ref. 9). These estimates (derived from the Ci/gram values in NUREG/CR-3474) are adjusted for the different mass of PBAPS components, projected operating life, as well as for different periods of decay. Additional short-lived isotopes will be derived from NUREG/CR-0130 (Ref. 10) and NUREG/CR-0672 (Ref. 11) and benchmarked to the long-lived values from NUREG/CR-3474.

13. This study estimates that there will be some radioactive waste generated which is greater than 10 CFR 61 Class C quantities, resulting from disposal of the highly activated sections of the reactor vessel internals. This waste will most likely be disposed of as high-level waste in the DOE's deep geological repository unless an alternative solution is approved by the NRC. The cost of disposal, unlike that for the spent fuel, is not covered by DOE's 1 mill/kWhr surcharge, and has been estimated from equivalent disposal costs for spent nuclear fuel.

14. Control elements will be removed and disposed of along with the reactor vessel internals.

15. The costs associated with the caretaking of spent fuel in the ISFSI are included with the decommissioning cost for Unit 3.

16. This study does not address the cost of the removal or disposal of spent fuel from the site. This cost is assumed to be covered by the DOE 1 mill/kwhr surcharge.

17. The final reactor core discharge will remain in the spent fuel pool for approximately five years, where it will then be transferred to a pre-existing dry storage facility (ISFSI). It is assumed that a modular type

ISFSI will have been constructed to support plant operations. An incremental number of modules will be constructed to support decommissioning of the Reactor Building, the costs for which are included in this estimate.

18. The ISFSI will use a horizontal concrete storage module system. The study assumes dual purpose (storage and transport) canisters to be paid for by PECO. PECO will also be responsible for the concrete storage modules for these canisters. Only those additional modules, needed to empty the spent fuel pool at shutdown, are reflected within the decommissioning cost, i.e., operational requirements are not addressed. Capital expenditures were based upon a canister design of 52 fuel bundles per canister.

19. The spent fuel is assumed to be stored for 27 years after Unit 3 shutdown (until 2041) with periodic shipments to the DOE high-level waste repository. The cost for the storage of spent fuel will be included with the cost for decommissioning Unit 3. The decommissioning cost for the ISFSI is identified as a separate line item cost in Appendix C for Unit 3.

20. Scrap generated during decommissioning is not included as a salvage credit line item in this study for two reasons: (1) the scrap value merely offsets the associated site removal and scrap processing costs, and (2) a relatively low value of scrap exists in the market. Scrap processing and site removal costs are not included in the estimate.

21. Decommissioning will take place sufficiently far in the future that all equipment will be worn, obsolete and suitable for scrap as deadweight quantities only. No equipment is salvageable as used equipment.

22. The PECO staffing requirements during decommissioning vary with the level of effort associated with the various phases of the project. Once the decommissioning program commences, only those staff positions which will be necessary to support the decommissioning program are included. There are no costs for staff transition from operations to decommissioning.

23. This study assumes that PECO will serve as the Decommissioning Operations Contractor (DOC) for the decommissioning project. As such, PECO will provide sufficient staff to perform the preparatory demolition planning and scheduling, and manage the demolition efforts. Site security, radiological controls, quality assurance and overall site

administration during decommissioning and demolition will also be provided by PECO. The demolition work is performed by PECO, or a demolition subcontractor who will provide adequate staff, labor, equipment, materials and overhead to complete the demolition.

24. Engineering services for such items as writing activity specifications, detailed procedures, detailed activation analyses, structural modifications, etc. are assumed to be provided by PECO.

25. PECO will remove all items of furniture, tools, mobile equipment such as forklifts, trucks, bulldozers, other similar mobile equipment and other such items owned by PECO that will be easily removed without the use of special equipment.

26. Existing warehouses will remain for use by PECO and its subcontractors. The warehouses will be dismantled as they are no longer needed to support the decommissioning program.

27. PECO will perform the following activities at no cost or credit to the project:

    - Fuel oil tanks will be emptied. Tanks will be cleaned by flushing or steam cleaning as required prior to disposal.
    - Acid and caustic tanks will be emptied through normal usage.
    - Excess acid or caustic is removed and the storage container returned to the vendor.
    - Lubricating and transformer oils will be drained and removed from site by a waste disposal vendor.

28. The decommissioning activities will be performed in accordance with the current regulations which are assumed to be in place at the time of decommissioning.

29. This study follows the principles of ALARA through the use of work duration adjustment factors which incorporate such items as radiological protection instruction, mock-up training, the use of respiratory protection and personnel protective clothing. These items lengthen a task's duration, which increases the costs and lengthens the schedule. ALARA planning is considered in the costs for engineering

and planning, and in the development of activity specifications and detailed procedures.

30. This study was performed in accordance with the published study from the Atomic Industrial Forum/National Environmental Studies Project report AIF/NESP-036, "Guidelines for Producing Commercial Nuclear Power Plant Decommissioning Cost Estimates". The contents of those guidelines were prepared under the review of a task force consisting of representatives from utilities, state regulatory commissions, architect/engineering firms, the Federal Energy Regulatory Commission, the NRC, and the National Association of Regulatory Utility Commissioners.

31. Nuclear liability insurance provides coverage for damage or injuries due to radiation exposure from equipment, material, etc. used during decommissioning. Nuclear liability insurance is phased out upon final decontamination of the site. PECO provided current nuclear liability and property insurance premiums which were factored to reflect lower coverage limits and return of premiums during decommissioning activities.

32. Only existing site structures and those presently planned will be considered in the dismantling cost.

33. The perimeter fence and in-plant security barriers will be moved as appropriate to conform with the Site Security Plan in force at the various stages in the project.

34. The existing electrical switchyard will remain after the PBAPS decommissioning in support of the electrical transmission and distribution system.

35. Underground concrete pipe is assumed to be collapsed and backfilled if it is located less than 10 feet below grade. Underground steel pipe, if located less than 10 feet below grade, will be removed completely, surveyed for contamination, removed from the site and disposed of as clean scrap. Piping located greater than 10 feet below grade will be sealed with concrete plugs and abandoned in place.

36. Electrical manholes are assumed to be backfilled with suitable earthen material and abandoned.

37. All remaining site vestiges are assumed to be removed to a depth of three feet below grade level with the non-contaminated sub-grade foundations remaining in place. Water drain holes are assumed to be drilled in each of the foundation basemats to allow for natural drainage.

38. Building foundations are assumed to be backfilled with clean demolition debris, and the site graded and landscaped. All areas affected by dismantling activities will be cleaned up, covered with loam and seeded.

39. All road and parking area base material is assumed to remain in place. Road and parking areas with asphalt are assumed to be broken up and disposed of. All gravel road and parking areas are assumed to remain in place with the area covered with fill and loam and seeded.

40. Upon completion of the dismantling operations, the site is assumed to be returned to the condition that existed prior to installation of the reactor facility.

41. The site will be returned to unrestricted use after the NRC approval to terminate the possession-only license is received.

42. Property tax payments after shutdown of each unit are based upon land value only.

4.5 COST ESTIMATE SUMMARY

A summary of the decommissioning costs with annual expenditures is provided in Tables 4.1a-4.1d. Table 8.1 also shows the breakdown of the decommissioning costs into the components of decontamination, removal, packaging, transportation, waste disposal, project management (staffing) and other cost categories. The costs were extracted from the detailed reports in Appendix C.

The detailed cost tables (Appendix C) show the detailed listing and costs of major activities for Units 2 and 3, respectively, for the DECON and SAFSTOR decommissioning alternatives. Note that "Decon" as used in the headings of these tables, refers to decontamination. It should be noted that "Total" as used in the heading of tables, is the sum of Decon, Remove, Pack, Ship and Bury as well as other miscellaneous items not listed (such as engineering and preparations). Staff relocation expenses are those costs associated with moving specialty contractor personnel to the site, either for per diem allowance or for moving expenses.

4.6 DECOMMISSIONING vs. SITE RESTORATION

The total projected station cost of decommissioning PBAPS for the DECON alternative is $831,386,496. The majority of these costs are directly attributable to the engineering and planning and the actual disposition of the residual radioactive material. It should be noted, however, that a direct accounting of only these costs is not entirely accurate in portraying the actual cost of "decommissioning" as defined by the NRC. Consideration must also be given to the methods of executing the decommissioning process. The following paragraphs describe, in general, the activities which are both necessary to complete the decommissioning process and which extend beyond the disposition of the radioactively contaminated inventory

Nuclear power plants are designed to contain the radioactive material inherent in the normal operation of the facility. Accordingly, radioactive and potentially radioactive systems are located in shielded labyrinths, tunnels and pipe chases. This inaccessibility, while essential during operation, serves to impede decommissioning activities. Consequently, disposition of these components requires that, in many situations, additional access (and working space) be developed. This access is achieved by dismantling structures and components along the intended path of egress and in the immediate working area. In most instances, this material is non-radioactive and therefore not normally perceived as a necessary constituent in facility decontamination. However, failure to establish adequate working room will increase the residence times for decontamination and dismantling activities resulting in increases in the cost and incurred occupational exposure.

The costs associated with the removal of non-contaminated and other releasable materials in support of the decommissioning process are commonly referred to as cascading costs. Cascading costs are identified in evaluating the dismantling processes involved in decommissioning PBAPS and are included with the license termination costs delineated in Appendix C. Consequently, for the utility to meet the intent of the NRC's definition of decommissioning, ("...release of the property for unrestricted use and termination of license") a cost of $746,263,584 would be required to terminate the facility's license(s), or approximately 90% of the total cost. The remaining costs would be required for site restoration as described in Section 3.

TABLE 4.1a
SUMMARY OF DECON DECOMMISSIONING COSTS
Peach Bottom Atomic Power Station Unit 2
(1995 Dollars)

Year	Period 1 Preparations	Period 2 Decommissioning	Period 3 Demolition Delay	Period 3 Site Restoration	Totals
2013	$11,724,481				$11,724,481
2014	$29,311,202				$29,311,202
2015	$2,960,030	$63,825,059			$66,785,089
2016		$68,359,997			$68,359,997
2017		$65,588,248			$65,588,248
2018		$66,331,125			$66,331,125
2019		$27,718,423	$286,711		$28,005,133
2020			$149,514	$7,644,150	$7,793,664
2021				$11,028,122	$11,028,122
2022				$3,263,115	$3,263,115
	$43,995,712	$291,822,852	$436,225	$21,935,387	$358,190,176

TABLE 4.1b
SUMMARY OF DECON DECOMMISSIONING COSTS
Peach Bottom Atomic Power Station Unit 3
(1995 Dollars)

Year	Period 1 Preparations	Period 2 Decommissioning	Period 3 Site Restoration	Post Period 3 Dry Fuel Storage	Totals
2014	$13,026,969				$13,026,969
2015	$25,972,787	$27,509			$26,000,296
2016		$74,276,171			$74,276,171
2017		$76,225,254			$76,225,254
2018		$75,998,225			$75,998,225
2019		$76,843,343			$76,843,343
2020		$24,156,013	$18,475,788		$42,631,802
2021			$26,687,493		$26,687,493
2022			$11,479,278	$1,010,478	$12,489,756
2023				$1,773,194	$1,773,194
2024				$1,778,052	$1,778,052
2025				$1,773,194	$1,773,194
2026				$1,773,194	$1,773,194
2027				$1,773,194	$1,773,194
2028				$1,778,052	$1,778,052
2029				$1,773,194	$1,773,194
2030				$1,773,194	$1,773,194
2031				$1,773,194	$1,773,194
2032				$1,778,052	$1,778,052
2033				$1,773,194	$1,773,194
2034				$1,773,194	$1,773,194
2035				$1,773,194	$1,773,194
2036				$1,778,052	$1,778,052
2037				$1,773,194	$1,773,194
2038				$1,773,194	$1,773,194
2039				$1,773,194	$1,773,194
2040				$1,778,052	$1,778,052
2041				$17,075,232	$17,075,232
	$38,999,756	$327,526,516	$56,642,560	$50,027,488	$473,196,320

TABLE 4.1c
SUMMARY OF SAFSTOR DECOMMISSIONING COSTS
Peach Bottom Atomic Power Station Unit 2
(1995 Dollars)

Year	Period 1 Dormancy Prep	Period 2 Dormancy	Period 3 Preparations	Period 4 Decommissioning	Period 5 Site Restoration	Totals
2013	$13,407,524					$13,407,524
2014	$31,999,414					$31,999,414
2015	*$3,078,903*	*$3,033,593*				*$6,112,496*
2016		$3,383,602				$3,383,602
2017		$3,374,357				$3,374,357
2018		$2,855,542				$2,855,542
2019		$1,144,580				$1,144,580
2020		$1,147,716				$1,147,716
2021		$1,144,580				$1,144,580
2022		$1,144,580				$1,144,580
2023		$1,144,580				$1,144,580
2024		$1,147,716				$1,147,716
2025		$1,144,580				$1,144,580
2026		$1,144,580				$1,144,580
2027		$1,144,580				$1,144,580
2028		$1,147,716				$1,147,716
2029		$1,144,580				$1,144,580
2030		$1,144,580				$1,144,580
2031		$1,144,580				$1,144,580
2032		$1,147,716				$1,147,716
2033		$1,144,580				$1,144,580
2034		$1,144,580				$1,144,580
2035		$1,144,580				$1,144,580
2036		$1,147,716				$1,147,716
2037		$1,144,580				$1,144,580
2038		$1,144,580				$1,144,580
2039		$1,144,580				$1,144,580
2040		$1,147,716				$1,147,716
2041		$1,030,501				$1,030,501
2042		$918,282				$918,282
2043		$918,282				$918,282
2044		$920,798				$920,798
2045		$918,282				$918,282
2046		$918,282				$918,282
2047		$918,282				$918,282
2048		$920,798				$920,798
2049		$918,282				$918,282
2050		$918,282				$918,282
2051		$918,282				$918,282
2052		$920,798				$920,798
2053		$918,282				$918,282
2054		$918,282				$918,282
2055		$918,282				$918,282
2056		$920,798				$920,798
2057		$918,282				$918,282
2058		$918,282				$918,282
2059		$918,282				$918,282
2060		$920,798				$920,798
2061		$918,282				$918,282
2062		$918,282				$918,282
2063		$918,282				$918,282
2064		$920,798				$920,798
2065		$918,282				$918,282
2066		$918,282				$918,282
2067		$918,282				$918,282
2068		$920,798				$920,798
2069		*$72,979*	*$14,877,154*			$14,950,133
2070			$11,047,930	$39,009,800		$50,057,730
2071				$91,950,668		$91,950,668
2072				$87,253,461		$87,253,461
2073				$11,477,176	$4,965,650	$16,442,826
2074					$7,025,525	$7,025,525
2075					$8,323,789	$8,323,789
2076					$4,059,272	$4,059,272
	$48,485,840	$63,761,368	$25,925,084	$229,691,104	$24,374,236	$392,237,632

TABLE 4.1d
SUMMARY OF SAFSTOR DECOMMISSIONING COSTS
Peach Bottom Atomic Power Station Unit 3
(1995 Dollars)

Year	Period 1 Dormancy Prep	Period 2 Dormancy	Period 3 Preparations	Period 4 Decommissioning	Period 5 Site Restoration	Totals
2014	$17,592,918					$17,592,918
2015	$35,076,242	$1,916				$35,078,158
2016		$5,008,905				$5,008,905
2017		$4,995,219				$4,995,219
2018		$4,995,219				$4,995,219
2019		$4,313,788				$4,313,788
2020		$2,963,382				$2,963,382
2021		$2,955,285				$2,955,285
2022		$2,955,285				$2,955,285
2023		$2,955,285				$2,955,285
2024		$2,963,382				$2,963,382
2025		$2,955,285				$2,955,285
2026		$2,955,285				$2,955,285
2027		$2,955,285				$2,955,285
2028		$2,963,382				$2,963,382
2029		$2,955,285				$2,955,285
2030		$2,955,285				$2,955,285
2031		$2,955,285				$2,955,285
2032		$2,963,382				$2,963,382
2033		$2,955,285				$2,955,285
2034		$2,955,285				$2,955,285
2035		$2,955,285				$2,955,285
2036		$2,963,382				$2,963,382
2037		$2,955,285				$2,955,285
2038		$2,955,285				$2,955,285
2039		$2,955,285				$2,955,285
2040		$2,963,382				$2,963,382
2041		$2,457,253				$2,457,253
2042		$1,967,342				$1,967,342
2043		$1,967,342				$1,967,342
2044		$1,972,732				$1,972,732
2045		$1,967,342				$1,967,342
2046		$1,967,342				$1,967,342
2047		$1,967,342				$1,967,342
2048		$1,972,732				$1,972,732
2049		$1,967,342				$1,967,342
2050		$1,967,342				$1,967,342
2051		$1,967,342				$1,967,342
2052		$1,972,732				$1,972,732
2053		$1,967,342				$1,967,342
2054		$1,967,342				$1,967,342
2055		$1,967,342				$1,967,342
2056		$1,972,732				$1,972,732
2057		$1,967,342				$1,967,342
2058		$1,967,342				$1,967,342
2059		$1,967,342				$1,967,342
2060		$1,972,732				$1,972,732
2061		$1,967,342				$1,967,342
2062		$1,967,342				$1,967,342
2063		$1,967,342				$1,967,342
2064		$1,972,732				$1,972,732
2065		$1,967,342				$1,967,342
2066		$1,967,342				$1,967,342
2067		$1,967,342				$1,967,342
2068		$1,972,732				$1,972,732
2069		$1,420,675				$1,420,675
2070		$447,928	$7,064,446			$7,512,373
2071			$10,794,870	$17,543,198		$28,338,068
2072				$101,749,820		$101,749,820
2073				$102,385,333		$102,385,333
2074				$50,896,253	$15,339,069	$66,235,322
2075					$30,594,317	$30,594,317
2076					$19,001,166	$19,001,166
	$52,669,160	$138,906,432	$17,859,316	$272,574,604	$64,934,552	$546,944,064

5. SCHEDULE ESTIMATE

The schedule for individual and integrated decommissioning scenarios considered in this study follows the sequence presented in the AIF/NESP-036 study (Ref. 3) with minor changes to reflect recent experience and revised estimates. In addition, the scheduling has been revised to reflect the spent fuel scenario which is currently planned for PBAPS.

TLG has prepared a schedule for decommissioning PBAPS. The assumptions supporting this schedule are listed in Section 5.1. Figure 5.1 presents the schedule of key activities. Note that the activities listed in the schedules do not reflect a one-to-one correspondence with the activities in the cost tables in Appendix C, but reflect dividing some activities for clarity and combining others for convenience. The schedule was prepared using the "Microsoft Project" computer software (Ref. 12).

5.1 SCHEDULE ESTIMATE ASSUMPTIONS

The schedule estimate reflects the results of a precedence network developed for PBAPS decommissioning activities, i.e., a PERT (Program Evaluation and Review Technique). The durations used in the precedence network reflect the actual man-hour estimates from the cost tables in Appendix C. The schedule output is then adjusted by stretching certain activities over their slack range; other activities were pushed to the end of their slack period. The following assumptions were made in the development of the decommissioning schedule for PBAPS.

1. All work except vessel and internals removal activities is performed during an 8-hour workday, 5 days per week with no overtime. There are eleven paid holidays per year.

2. The Reactor Buildings' fuel handling facilities will be isolated and serve as interim wet fuel storage facilities until such time that all spent fuel has been discharged from the spent fuel pool, i.e., within five years and two months from shutdown of Units 2 and 3.

3. Vessel and internals removal activities are performed by using separate crews for different activities working on different shifts, with a corresponding backshift charge for the second shift.

4. Multiple crews work parallel activities to the maximum extent possible consistent with optimum efficiency, adequate access for cutting, removal

and laydown space, and with the stringent safety measures necessary during demolition of heavy components and structures.

5. For plant systems removal, the systems with the longest removal durations in areas on the critical path are considered to determine the duration of the activity.

6. Following completion of the Unit 2 vessel cutting activity, equipment is relocated to Unit 3.

5.2 PROJECT SCHEDULE

The period-dependent costs presented in the cost tables in Appendix C are based upon the durations developed in the schedule for the DECON alternative. Durations are established between several milestones in each project period; these durations are used to establish a critical path for the entire project. In turn, the critical path duration for each period is used as the basis for determining the total costs for these period-dependent items.

Project timelines are included in this section as Figures 5.2a and 5.2b. Milestone dates are based on a 40-year plant operating life from the issuance of the operating license.

FIGURE 5.1
DECON ACTIVITY SCHEDULE

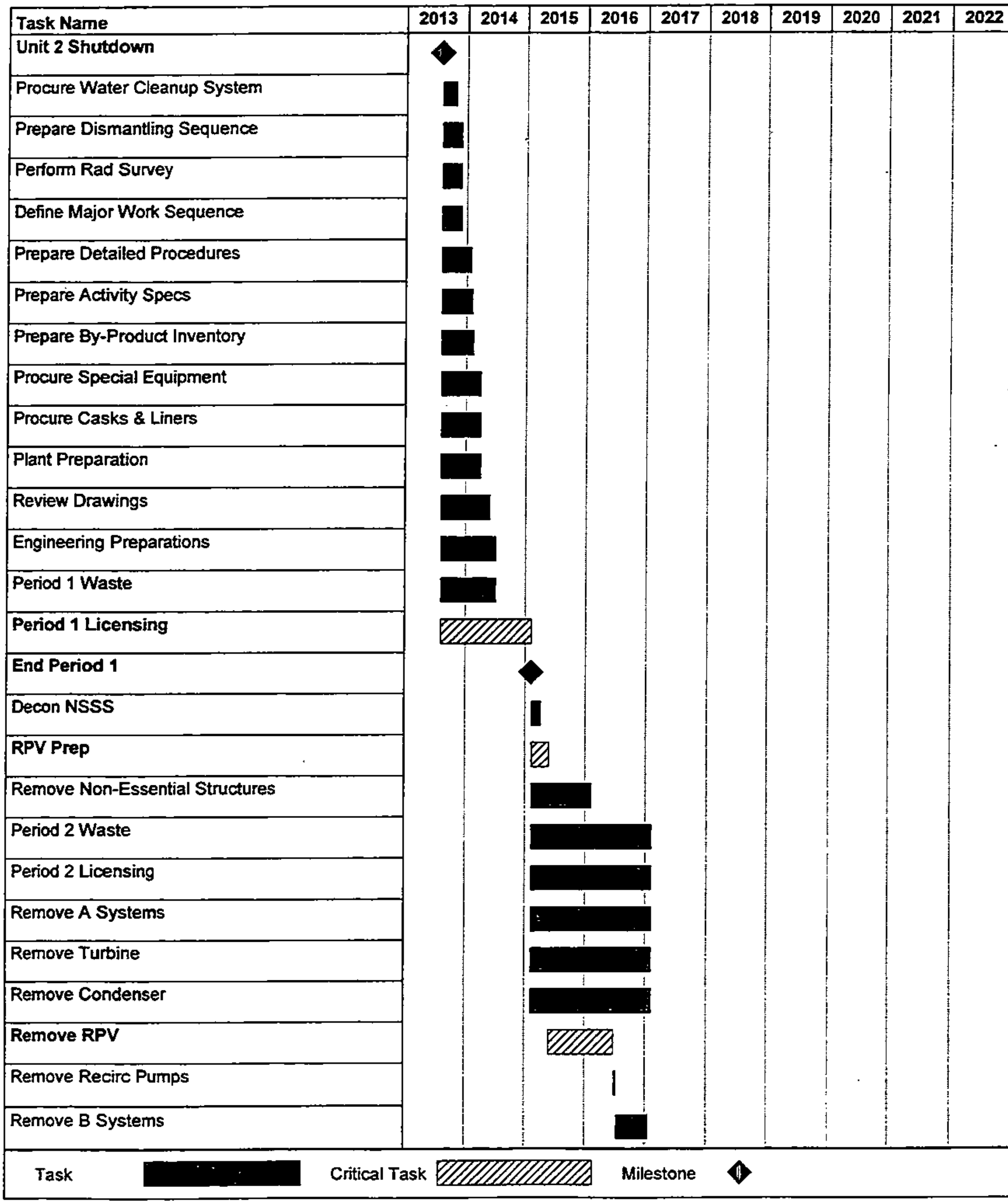


FIGURE 5.1
DECON ACTIVITY SCHEDULE
(continued)

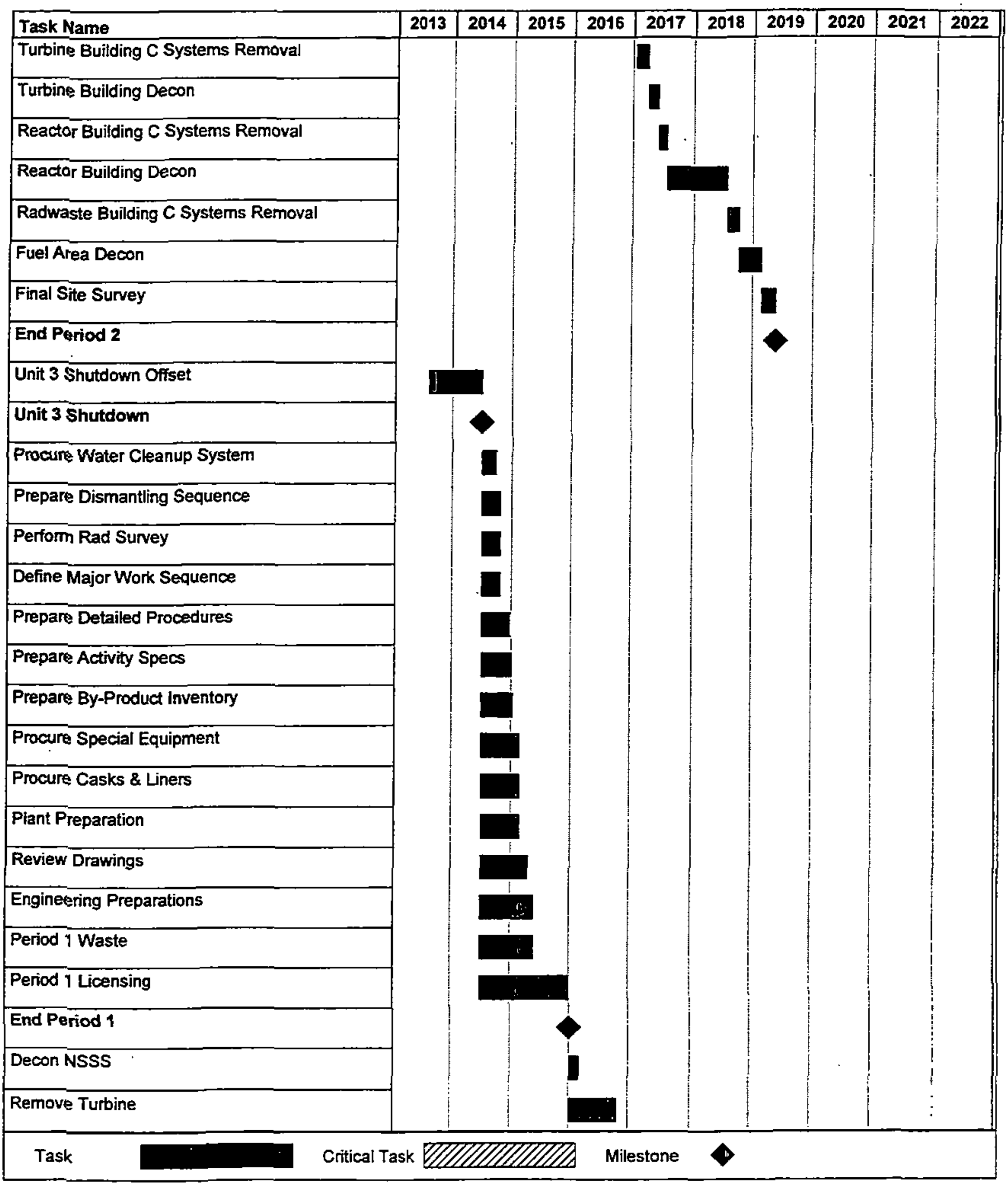


FIGURE 5.1
DECON ACTIVITY SCHEDULE
(continued)

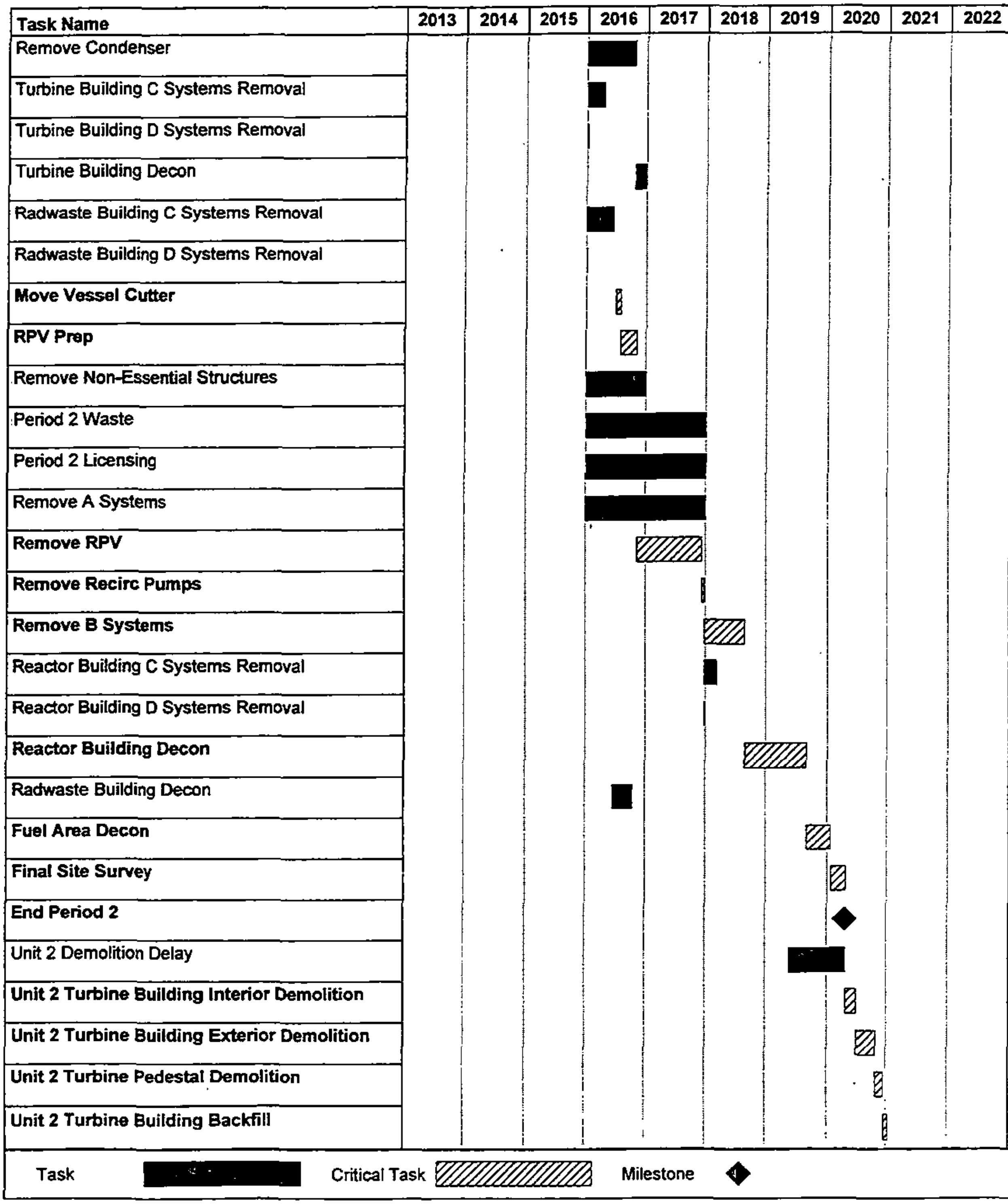


FIGURE 5.1
DECON ACTIVITY SCHEDULE
(continued)

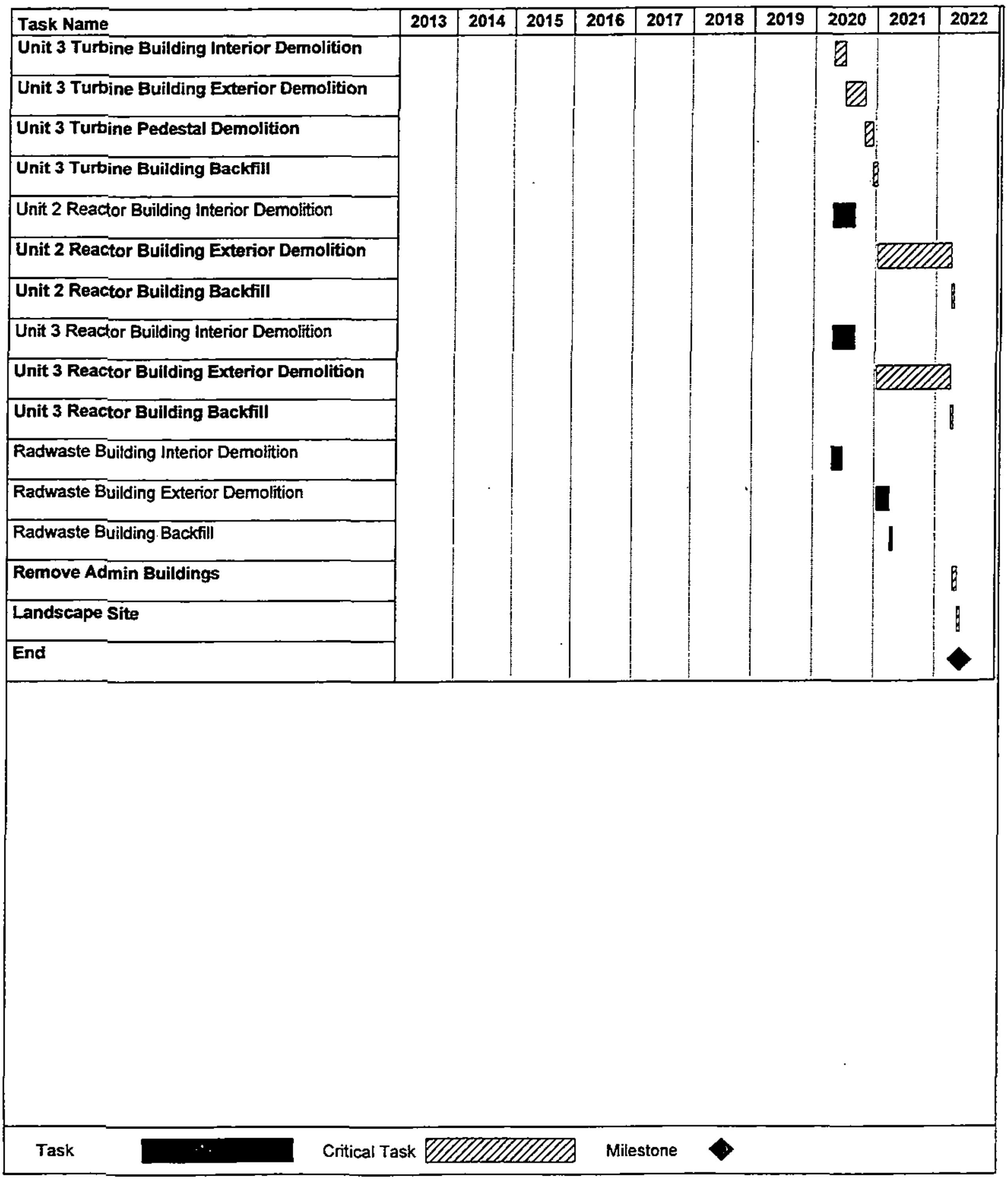
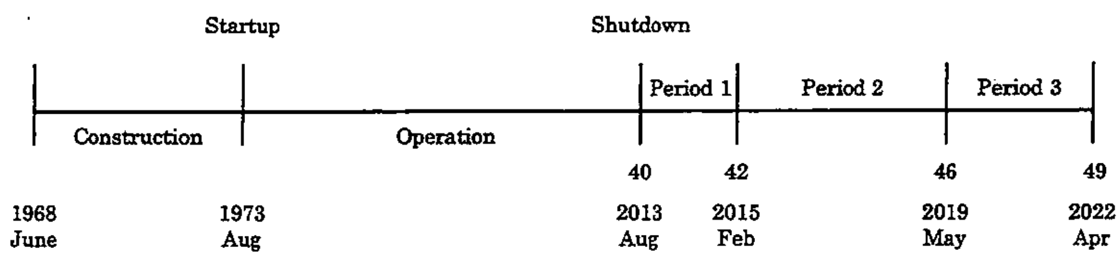


FIGURE 5.2a
DECON DECOMMISSIONING TIMELINES
(not to scale)

UNIT 2



UNIT 3

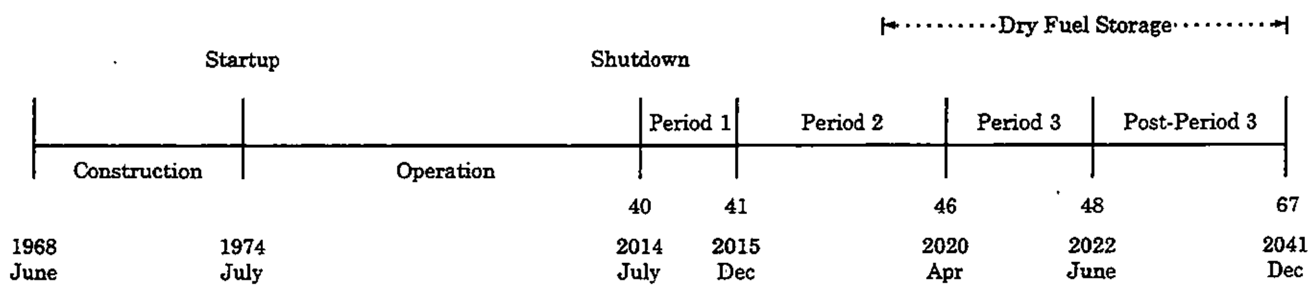
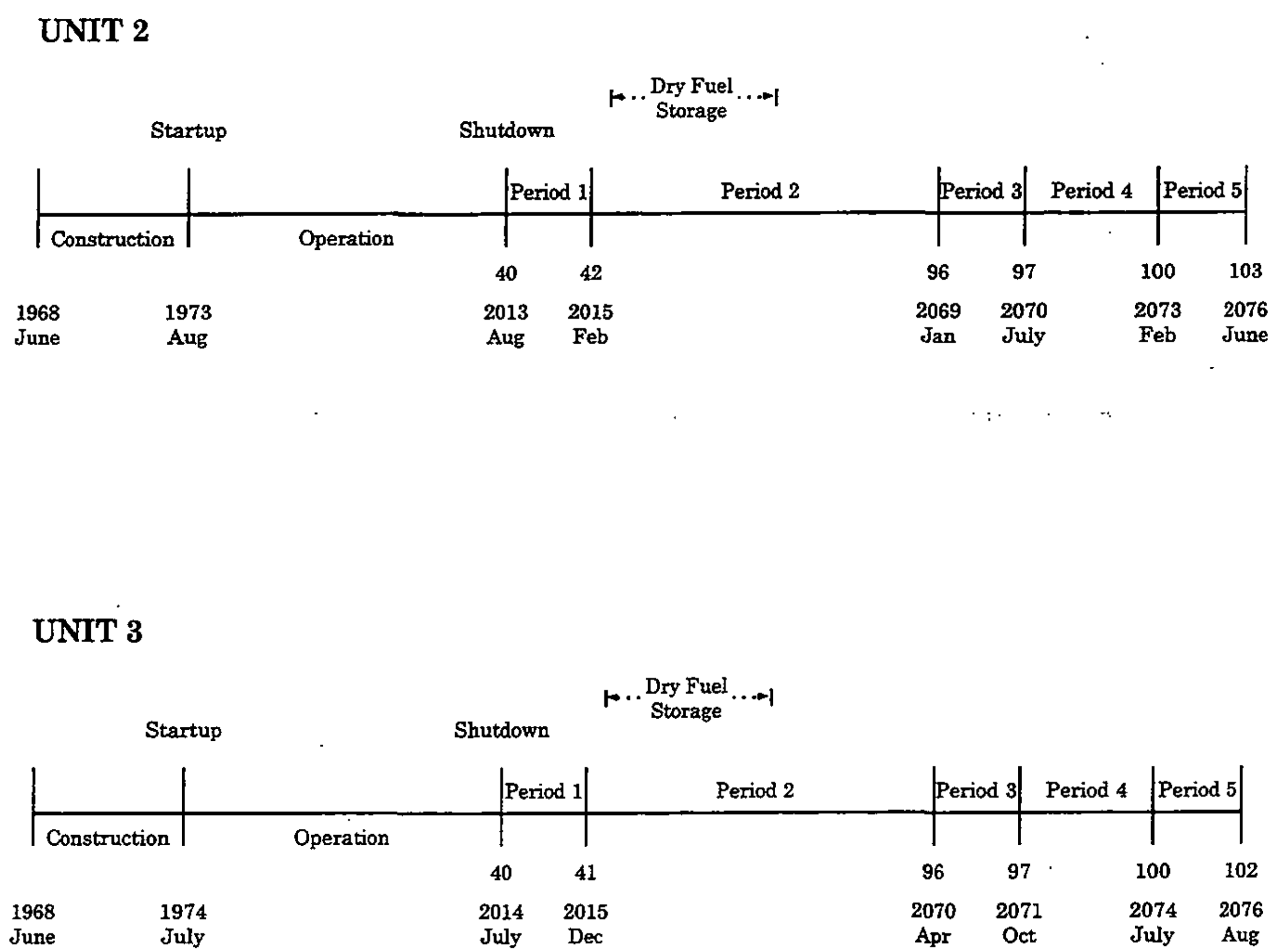


FIGURE 5.2b
SAFSTOR DECOMMISSIONING TIMELINES
(not to scale)



6. RADIOACTIVE WASTES

The ultimate goal of the decommissioning program is the removal of all radioactive material from the site which would restrict its future use. This requires the removal of all radioactive material from the site which is in excess of applicable legal limits.

Under the Atomic Energy Act, the NRC is responsible for protecting the public from sources of ionizing radiation. Title 10 of the Code of Federal Regulations delineates the production, utilization and disposal of radioactive materials and processes. In particular, 10 CFR Part 61 controls the burial of radioactive material; Part 71 defines radioactive material.

The radioactive waste volumes generated during the various decommissioning programs at PBAPS are shown by line activity in the cost tables in Appendix C. Waste volumes shown in Table 6.1 are quantified consistent with 10 CFR 61 classifications. The waste volumes shown are calculated based on the gross container volume to be shipped and buried in the controlled burial ground. Table 6.1 provides estimated volumes of radioactive waste, by classification, produced by the decommissioning of PBAPS.

Most of the materials being transported for controlled burial are categorized as LSA material containing Type A quantities as defined in 49 CFR 173-178 (Ref. 13). The containers must be strong, tight packages. For this study, commercially available steel containers are presumed to be used for piping, small components and concrete.

The reactor vessel and internals are categorized as large quantity shipments and, accordingly, must be shipped in reusable shielded casks with disposable liners. In this case, the liner volume is taken as the waste volume. No process system containing or handling radioactive substances at shutdown is presumed releasable as non-contaminated scrap metal because of the presence of long-term radionuclides.

The waste volume attributed to site decontamination is primarily generated during Period 2 of DECON. The radioactive waste generated as a result of the decommissioning of PBAPS is destined for disposal at the future Appalachian Compact Low-Level Waste Disposal facility to be located in Pennsylvania within 350 miles of the site. In this study, the base waste burial fee assumed for decommissioning is $298.20 per cubic foot. This figure was obtained from the rate structure in place as of July 1995 at the Chem-Nuclear Systems, Inc., Barnwell LLW Management Facility (Barnwell) in South Carolina. Curie and weight surcharges are also applied using this rate structure.

The non-compactable (metallic) radioactive waste generated from removal of the plant equipment is assumed to be sent to an off-site vendor for recycling to reduce the final radioactive waste disposal volume. Based upon typical radiological characterizations and industry experience, the inventory of contaminated PBAPS material was segregated based on the likelihood of volume reduction and decontamination for radiological free release. This reduced burial volume, resulting from reprocessing/recycling radioactive equipment off site, is reflected in the report. The cost of off-site processing of non-compactable metallic waste is estimated to be approximately $100 per cubic foot, and appears in the "other" category in the detailed decommissioning cost tables in Appendix C.

TABLE 6.1

DECOMMISSIONING RADIOACTIVE WASTE BURIAL VOLUMES

	Waste Class [1]	Volume (Cubic Feet) [2]
DECON		
Unit 2	A	171,161
	B	33,303
	C	476
	>C	664
Total		**205,604**
Unit 3	A	236,151
	B	34,378
	C	408
	>C	664
Total		**271,602**
SAFSTOR		
Unit 2	A	173,723
	B	11,367
	C	340
	>C	664
Total		**186,094**
Unit 3	A	237,896
	B	12,557
	C	340
	>C	664
Total		**251,457**

1. Waste is classified according to the requirements as delineated in Title 10 of the Code of Federal Regulations, Part 61.55
2. Column may not add due to rounding.

7. OCCUPATIONAL EXPOSURE

Estimates of occupational radiation exposure were developed by TLG. These estimates are scoping in nature and are performed to provide an upper bound to the exposure limits for comparison with NRC maximum dose limitations.

Radiation doses to decommissioning workers are calculated as the product of the estimated radiation zone work force requirements and the radiation exposure rates estimated for each decommissioning task. The decommissioning occupational exposure estimates are based on the following assumptions:

1. Occupational exposure estimates include only those from the craft labor necessary for decontamination, removal and packaging activities, as well as all required health physics personnel exposures in support of these activities. Casual exposures to the plant staff are not included in this estimate.

2. Personnel exposure to radiation is minimized by utilizing shielding and remote handling techniques and avoiding higher radiation fields when personnel presence is not necessary.

3. Local exposure rates near items such as tanks and pipes are reduced by a successful chemical decontamination program prior to work in that area.

4. Careful prompt accounting of accumulated radiation exposure is maintained to rapidly identify tasks causing excessive dose accumulation by workers so that corrective action can be taken.

5. Exposures as the result of spent fuel storage activities are expected to be minimal, and therefore, are not included.

6. Cobalt-60 is the primary contributor to radiation exposure.

It should be noted that the radiation exposure rates used to calculate the exposures shown in Appendix C are based on optimum conditions; factors such as plant age, maintenance and operating history could cause the expected exposure rates at the time of decommissioning to vary significantly. Implementation of the DECON alternative yields the higher occupational radiation exposure because the work is performed soon after shutdown, without the benefit of any extended decay time for the radionuclides on site.

8. RESULTS

Decommissioning technology is well established and the tools and equipment necessary to completely dismantle PBAPS are available and have been demonstrated. The projected costs to decommission the plant, presuming the use of an integrated station DECON alternative, including the five year and two month operation of the Reactor Buildings' fuel handling equipment as an interim wet fuel storage facility, and post-decommissioning dry fuel storage until 2041, is $831,386,496. This cost includes the complete removal/remediation of all site vestiges. The estimate reflects the site-specific features of PBAPS and the projected cost of radioactive waste shipping and disposal. An analysis of the major activities contributing to the total cost is shown in Table 8.1.

The decommissioning and utility staffs along with the removal activity combine to represent the majority of the cost to decommission PBAPS. This is a direct result of the labor-intensive nature of the decommissioning process. Burial is the next largest cost component reflecting increasing waste burial charges and weight and curie surcharges. Transportation costs are most sensitive to increases in fuel costs and distances to existing or new burial facilities. Removal costs are dependent on the degree of remotely operated equipment available in the future and the associated higher cost of that equipment versus the savings in labor costs.

This study for PBAPS provides an estimate for decommissioning the site under current requirements based on present-day costs and available technology. As additional dismantling experience on large reactors becomes available, cost estimates will be modified to reflect this experience. In addition, there are costs associated with decommissioning activities that historically increase at rates significantly greater than inflationary trends. For example, the cost of radioactive waste burial has increased rapidly in the last few years. It is therefore appropriate that this cost estimate be reviewed periodically, and updated/revised as required.

TABLE 8.1

SUMMARY OF DECON DECOMMISSIONING COSTS

Work Category	Costs 95$ (thousands) [1]	Percent of Total Costs [1]
Unit 2		
Decontamination	19,884	5.55
Removal	56,208	15.69
Packaging	13,031	3.64
Shipping	3,476	0.97
Burial (off-site)	114,319	31.92
Decommissioning Staffs	69,558	19.42
Other [2]	81,715	22.81
Subtotal	**358,190**	**100.00**
Unit 3		
Decontamination	23,081	4.88
Removal	96,112	20.31
Packaging	13,521	2.86
Shipping	4,842	1.02
Burial (off-site)	127,600	26.97
Decommissioning Staffs	105,792	22.36
Other [2]	102,248	21.61
Subtotal	**473,196**	**100.00**
STATION TOTAL (with contingency)	**831,386**	

1. Columns may not add due to rounding.
2. Other includes: engineering & preparations, undistributed costs and off-site LLW recycling costs.

9. REFERENCES

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3. T.S. LaGuardia et al., "Guidelines for Producing Commercial Nuclear Power Plant Decommissioning Cost Estimates", AIF/NESP-036, May 1986.

4. W.J. Manion and T.S. LaGuardia, "Decommissioning Handbook", U.S. Department of Energy, DOE/EV/10128-1, November 1980.

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6. Cost Engineers' Notebook: American Association of Cost Engineers, AA-4.000, pg 3 of 22, Rev. 2 (January 1978) (Updated periodically).

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9. J.C. Evans et al., "Long-Lived Activation Products in Reactor Materials" NUREG/CR-3474, Pacific Northwest Laboratory for the Nuclear Regulatory Commission. August 1984.

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11. H.D. Oak, et al., "Technology, Safety and Costs of Decommissioning a Reference Boiling Water Reactor Power Station," NUREG/CR-0672 and addenda, Pacific Northwest Laboratory for the Nuclear Regulatory Commission. June 1980.

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13. U.S. Department of Transportation, Section 49 of the Code of Federal Regulations, "Transportation", Parts 173 through 178.

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