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Commercial Experience with Facility Deactivation to Safe Storage

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Commercial Experience with Facility Deactivation to Safe Storage

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Abstract

The Department of Energy (DOE) has shutdown many production reactors; the Department has begun a major effort to also shutdown a wide variety of other nuclear facilities. Because so many facilities are being closed, it is necessary to place many of them into a safe-storage status, i.e., deactivation, before conducting decommissioning - for perhaps as long as 20 years. The challenge is to achieve this safe-storage condition in a cost-effective manner while remaining in compliance with applicable regulations. The DOE Office of Environmental Management, Office of Transition and Management, commissioned a lessons-learned study of commercial experience with safe storage and decommissioning. Although the majority of the commercial experience has been with reactors, many of the lessons learned presented in this document can provide insight into transitioning challenges that will be faced by the DOE weapons complex.

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Acknowledgments

The authors of this report acknowledge, with appreciation, the information provided by the commercial nuclear plants visited during the construction of this report as well as those contacted via fax machine or phone. All plants contacted were very open and willing to share information. A special thanks is given to all those individuals who were so generous with their time, most of which are listed below. This document was greatly enhanced by conversations with and materials received from these individuals. We have attempted, as accurately as possible, to present commercial nuclear facilities' experiences with deactivation. However, the information documented here reflects the authors' understanding of, and, in some cases, interpretation of discussions with knowledgeable personnel and materials reviewed. For this, we accept full responsibility.

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Preface

One of the more difficult discussions during the development of this document centered around how to best present the information collected on the various commercial nuclear facilities. Even though we agreed on the ten categories of information format, delineating firm boundaries between these categories was a point of considerable contention. Since the purpose of the ten categories was to place information into a format that individuals interested in a particular topic could easily find, we decided to accept the fact that redundancy was going to occur, i.e., that some information was going to appear in more than one place. We apologize to those readers who have to bear the somewhat annoying repetition of information however, in terms of the overall goal of the document, it was unavoidable.

Another point of contention was whether the lessons learned should be defined strictly as those lessons learned by a facility through implementation of a policy, technology, etc. A number of the facilities had not yet gotten to the point where they had implemented much of anything. However, they had spent a great deal of time and effort discussing and developing how they were going to proceed with their activities. We finally agreed that even though these are not strictly lessons learned, they have value, at the very least they provide insight and ideas for others faced with similar problems.

Summary

The Department of Energy (DOE) defense complex consists of numerous sites and facilities located in 32 states that have been part of the nuclear material production complex for almost fifty years. Many of these facilities have been permanently closed, and others are targeted for closure over the next two decades. Many of these facilities have been engaged in hazardous materials processing or testing since the 1940s and 1950s, resulting in a technical and economic challenge for environmental cleanup.

Congress has given the DOE Office of Environmental Management (EM) the responsibility to address the environmental challenges posed by the shutdown of numerous DOE facilities. Because of the number of facilities being closed, it is necessary to put many of them into a safe-storage status - before conducting decommissioning - for perhaps as long as 20 years. The challenge is to achieve this safe-storage condition in a cost-effective manner, while remaining in compliance with applicable regulations.

Transitioning facilities to a safe-storage condition brings up many difficult questions, such as whether to perform decontamination now (with the help of an experienced work force), how well the facility's present status must be characterized, what facility systems must remain operational, what existing and new hazards are to be protected against during prolonged safe storage, what kind and what extent of surveillance is required, how the downsizing of the work force is dealt with, and how the facility responds to stakeholders' concerns.

The commercial nuclear industry also has been struggling with similar questions, and the DOE-EM Office of Facility and Material Stabilization (previously the Office of Facility Transition and Management) tasked Sandia National Laboratories and Los Alamos National Laboratory with reviewing and documenting commercial experience with safe storage and decommissioning. Visits by project members to a number of nuclear facilities, interviews via telephone and fax machine, and reviews of documents were performed to describe general issues from the perspectives of the regulator and the regulated. Although the majority of the commercial experience has been with reactors, many of the lessons learned presented in this document can provide insight into transitioning challenges that will be faced by the DOE weapons complex.

U.S. Nuclear Regulatory Commission and DOE regulations, guidelines, and utility experiences were reviewed to develop an understanding of what is meant by safe-storage (SAFSTOR). The result of this review indicated that safe-storage is more a qualitative definition than a quantitative description. In other words, the "specific" definition that a facility or site uses for its safe storage state is decided (and negotiated) on a site-by-site basis. However, in general SAFSTOR is considered to be an interim period in the lifecycle of a nuclear facility during which the facility is kept in a safe, non-operating, environmentally sound condition that requires minimal surveillance and maintenance. SAFSTOR is viewed by the U.S. Nuclear Regulatory Commission (NRC) and commercial utilities as one phase in the transitional process leading to the eventual decommissioning of a nuclear power plant including decontamination

to levels that permit release for unrestricted use. SAFSTOR provides a means to satisfy the requirements for the protection of the public while minimizing the commitments of time, money, occupational radiation exposure, and waste disposal space.

Study/survey results

The following is a compilation of the results of a study and survey conducted by Sandia and Los Alamos based on interviews conducted at the Fort St. Vrain (FSV), Pathfinder, Rancho Seco, Shoreham, and Trojan nuclear facilities, in addition to document reviews of pertinent activities at the Dresden, Fermi, Humboldt Bay, Shippingport, and Yankee Rowe plants. The results of this study are summarized under 10 categories.

1. Hazard characterization

As is the case for nuclear utilities, it is likely, for DOE facilities as well, that the type and scope of safe-storage and decontamination activities will be determined by the facility hazards. Utilities found that the hazards present at a site must be relatively well characterized before any safe-storage or decontamination activities are implemented. In general, utilities found that characterization activities must be undertaken in an intelligent manner - that is, they concluded there was not enough money or time to be absolutely certain that every nook and cranny had been characterized adequately.

Utilities used unique methods to guide characterization of their sites, many of which may work at DOE sites. An example is the grid and color code system used at the Pathfinder plant, where areas anticipated to be contaminated used a smaller grid (and different color) for sampling those areas that were unlikely to be contaminated. FSV took 35,000 radiological data points and used a bar code system to track this information. Trojan divided characterization into four major areas: environment (roads, ponds, yards, etc.), structures (all on-site buildings), systems, and activated systems. The plant systems area was divided into four categories; known contaminated, potentially contaminated, indeterminate, and clean systems. Each of these categories was characterized differently.

In some instances (i.e., for reactor fission and activation products), the safe-storage period will result in a significant reduction in radiation, contamination levels, and risk associated with future cleanup. There would appear to be less to gain for facilities with transuranics. Utilities found that a key consideration in making a decision to defer decontamination activities until the end of the safe-storage period is the reduction in worker dose. However, this consideration has to be balanced against the loss of knowledgeable plant staff and operable process systems that may not be available in the future.

2. Management/programmatic issues

Utility experience demonstrates the importance of defining a well-established facility endpoint before planning safe-storage or decommissioning activities. A wide variety of activities and

associated technologies are necessary to take a site from its current state to its maintenance in safe-storage. The drivers of the management process are (1) the decision on disposition of the site and (2) the current hazards. This means that it is vital that management of a safe-storage project begin with the end in mind: every system, component, area, etc., must have a description of its safe-store condition established before any activities begin on that system. Equally important is a clear knowledge of the hazards present. One must know where one is and where one is going so that the activities performed are always moving in the right direction.

Once the two endpoints are established - where one is and where one is going - the various paths that can be followed can be explored. Along each path are numerous activities. The task of management is to evaluate and choose the best path (and its associated activities). When evaluating the various safe storage and/or decommissioning activities (and technologies), there are a number of factors to consider: (1) risks to human health and safety (both public and worker); (2) availability and costs; (3) potential to cause environmental damage; (4) concerns of stakeholders; (5) regulatory issues; (6) effectiveness of the technology in performance of safe-storage tasks; (7) interactions and integration between technologies and other activities performed at the sites; and (8) recycle and reuse opportunities. All of these factors were addressed by the commercial nuclear facilities; however, the scope of preparing their facilities for safe storage is much smaller than that of DOE facilities.

The primary drivers leading to utility decisions to go to SAFSTOR are (1) the lack of set-aside funding for immediate decommissioning and (2) the lack of a high-level waste (HLW) repository for spent fuel. Potential DOE drivers are (1) limitations in methodologies to prioritize facilities for decommissioning and (2) insufficient funding to clean up the entire complex at once. Risk-based decision models are being developed to assist with the facility prioritization process, however they face a number of challenges. Major problem areas for risk-based models include keeping up with constantly changing and increasing numbers of regulations and specifications and how to prioritize across multiple sites located in different states.

3. Requirements and regulatory issues

Numerous regulatory requirements, standards, and guidance prescribed by the NRC, the Department of Transportation, the Environmental Protection Agency (EPA), the U.S. Occupational Safety and Health Administration and the states must be observed. Utility experience has shown the importance of being very proactive with regulators and involving them in the planning and decision-making process. Cost-benefit studies have been successful in negotiations with state regulators.

Site and material release levels have not been determined, but draft rules have been developed by a joint NRC/DOE/EPA task force working on the site release criteria for sites licensed by the NRC. The EPA is expected to establish similar site release rules for DOE sites within the next two years. During the period of this study, there was no lower "limit" for acceptable

radioactivity levels. At commercial plants undergoing preparation for safe storage or decommissioning, it was important to develop an acceptable methodology that would receive regulatory acceptance because the dismantlement/decontamination approach selected would not result in a "bare walls" plant after completion of physical decommissioning. SAFSTOR radiological endpoints appear to be determined by each utility on a site-by-site basis.

Utility experience suggests that it is advantageous to revise the facility Safety Assessment Report (SAR), Operational Safety Requirements (OSR's), Technical Specification (tech spec) Requirements, etc., to be consistent with the revised status of the facility as soon as possible after shutdown. Considerable cost savings are possible through reduced training, maintenance, and surveillance efforts and the associated reduced staffing requirements.

4. Transitioning facility risk issues

Utilities felt that there were no significant radiological risks to surveillance and maintenance personnel during SAFSTOR. Because of the reduction or elimination of preventive maintenance, however, risks from degradation of equipment and facilities over time are of concern. Some utilities chose to maintain containment ventilation to prevent the buildup of molds and fungi to avoid future health risks that might increase if things were welded shut. The only safety-related equipment kept operational at most nuclear plants was that associated with operation of the spent fuel pool. Utilities stressed the importance of evaluating the potential hazard implications of removing a system from service before deactivating it. In general, potential accidents evaluated during the SAFSTOR period have a low probability, are few in number, and are of minor consequence in comparison with accidents associated with operations.

The Trojan plant used a decision-analysis approach to prioritize decommissioning alternatives. The prototype model performed a high-level economic analysis focused on timing, prioritizing decommissioning activities, and understanding risks, including transportation risks, and uncertainties associated with decommissioning. Alternative approaches were evaluated considering waste costs, timing of component removal, and radiation levels.

For many of the DOE facilities shut down for long periods of time, there is likely to be significant degradation of the physical plant, which may need to be upgraded to achieve SAFSTOR. Utility experience indicates that most accidents occurring during SAFSTOR and decommissioning are normal, industrial-type accidents. FSV performed a probabilistic risk assessment for both nuclear and non-nuclear hazards. The main hazards identified included fires, tornadoes, and industrial-type accidents. Fire was the most threatening potential accident with respect to radiological releases to workers and to the public. It was also more likely to occur. Overall, at FSV, if a potential accident scenario had a likelihood of occurrence of less than 1 in 10,000/yr, it was ignored. However, if its likelihood was greater than 1 in 1,000/yr, mitigative actions were taken to reduce its likelihood. Unfortunately, there are numerous unique radiological hazards at many of the DOE facilities which means that it is likely that they will have to be addressed on a facility-by-facility basis.

5. *Cost increases and uncertainty*

Every utility contacted felt that prompt decontamination and dismantlement was the least costly option, provided that adequate funding and low-level and high-level waste repositories were available. Lacking sufficient funding and/or the availability of waste repositories, SAFSTOR was the only feasible option. Utilities recognized that there was risk associated with SAFSTOR, including the loss of knowledgeable plant workers, uncertainty regarding future risks of the SAFSTOR process (such as an increasingly complex regulatory environment and public attitude), probable increases in low-level waste (LLW) disposal costs, continuing long-term liability, and the cost of plant insurance, surveillance, and maintenance. The utilities anticipated some cost-savings as a result of the decay of fission and activation products during SAFSTOR, however this will not be the case for facilities contaminated with long-lived transuranics (TRU).

For utilities, LLW disposal costs represent the major portion of - and uncertainty in - projected decommissioning costs. Historically, costs for LLW disposal have risen at a higher rate than inflation. At Rancho Seco, original LLW costs were \$1.00/ft³, and 1993 estimates exceed \$440/ft³ at a LLW facility planned at Ward Valley, assuming a 1996 opening (which is unlikely to happen). Based on an estimated 7,300 yd³ of LLW, the Sacramento Municipal Utility District (SMUD), owner and operator of the Rancho Seco plant, estimates about \$100 million for LLW disposal costs and recognizes that costs might go higher. To address the uncertainties associated with LLW storage, SMUD constructed a \$5-million LLW storage building in case Ward Valley does not open or is delayed. In addition, with the new open environment, stakeholders are more likely to object to new LLW repositories. To further reduce SAFSTOR costs, SMUD is planning to build an onsite Independent Spent Fuel Storage Installation (ISFSI), which SMUD estimates will cost \$16 million to build, with operating costs of about \$2.6 million/yr, as compared with \$10.6 million to keep the spent fuel pool operating. The major cost savings will be in reducing operating and maintenance personnel.

In addition to LLW internment costs are the shipping costs which are sensitive to fuel-cost changes and distance to the disposal facility. Removal costs depend on the amount of remotely operated equipment available in the future when dismantling occurs and the higher costs of that equipment versus the savings in labor costs. All this leads to the statement that the availability of inexpensive LLW storage is vital to cost-effective decommissioning.

6. *Stakeholder concerns*

In contrast to the near total lack of stakeholder interest expressed after utilities shut down nuclear plants, the DOE has experienced considerable continuing stakeholder interest at nearly all of its sites. Utility experience suggests that having an effective program for involving and sharing information with stakeholders, the local community, and government officials is an important part of a smooth transitioning process. This allows a facility to anticipate stakeholder reactions and plan for contingencies. An example of this philosophy, which was used by FSV, is illustrated by the removal of the spent fuel from FSV. The utility intended to begin defueling

and shipment of the fuel to the Idaho National Engineering Laboratory in early 1991. Idaho Gov. Cecil Andrus strenuously objected, however, and a series of legal maneuvers ensued. The fuel was scheduled to be removed and shipped to permit the start of decommissioning in January 1992, these complications delayed that schedule. The utility had foreseen this possibility, however, and had moved ahead with construction of an ISFSI, which subsequently was used to store the spent fuel.

Programs that have been effective for the utilities have many good ideas for sharing information with the public. At several of the plants, local community groups, including children, are invited to visit the site. Senior plant personnel attend meetings in the community and answer questions about what was being done and planned at the plant. Quarterly news fliers were sent out to the local community to share plant information, discussions included what work was currently in progress and what had been done. Communications with the nuclear community - local, society, industrial, and environmental groups - also occurred.

In addition to creating and maintaining a trusting relationship with the public, there is also a need to create a good working relationship with appropriate regulatory bodies. The success of decommissioning activities at utilities was significantly assisted by a good working relationship with regulators.

7. Waste minimization

The lack of availability of waste disposal sites and the variable, but generally high, disposal costs provide a strong motivation to utilities to minimize generation of radiologically contaminated waste. The high waste disposal costs provide incentive to the utilities to compact waste, decontaminate equipment, or recycle, if possible. Waste minimization procedures used by utilities included compaction, smelting, reuse, and free-release (if it was cost-effective). Additional cost savings were obtained by preplanning loading and unloading and using self-shielding for packaging.

Waste disposal operations are highly sensitive to changes in regulation, as was noted by the Shippingport plant, and are the area of decommissioning most likely to be affected by public opinion. Both the DOE and the utilities have a common political problem with the treatment and disposal of mixed wastes. The utilities have made the identification and minimization of mixed wastes a high priority item in their SAFSTOR activities.

8. Industry involvement

All utilities appear to use the services of experienced engineering contractors to perform or independently validate cost estimates for decommissioning activities. In addition, contractor assistance often is used for radioactive waste (radwaste) management, to provide decommissioning expertise, and to provide additional radiation protection and health physics support. Many utilities plan to use specialty consultants and contractors to assist in document preparation, spot decontamination, waste packaging, and disposal services. The utilities'

experience seems to be most similar to the DOE Environmental Restoration Management Contractor (ERMC) approach.

If the types of technologies available in private industry are known, contact can be made with the company and a demonstration of that technology given to determine the applicability, reliability, and safety associated with that technology. Technologies under development (by the DOE or other organizations) that can be adapted for commercial use, present an excellent opportunity for joint work agreements between the organization and private industry.

Utilities found that sharing experiences among facilities undergoing deactivation appeared to be worthwhile. The establishment of and participation in decommissioning support groups [e.g., Energy Facilities Contractors Group (EFCOG)] where similar facilities undergoing decommissioning can share experiences, lessons learned, etc., may be helpful.

9. Recycle and reuse opportunities

Commercial utility salvage efforts to date suggest that, in general, salvage sales and asset recovery programs have demonstrated limited potential to provide a significant income. The primary savings often appears to be in the avoidance of disposal costs, which has the potential to save a fair amount of money. Some major components can be decontaminated and disposed of by a waste recovery vendor. In some cases, a large percentage of the metallic inventory can be sent to a waste recovery vendor and decontaminated to levels permitting unrestricted use at a significant cost savings. Even though the scrap values may be low, they offset the associated removal and reprocessing costs.

Another valuable suggestion from the commercial nuclear industry is to look for reuse opportunities for buildings and equipment at a site. Portland General Electric, owner and operator of the Trojan plant, reduced the number of occupied buildings at the plant site from five to one and is looking at other uses for the buildings. Potential uses include a vocational technical school or an environmental monitoring and training center.

Some avenues available to private utilities are not really feasible options for government organizations such as the DOE; e.g., utilities can donate equipment or facilities to educational/charitable institutions and receive a tax deduction. However, to reduce/eliminate remediation costs, selling or paying a third party to take ownership of a facility, thereby eliminating SAFSTOR or decommissioning remediation costs may be a viable option.

In a similar manner, organizations may be able to "reuse" facilities and onsite equipment for applications in the commercial sector. In many instances, government organizations at a site have a commitment to make every effort to maintain the local economy and provide jobs as their facility transitions.

10. *Technology development*

Existing safe storage and decommissioning techniques appear to be sufficient to meet the needs of the commercial nuclear industry. The Trojan management felt that the technology is at hand to cut up and remove large components and decontaminate components and structures. Northern States Power viewed decommissioning as a high volume of low-technology work. Decontamination and disassembly techniques being used by the Long Island Power Authority at Shoreham are consistent with those used routinely throughout the nuclear industry (*in situ* chemical decontamination, ultra-high-pressure water lancing, abrasive grit blasting, conventional cutting tools, diamond wire saw cutting, under water plasm-arc, and metal-disintegration machining equipment). However, the minimization and stabilization of mixed wastes is an area that needs additional technology development.

Lessons learned

Lessons learned and results of the survey of commercial nuclear plant transitioning experiences can be used to provide insight into ways that the DOE can deactivate facilities to achieve a designated safe-storage state in a timely, cost-effective manner, while still providing minimal risk to health and safety. It is important, however, not to be limited to the suggestions discussed here. Individuals struggling with issues in the environmental remediation environment may develop other valuable suggestions from the information provided.

Nomenclature

A/C	architect/contractor
A/E	architect/engineer
AEC	U.S. Atomic Energy Commission
AIF/NESP-036	Atomic Industrial Forum/National Environmental Studies Project (report number)
ALARA	as low as reasonably achievable
ANS	American Nuclear Society
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
BN	Burlington Northern Railroad
BOP	balance of plant
BRC	below regulatory concern
BWR	Boiling Water Reactor
CAA	Clean Air Act, as Amended
CECo	Commonwealth Edison Company
CEQ	Council on Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as Amended
CFR	Code of Federal Regulations
CPI	consumer price index
CPUC	Colorado Public Utilities Commission
CRADA	cooperative research and development agreement
CRBRP	Clinch River Breeder Reactor Plant
CWA	Clean Water Act, as Amended
D&D	decontamination and decommissioning
DLC	Duquesne Light Company
DNFSB	Defense Nuclear Facilities Safety Board
DOC	decommissioning operations contractor
DoD	US Department of Defense
DOE	US Department of Energy
DOT	US Department of Transportation
DSAR	Defueled Safety Analysis Report
EA	Environmental Assessment
EBR-I	Experimental Breeder Reactor-I
EFCOG	Energy Facilities Contractors Group
EM	DOE Office of Environmental Restoration and Waste Management
EM-60	DOE Office of Facility Transition and Management
EP	environmental protection
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
ER	Environmental Report
ERDA	Energy Research and Development Administration

ERMC	Environmental Restoration Management Contractor
ESG	Energy Services Group
FFA	Federal Facilities Amendments
FFCA	Federal Facilities Compliance Act
FFTF	Fast Flux Test Facility
FRA	Federal Railroad Administration
FSAR	Final Safety Analysis Report
FSV	Fort St. Vrain Nuclear Generating Station
GAO	Government Accounting Office
GE	General Electric
GEIS	Generic Environmental Impact Statement
GET	General Environmental Training
HBPP	Humboldt Bay Power Plant
HEPA	high-efficiency particulate air (filter type)
HLW	high-level waste
HTGR	High Temperature Gas-Cooled Reactor
HVAC	heating, ventilation, and air conditioning
ICPP	Idaho Chemical Processing Plant
ICRP	International Commission on Radiological Protection
IMTS	Improved Mobile Telephone Service
INEL	Idaho National Engineering Laboratory
INPO	Institute of Nuclear Power Operations
IPP	Independent Power Producer
IRP	Independent Review Panel
ISFSI	Independent Spent-Fuel Storage Installation
LANL	Los Alamos National Laboratories
LGR-HTGR	large graphic reactor-high temperature gas reactor
LILCO	Long Island Lighting Company
LIPA	Long Island Power Authority
LIS	Licensing Information Services
LL	low-level
LLW	low-level waste
LMFBR	liquid metal fast breeder reactor
LMGMR	liquid metal graphite moderated reactor
LSA	low specific activity
LWBR	light water breeder reactor
M&O	maintenance and operations
MOV	motor operated valve
NEA/OECD	Nuclear Energy Agency/Organization for Economic Cooperation and Development
NECO	Nuclear Engineering Company
NEPA	National Environmental Policy Act
NPL	National Priorities List
NQA	Nuclear Quality Assurance

NR	Naval Reactors
NRC	U.S. Nuclear Regulatory Commission
NSP	Northern States Power Company
NSSS	Nuclear Steam Supply System
NUMARC	Nuclear Management and Resource Council
NYPA	New York Power Authority
OCC	Office of Consumer Counsel
OPS	operations
OSHA	Occupational Safety and Health Administration
OSR	Operational Safety Requirements
P&ID	piping and instrument drawing
PCB	polychlorinated biphenyls
PCI	Power Cutting, Inc.
PCRV	prestressed concrete reactor vessel
PDP	Proposed Decommissioning Plan
PG&E	Pacific Gas and Electric Company
PGE	Portland General Electric
PNL	Pacific Northwest National Laboratory
POL	Possession Only License
PPG	Public Policy Group
PR	public relations
PRA	Probabilistic Risk Assessment
PRDA	Program R&D Announcement
PRDC	Power Reactor Development Company
PSC	Public Service Company of Colorado and Public Service Commission of New York
PSO	Program Secretarial Office
PWR	pressurized water reactor (also PWR/LWBR)
QA	Quality Assurance
radwaste	radioactive waste
RCRA	Resource Conservation and Recovery Act of 1976, as Amended
RF	radio frequency
RG	Regulatory Guide (1.86)
RP	Reactor Protection
RPM	Radiation and Process Monitor
RPV/NST	reactor pressure vessel/
RWST	Refueling Water Storage Tank
SAR	Safety Assessment Report
SCO	Shipping Coordinator's Office
SDWA	Safe Drinking Water Act, as Amended
SEG	Scientific Ecology Group (Westinghouse)
SMUD	Sacramento Municipal Utility District
SNL	Sandia National Laboratories
SNMs	Strategic Nuclear Materials

SRC	Site Review Committee
SRP	Savannah River Plant
SSDPO	Shippingport Station Decommissioning Project Office
TAG	Technical Advisory Group
tech specs	technical specifications
TLG	Tom LaGuardia (Engineering)
TMI	Three Mile Island
TRANSCOM	DOE Transportation and Communications
TRU	Trans-Uranic Wastes
TSC	Technical Support Coordinator
TSCA	Toxic Substances Control Act, as Amended
TSR	Technical Safety Requirements
TVA	Tennessee Valley Authority
WHC	Westinghouse Hanford Corporation
YAEC	Yankee Atomic Electric Company
YNPS	Yankee Rowe Nuclear Power Station

1.0 INTRODUCTION

The Department of Energy (DOE) defense complex consists of numerous sites and facilities located in 32 states that have part of the nuclear material production complex for almost fifty years. Many of these facilities have permanently closed, and many others are targeted for closure over the next two decades. Many of these facilities have been engaged in hazardous materials processing or testing since the 1940s and 1950s, resulting in a technical and economic challenge for environmental cleanup.

The DOE Office of Environmental Management (previously Restoration and Waste Management) has been tasked by Congress with the responsibility for environmental remediation at the DOE facilities. Many of these facilities are facing situations similar to those that shut down commercial nuclear power plants have experienced for many years, i.e., how to deactivate facilities, place them in safe storage and, finally, decommission them in a safe, cost effective manner while remaining in compliance with applicable regulations. The DOE Office of Material and Facility Stabilization (previously Facility Transition and Management) assigned Sandia National Laboratories (SNL) and Los Alamos National Laboratory (LANL) to review and document these commercial experiences.

For a typical facility, there are several phases in facility life, i.e.: design, construction, and startup; operations; standby; deactivation to and maintenance and surveillance in safe storage, and finally, decommissioning. The main focus of this report is the movement of a site or facility to a stable, controlled safe-storage state, called SAFSTOR by the commercial nuclear industry. For commercial nuclear plants, the deactivation of a facility significantly decreases operating expenses, and as discussed later, significant cost savings can be achieved in a very short time by transitioning quickly to SAFSTOR.

The objective for this project is discussed in detail in Section 1.1. Various definitions and discussions of what is meant by *the safe storage state* are presented in Section 1.2. In Section 1.3, the technical approach is discussed as well as the following tasks: (1) selecting the nuclear facilities from which to solicit information regarding safe storage, i.e., deactivation activities, (2) identifying topics of interest to DOE sites and facilities that will be deactivated to or prepared for a safe storage state, and (3) developing a questionnaire used during the site visits to focus interviews and discussions. The specific questions were based on issues identified for the 10 selected topic areas. Section 1.4 discusses the sources of information (i.e., the documents reviewed).

Section 2.0 contains a brief history of the ten commercial nuclear facilities from which information was solicited. Section 3.0 summarizes the results of the on-site interviews and document reviews. In section 4.0 the results and lessons learned discussed in section 3.0 are related to the DOE environment and used to make suggestions for ways that the DOE can deactivate facilities to achieve a designated *safe storage* state in a timely, cost-effective manner while still providing minimal risk to health and safety. References are contained in section 5.0. Appendix A summarizes the results of the on-site interviews at the Trojan, Fort St. Vrain,

Rancho Seco, Shoreham, and Pathfinder nuclear facilities as well as document reviews of pertinent activities conducted at the Dresden, Fermi, Shippingport, Humboldt Bay, and Yankee Rowe plants. Appendix B contains a list of applicable regulations, regulatory guidance and industry standards compiled by the Fort St. Vrain Nuclear Generating Station.

1.1 Objective

The objective of this project was to review and document commercial experience with nuclear facility deactivation and the safe storage period, decommissioning and to suggest areas where commercial experience may apply to DOE programs. Visits by project members to a number of nuclear facilities, interviews via phone and fax machine, and reviews of documents were done to describe the following general issues from the perspective of the regulator and the regulated:

- events and conditions leading to decisions to place a facility in transition to shutdown and remediation;
- the effect of strategies developed concerning reducing regulatory issues, technical oversight, operational costs, and other factors;
- the logic used to transition operations and regulatory documents such as technical specifications from an operating to a safe-storage (SAFSTOR) condition;
- regulatory issues affecting transition strategies;
- stakeholder concerns and strategies for dealing with these concerns; and
- lessons learned about how similar ventures would now be conducted.

The information collected was used to identify areas in which parallels to DOE programs in deactivation to SAFSTOR and final decommissioning can be drawn. Additional discussions focused on identifying potential regulatory concerns and *transition points* at which regulatory compliance requirements shift from one phase of facility life, such as operations, to another phase, such as deactivation to SAFSTOR.

All information gathered as interviews or document reviews is documented in this report. Parallels in logic employed by the different utilities have also been documented to identify common or generic planning and engineering steps applicable to transition activities.

1.2 SAFSTOR Definitions

This report is primarily concerned with the transitioning, or deactivation as it is called in the commercial industry, of facilities from an operating state to a SAFSTOR condition. The following sections review differing regulations and definitions of SAFSTOR and deactivation as defined by the U.S. Nuclear Regulatory Commission (NRC), the Nuclear Management and Resource Council (NUMARC) process for decommissioning prematurely shutdown plants, deactivation processes used to achieve SAFSTOR, and draft DOE facility transition guidance.

As will be seen by the various definitions and discussions of what is meant by the safe-storage state, safe storage is more a qualitative definition than a quantitative description. In other words, the "specific" definition that a facility or site uses for its safe-storage state is decided (and negotiated) on a site-by-site basis. For commercial nuclear power plants, the SAFSTOR state depends on the site (i.e., single or multiple units), the availability of decommissioning funds, the availability of low-level and high-level waste repositories, and the cost of decommissioning.

1.2.1 Description of SAFSTOR Process

NUREG-0586, Final Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities, August 1988, discusses alternatives (in addition to the No Action alternative) that can be selected for decommissioning a nuclear power plant. SAFSTOR is defined as a period of protective storage in the life cycle of a nuclear facility during which the facility is maintained in a *safe, non-operating, environmentally sound condition that requires minimal surveillance and maintenance*. SAFSTOR is considered by the NRC and commercial utilities as one phase in the transition process leading to the eventual decommissioning of a nuclear power plant. SAFSTOR consists of a brief period of preparation for safe storage, followed by the safe storage period during which security, surveillance, and maintenance activities at the facility are conducted.

SAFSTOR can last for as long as 60 years after final shutdown, after which the nuclear facility passes into the next phase of its life cycle, decommissioning (DECON), or the reduction of residual radioactivity at the facility to the point at which the facility can be released for unrestricted use.

The following are the three categories of the SAFSTOR alternative, as defined by the NRC:

- *Custodial SAFSTOR* requires a minimum of cleanup and decontamination effort initially, followed by a period of continuing care with the active protection systems (primarily ventilation) kept in service throughout the storage period. Full-time, on-site surveillance by operating and security forces is required to carry out radiation monitoring, to maintain the equipment, and to prevent accidental or deliberate intrusion into the facility with subsequent exposure to radiation or dispersal of radioactivity beyond the confines of the facility.
- *Passive SAFSTOR* requires a more comprehensive cleanup and decontamination effort initially, sufficient to permit deactivation of the active protective (ventilation) system during the continuing care period. The structures are strongly secured, and electronic surveillance is provided to detect accidental or deliberate intrusion. Periodic monitoring and maintenance of the integrity of the structures are required.
- *Hardened SAFSTOR* requires comprehensive cleanup and decontamination and the construction of barriers around areas containing significant quantities of radioactivity.

These barriers are of sufficient strength to make accidental intrusion impossible and deliberate intrusion extremely difficult. Surveillance requirements are limited to detection of attack upon the barriers, maintenance of the integrity of the structures, and infrequent monitoring.

SAFSTOR is not an "endstate" - all three SAFSTOR options require decommissioning of the facility at the conclusion of the SAFSTOR period so that the property can be released for unrestricted use.

During the interim between nuclear facility shutdown and decommissioning, SAFSTOR provides an option for protecting the public from radiation exposures while decreasing the resources required for security, surveillance, and maintenance during the storage period compared to the requirements for an operational nuclear power plant. It also reduces the resources that would have to be committed initially if a nuclear facility were to be decontaminated and decommissioned immediately after shutdown and defers the need for nuclear waste disposal facilities. Disadvantages of SAFSTOR are that personnel familiar with a facility may not be available when it is finally decommissioned; the site is unavailable for other uses until decommissioning activities are complete; uncertainty exists with respect to new decommissioning regulations that may be imposed at a later date; and there is a continuing requirement for security, surveillance and maintenance.

1.2.2 Normal Commercial Reactor Decommissioning Submittal Process

U.S. NRC Regulatory Guide 1.86, Termination of Operating Licenses for Nuclear Reactors, provides regulatory guidance to help licensees address the requirements of 10 CFR 50.82, Applications for Termination of Licenses. The Regulatory Guide specifies the requirements that must be satisfied to terminate an operating license, including the requirement that the dismantlement of the facility and disposal of the component parts not be inimical to the common defense and security or to public health and safety.

NRC Draft Regulatory Guide DG-1005, Standard Format and Content for Decommissioning Plans for Nuclear Reactors, identifies the information needed and a format acceptable to the NRC staff for preparing and submitting a Decommissioning Plan. 10 CFR 50.75(f) requires a licensee at (or about 5 years prior to) the projected end of operation to submit a preliminary Decommissioning Plan containing a cost estimate for decommissioning and an up-to-date assessment of the major technical factors that could affect planning for decommissioning. These factors include:

- the decommissioning alternative,
- major technical actions necessary to carry out decommissioning safely,
- the current situation with regard to disposal of high- and low-level radioactive waste, and
- residual radioactivity criteria, and other site-specific factors that could affect decommissioning planning and cost.

For SAFSTOR, the NRC Draft Regulatory Guide DG-1005 indicates that the Decommissioning Plan must contain (1) details for preparing the facility for SAFSTOR, (2) plans for monitoring and surveillance during SAFSTOR, (3) plans for completing decommissioning, and (4) plans to ensure that funds for maintaining the facility in SAFSTOR and completion of decommissioning are available. The major sections of the Decommissioning Plan are as follows:

1. Summary
2. Choice of Decommissioning Alternative and Description of Activities Involved
 - 2.1 Decommissioning Alternative
 - 2.2 Decommissioning Activities, Tasks, and Schedules
 - 2.3 Decommissioning Organization and Responsibilities
 - 2.4 Training Program
 - 2.5 Contractor Assistance
3. Protection of Occupational and Public Health and Safety
 - 3.1 Facility Radiological History and Status
 - 3.2 Radiation Protection - As Low As Reasonably Achievable (ALARA) and Health Physics Program
 - 3.3 Radioactive Waste Management - Processing and Disposal
 - 3.4 Accident Analysis
4. Proposed Final Radiation Survey Plan
5. Updated Cost Estimate for Decommissioning Method Chosen
6. Technical and Environmental Specifications in Place During Decommissioning
7. Quality Assurance Provisions in Place During Decommissioning
8. Physical Security Plan Provisions in Place During Decommissioning

The first step that a licensee undertakes in the decommissioning process is to request a Possession Only License (POL). With this license, no reactor operation is permitted. NRC Regulatory Guide 1.86 requires appropriate administrative controls and facility requirements (i.e., those controls and requirements imposed by Part 50 and technical specifications, i.e., Tech Specs) to assure that proper surveillance is performed and that the reactor facility is maintained in a safe condition and not operated.

The request to obtain a POL must include the following information:

- a description of the current status of the facility,
- a description of measures to be taken to prevent criticality or reactivity changes and to minimize releases of radioactivity from the facility,
- proposed changes to the technical specifications that reflect the POL facility status and the necessary disassembly/retirement activities,
- a safety analysis of both the activities to be accomplished and the proposed changes to the technical specifications, and
- an inventory of activated materials and their location in the facility.

1.2.3 SAFSTOR for Prematurely Shutdown Nuclear Plants

The November 1992 NUMARC Final Report, "Regulatory Process for Decommissioning Prematurely Shutdown Plants," discusses the regulations applicable to a nuclear plant as it proceeds from termination of operations through issuance of a POL. The study focused on plants that have shut down prematurely and hence did not have an NRC-approved Decommissioning Plan. Obtaining a POL and placing the plant in a type of SAFSTOR condition allows time for more detailed planning and submittal of a Decommissioning Plan to the NRC. To minimize the cost of a shut down before the end of its life cycle, the utility must act quickly to reduce the number and scope of regulatory programs that are no longer applicable or needed to protect the health and safety of the public.

The NUMARC study indicates that after initial plant closure and before POL approval, the licensee can continue to conduct all the equipment shutdown, removal, disposal, and other activities that the operating license would allow. Systems no longer needed to maintain plant safety in its permanently shutdown and defueled condition can be removed from service. These systems do not have to be maintained or preserved unless there is some possible future use for them.

National Environmental Policy Act (NEPA) regulations prevent the licensee from doing anything to the permanently shutdown plant that would preclude any of the decommissioning options and from doing or not doing anything that may substantially increase the cost of decommissioning.

NUMARC suggests that the facility transition plan include doing the following:

1. Apply for a POL. With a POL the licensee can substantially reduce the regulatory programs applicable to the plant.
2. Request regulatory relief on those programs/requirements that continue to apply and can be reduced for a permanently shutdown plant (i.e., emergency plan, security plan, operator training, etc.).
3. Minimize credible radiological accident and sabotage scenarios.
4. Apply for approval of revised Technical Specifications consistent with the defueled mode.
5. Submit a revised safety analysis consistent with the defueled mode and hazards in the facility.
6. Propose an operator training program consistent with activities to be performed during deactivation.
7. Determine the need for maintaining operable systems and components consistent with the shutdown of the reactor and consistent with technical specifications (see 4).
8. Revise and submit scaled-down versions of the emergency plan, the security plan, the operator training program, the radiological environmental monitoring program, and the fire protection plans.

9. Request 10 CFR exemptions as appropriate (Price Anderson, Insurance, Inservice Inspection, Appendix J, etc.).
10. Re-evaluate the requirements for the Quality Assurance (QA) plan.

NUMARC emphasizes the importance of securing a POL as soon as possible to reduce costs.

1.2.4 Deactivation Activities Required to Achieve SAFSTOR

Deactivation is viewed as that group of activities undertaken to transfer the facility from a standby or operational state to SAFSTOR. Historically, deactivation activities appear to be facility dependent because no specific criteria (i.e., radiological criteria) define SAFSTOR or exist for it.

ANSI/ANS-15.10-1981, Decommissioning of Research Reactors, defines SAFSTOR as a means to fix and maintain a facility so that the risk to safety is acceptable for the period of storage followed by decontamination or decay, or both, to an unrestricted level. SAFSTOR includes the following:

- performance of a comprehensive plant radiation survey,
- removal from the facility of all fuel assemblies,
- removal from the facility of radioactive fluids and wastes,
- removal or stabilization of contamination in accessible areas,
- operation of all required life-support and protection systems, such as heating, ventilation, and air conditioning (HVAC), radiation monitoring, fire protection, and environmental monitoring systems, as appropriate,
- deactivation of nonrequired systems,
- isolation and sealing of the remaining radioactive areas, and
- performance of routine security, maintenance, and surveillance.

The ANSI Standard indicates that the duration of the SAFSTOR alternative depends on several factors, including the structural condition of the facility, the lifetime of the residual reactivity, the future cost of the facility or site, or both and the cost of the security/maintenance/surveillance program. Radiological surveys are to be performed at intervals not to exceed 4 months. Personnel monitoring requirements may be relaxed when expected doses are less than 25% of the applicable values specified in 10 CFR, Part 20.101.

The NEA/OECD, "Decommissioning of Nuclear Facilities," report describes three possible decommissioning stages. Stage 1 Decommissioning is SAFSTOR. For reactors, the first contamination barrier is kept as it was during operation, but the mechanical opening systems are blocked and sealed (i.e., the valves, plugs, etc.). The containment building is kept in a state appropriate to the remaining hazards. The atmosphere inside the containment building is controlled for such factors as humidity and radioactivity. Access to the inside of the containment building is controlled, and personnel entering and exiting the containment area are monitored for radioactivity. For fuel-cycle facilities, some of the mechanical operating systems

may be retained for use during decontamination work. The plant is kept under surveillance. Equipment necessary for monitoring radioactivity, both inside the plant and in the area around the plant, is kept in good condition and used when necessary and in accordance with regulatory requirements. Routine inspections are carried out to assure that the plant remains in good condition.

The following paragraphs discuss guidelines established by or for DOE facilities and sites. Westinghouse/Hanford established the following guidelines for deactivation to facilitate transition planning:

1. Conduct removal and recovery, disposal, and/or redistribution of nuclear material, essential materials, supplies, and government-owned property that can be accomplished economically without major demolition.
2. Establish a safe, environmentally sound, and low-cost configuration in which the facility can be maintained. The configuration shall comply with applicable DOE Orders, policies, and regulatory requirements. Capabilities with potential application to decommissioning activities and for response to unforeseen events must also be maintained.
3. Develop and retain documentation of the plant operating history and configuration at the conclusion of deactivation for use in decommissioning planning.

Deactivation included the following tasks:

- planning of deactivation activities,
- removing facility material and equipment inventories,
- establishing the facility surveillance configuration, and
- disposing of facility deactivation and operating records.

The Westinghouse/Hanford document, WHC-SD-CP-AP-005, expands considerably on the above tasks, which are required to take a facility from an operating or standby mode to a SAFSTOR condition.

NRC Regulatory Guide 1.86 indicates that the facility may be left intact in SAFSTOR, except that all fuel assemblies and the radioactive fluids and waste should be removed from the site. Adequate radiation monitoring, environmental surveillance, and appropriate security procedures should be established under a POL to ensure that the health and safety of the public are not endangered. Those radioactive materials remaining on the site must be isolated from the public by physical barriers or other means to prevent public access to hazardous levels of radiation. Surveillance is necessary to assure the long-term integrity of the barriers. The amount of surveillance required depends upon (1) the potential hazard to the health and safety of the public from radioactive material remaining on site and (2) the integrity of the physical barriers.

The July 12, 1995, "Material Stabilization and Facility Deactivation Project Policies and Supplementary Information," delineates decision criteria and specific objectives to be considered in establishing deactivation activities.

The decision criteria indicate the following activities:

1. Eliminate or stabilize environmental safety risks as defined by regulations, NRC codes and standards, and industry practice (RG 1.86).
2. Leave in place equipment, systems, and materials for which an end state has not been defined or is unavailable.
3. Complete activities dependent on plant specific process, operating, and facilities engineering expertise.
4. Complete activities dependent on the functioning of facility-specific equipment that will be inoperable following a 10-year deactivation period.
5. Configure the facility for, and limit access to, quarterly assessment entry.
6. Establish and archive records for reactivating systems essential for decontamination and dismantlement, and previous characterization efforts.
7. Leave facility in an orderly state.

Facility deactivation (i.e., SAFSTOR) is designed to achieve a safe, environmentally sound condition that requires minimal surveillance and maintenance for as long as ten years until decontamination and dismantlement activities occur. Achievement of the objectives listed below will produce insignificant on-site and off-site radiological and environmental risk, retain a minimum of active systems that require surveillance and maintenance, and minimize actual program costs. Deactivation will be planned and performed within an overall framework of potential future use, unless conditions dictate otherwise.

1. Remove or stabilize radioactive source terms to reduce the risk to a low hazard level in accordance with DOE Order 5480.23.
2. Remove strategic nuclear materials (SNMs) to meet less than level Category IV in accordance with DOE Order 5533.3.
3. Remove hazardous and dangerous chemical inventories.
4. Ensure that confinement structures are structurally sound and in good repair to contain radioactive materials and prevent entry of rain or snow melt water.
5. Deactivate, consolidate, or cascade the facility HVAC systems so that only the necessary exhaust systems will remain operational.
6. Control facility access to preclude personnel entry other than that required for quarterly radiation and other surveys.
7. Prevent personnel from utilizing the building and deactivate/clean out all personnel support systems (i.e., offices, ventilation systems, etc.).
8. Remove, to the extent practical, all combustible materials.
9. Deactivate loss prevention systems and all other electrical systems, retaining only those required to ensure the integrity of the confinement structure.

10. Install and monitor systems needed for surveillance until decommissioning activities commence. Monitoring should be done outside the contaminated facility.
11. Flush the internal surfaces of all process and chemical vessels to remove water-soluble chemical and/or radioactive residue.
12. Flush and drain the interior of process and chemical piping to remove water soluble residue.
13. Flush with nitric acid and/or water the external surfaces of canyon vessels and the internal surfaces of cells to remove significant radioactive or chemical residues.
14. Coat, as required to fix contamination and minimize migration, cell floors that have deteriorated and have significant radionuclide retention.
15. Leave in place, as a general rule, canyon vessels, process and utility tanks, piping, and deactivated electrical systems.
16. Remove for other use, as desired, separable capital equipment not in radiologically controlled zones.

1.2.5 DOE Facility Transition - Deactivation to SAFSTOR

As discussed previously, once a decision is made to terminate commercial reactor operations permanently, the owner applies to the NRC for a POL. This request or application requires facility information somewhat similar to that required as part of the EM-60 Acceptance Process (i.e., facility status, hazard inventory, and safety envelope) as summarized below.

DOE Surplus Facilities Management Acceptance Criteria stipulate conditions that must be met before a facility can be formally declared *surplus*. These criteria are summarized as follows:

- The facility shall be in a radiologically safe condition. The structure- and radiation-monitoring systems shall be in such physical condition as to contain and monitor any radioactive contamination. A current radiation contamination survey of the facility and surrounding areas shall be available. Security systems and procedures shall prevent unauthorized entry. All stored SNM, reactor fuels, high-level waste (HLW), contaminated liquid wastes, and hazardous chemicals shall be removed from the facility.
- The deactivation of the facility shall have been documented. Final radiological surveys, final configuration and maintenance surveillance requirements, and drawings, procedures, manuals, and unplanned occurrence records shall be available. A maintenance and surveillance plan, cost estimates, and a final inventory of contaminated material shall be prepared.
- Acceptance requirements must be documented. This includes the latest radiological survey, safety assessments, maintenance and surveillance plan, hazardous chemical survey, existing decommissioning plans, site-use plans, and an explanation of any contractual commitments that could affect future decommissioning.

The EM-60 Final Guide, "Guidance for Facility Transition Process," states that a Program Secretarial Office (PSO) provides both an initial and a final notification of intent to transfer surplus contaminated facilities to EM. Initial notification of an intended facility transfer is given when a PSO submits data for, or updates information in, the Surplus Facility Inventory. Final notification occurs when the donor PSO provides a memorandum to the Assistant Secretary for Environmental Restoration and Waste Management identifying a proposed facility as "surplus and contaminated" and stating the fiscal year for the transfer. In conjunction with the memorandum, facility data should be provided as specified below:

Physical Plant

- *Facility Safety Status* - Status of hazards, including results of the most recent hazard screening, and identification of areas where human entry for inspection work is restricted, routinely avoided or requires special safety precautions, equipment or procedures.
- *Operability* - Actions required to operate facilities to the extent required for clean out.
- *Deactivation* - Assessment of deactivation plans and conceptual alternatives to identify areas where cost effectiveness could be improved.

Material Inventories

- *Radioactive and Hazardous Material Contamination* - Identification of the location, quantity, extent, and type of contamination and plans to stabilize it.
- *Radioactive and Hazardous Materials or Waste Inventory* - Inventory of the hazardous waste present, including radioactive and other hazardous chemicals.
- *SNM Plans* - Plans to identify, remove, or consolidate SNM.

Compliance Status

- *Transition Standards Program*
- *Compliance with DOE Orders*
- *Compliance with Permits*
- *Compliance with Regulatory Requirements* (e.g., Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), Resource Conservation and Recover Act (RCRA), Occupational Safety and Health Act (OSHA), and National Environmental Policy Act (NEPA))
- *Interagency Agreements*
- *Corrective Actions* - List of outstanding corrective actions from previous audits, etc. (Defense Nuclear Facilities Safety Board (DNFSB), Tiger Team).
- *Safety Envelope* - Description of the current safety envelope. Technical safety requirements (TSR) surveillance program. Scope and estimate of work to bring the facility into compliance, with operational safety requirements (OSR's) in effect.

Administrative Planning

- *Manpower Planning* - Personnel skill and expertise inventory mix for those personnel transitioning with the facility, etc.
- *Budget/Planning Schedule*

- *Performance Indicators* - Evaluate to determine areas where additional focused management may be needed.

1.3 Technical Approach

This section describes the technical approach employed to review commercial nuclear power plant deactivation to safestore and decommissioning experiences. To support this effort, several literature searches were performed to gather relevant data on commercial nuclear plant decommissioning experiences. Initially, a limited number of diverse sites from which to solicit information were identified. In addition, other facilities targeted for interviews via phone, fax, document reviews, etc., were identified to increase the information base. Selection criteria were used to identify the facilities to be targeted, the purpose of which was to obtain data meaningful for DOE and to focus the interview process.

To assist with information gathering, 10 major topic areas and associated issues were identified. Finally, a questionnaire was developed based on the 10 topic areas. The questionnaire was used during the site visits to focus interviews and discussions on those subject areas felt to be of most interest to DOE.

1.3.1 Site Selection

The objective of site selection was to ensure that the commercial nuclear facilities selected for this project were those that could provide the most valuable information. Table 1 lists nuclear power plants that are no longer in service and are in various phases of decommissioning. These candidate facilities were screened for inclusion in the report using a selection criteria matrix.

The selection criteria matrix shown in Table 2 was used to identify those facilities that would be visited, deemed inapplicable, or reviewed via documents or phone conversations. A more detailed explanation of the selection criteria follows.

- *Commercial Facility* - The name of the commercial nuclear power plant is listed in this column of the selection criteria matrix.
- *Geographic Location* - This criterion focused on assuring that the sites were from diverse locations across the country, to allow an assessment of how differing state regulations and stakeholder groups affect deactivation activities.
- *Time of Last Operation* - This criterion allowed changes in regulations, especially in recent years, to be assessed.
- *Facility Type/Stand-Alone Facility* - This criterion identified cost factors corresponding to facility economic infrastructures (such as shutdown of an isolated facility versus shutdown of a single facility at an otherwise operating site) and the nuclear plant type.

- *Units on Site* - This criterion identified the number of nuclear reactors at a particular site.
- *Stage of Decontamination and Decommissioning* - This criterion identified the current stage of D&D for the commercial facility. Several stages are considered: (1) ENTOMB - for those facilities that are entombed; (2) REPOWER - for those facilities being repowered; (3) SAFSTOR - SAFSTOR/1 if a facility is just starting deactivation activities, SAFSTOR/2 if a facility is in the middle of deactivation, and SAFSTOR/3 if a facility is nearing completion of deactivation; and (4) DECON - DECON/1 if a facility is beginning decontamination activities, DECON/2 if a facility is in the middle of decontamination activities, DECON/3 if a facility is nearing completion of decontamination activities, and finally, DECON/COMPLETED if a facility has finished decontamination activities.
- *Decon Plan?* - This column asks whether the plant has a Decommissioning Plan.
- *Near Term End State Envisioned* - In this criterion, the currently envisioned end state of a facility is identified. The end state is described as being in one of the following categories: (1) ENTOMB - for those sites targeted for entombment, (2) SAFSTOR for those sites to be placed into safe storage, or (3) DECON/ REPOWER - for those sites to be decontaminated and alternate site uses found.
- *Premature vs. End-of-Life Shutdown* - This criterion was used to identify the impact on deactivation activities if a facility is shut down prematurely.
- *Regulatory Process Differences* - This criterion identified differences due to the changes in the regulatory process.
- *Plant Contact* - This criterion identified which of the three types of plant contact occurred. (1) Visit - for those plants that were visited, (2) Doc - for those plants that received a document review and/or phone interviews, and (3) IGN - for those plants that were not contacted.

Management at the selected facilities were contacted regarding their willingness to entertain a site visit. All utilities contacted expressed an interest in participating in the effort and were cooperative in arranging a site visit.

Table 1. Nuclear Power Plants No Longer in Service

Plant (Location)	Net MWe	Type	Started	Closed
BONUS (Rincon, P.R.)	72	BWR	8/64	6/68
Dresden 1 (Morris, Ill.)	200	BWR	7/60	10/78
Fermi 1 (Monroe, Mich.)	61	LMFBR	8/66	11/72
Fort St. Vrain (Platteville, Colo.)	330	HTGR	1/79	8/89
Hallam (Hallam, Nebr.)	75	LMGMR	11/63	9/64
Hanford N Reactor (Richland, Wash.)	860	LGR	7/66	2/88
Humboldt Bay 3 (Eureka, Calif.)	63	BWR	8/63	7/76
Indian Point 1 (Buchanan, New York)	257	PWR	1/63	10/74
LaCrosse (Genoa, Wis.)	50	BWR	11/69	4/87
Pathfinder (Sioux Falls, So. Dak.)	59	BWR	7/66	10/67
Peach Bottom 1 (Peach Bottom, Pa.)	40	HTGR	6/67	11/74
Rancho Seco (Clay Station, Calif.)	913	PWR	4/75	6/89
San Onofre 1 (San Clemente, Calif.)	436	PWR	1/68	11/92
Shippingport (Shippingport, Pa.)	60	PWR/LWBR	12/57	10/82
Shoreham (Brookhaven, New York)	809	BWR	--	5/89
Three Mile Island 2 (Londonderry Twp., Pa.)	792	PWR	12/78	3/79
Trojan (Prescott, Ore.)	1095	PWR	5/76	11/92
Yankee (Rowe, Mass.)	167	PWR	7/61	9/91

* Nuclear News, September 1993, Vol. 36, No. 1, page 61.

** The Shoreham unit achieved criticality and produced power, but closed before it could begin commercial operation.

Table 2. Selection Criteria Matrix

Commercial Facility	Geographic Location	Time of Last Operation	Facility Type/ Stand-alone Facility	Units on Site	Stage of D&D	Decon* Plan?	Near Term End State Envisioned	Premature vs. End-of-Life Shutdown	Regulatory Process Differences	Plant Contact
BONUS	Rincon, P.R.	6/68	BWR	1	ENTOMB		ENTOMB		Old	Ign
Dresden 1	Morris, IL	10/78	BWR	3	SAFSTOR	Yes	SAFSTOR	Premature	Old	Doc
Fermi 1	Monroe, MI	11/72	LMFBR	2	SAFSTOR/3	Yes	SAFSTOR	Premature	Old	Doc
Fort St. Vrain	Platteville, CO	8/89	HTGR	1	DECON/2	Yes	DECON/ REUSE	Premature	New	Visit
Hallum	Hallum, NE	9/64	LMGMR	1	ENTOMB		ENTOMB			Ign
Hanford-N	Richland, WA	2/88	LGR	Multiple			SAFSTOR			Ign
Humboldt Bay 3	Eureka, CA	7/76	BWR/ 1&2 FOSSIL	1	SAFSTOR/3	Yes	SAFSTOR		Old	Ign
Indian Point 1	Buchanan, NY	10/74	PWR	3	SAFSTOR/3	Yes	SAFSTOR	End-of-Life	Old	Ign
La Crosse	Genoa, WI	4/87	BWR	1	SAFSTOR/2	Yes	SAFSTOR	Premature	New	Ign
Pathfinder	Sioux Falls, SD	10/67	BWR	1	REPOWER	Yes	REPOWER	Premature	Old	Visit
Peach Bottom 1	Peach Bottom, PA	11/74	HTGR	3	SAFSTOR/3		SAFSTOR			Ign
Rancho Seco	Clay Station, CA	6/89	PWR	1	SAFSTOR/1	Yes	SAFSTOR	Premature	New	Visit
San Onofre-1	San Clemente, CA	11/92	PWR	3						Ign
Shippingport	Shippingport, PA	10/82	PWR/ LWBR	1	DECON/ COMPLETED 7/89	Yes	Site Released/ Fully Decontaminated	End-of-Life	Old	Doc

* Decommissioning

Table 2. Selection Criteria Matrix (continued)

Commercial Facility	Geographic Location	Time of Last Operation	Facility Type/ Stand-alone Facility	Units on Site	Stage of D&D	Decon* Plan?	Near Term End State Envisioned	Premature vs. End of Life Shutdown	Regulatory Process Differences	Plant Contact
Shoreham	Brookhaven, NY	5/89	BWR	1	In Progress/1	Yes	DECON	Premature	New	Visit
Three Mile Island 2	Londonderry, Twp., PA	3/79	PWR	3	POL		SAFSTOR		Old	Ign
Trojan	Prescott, OR	11/92	PWR	1	In Progress/1	In Progress	SAFSTOR	Premature	New	Visit
Yankee	Rowe, MA	9/91	PWR	1	POL In Progress/2	In Progress	SAFSTOR	Premature	New	Doc

* Decommissioning

1.3.2 Topics

Ten major topic areas that may be of interest to DOE sites and facilities with respect to effective deactivation to safe storage and decommissioning were identified by SNL, all of which have a number of potential issues associated with them. The 10 topic areas were used to create a questionnaire (which is presented in section 1.3.3) to focus the utility interviews and discussions.

It was not unusual for information applicable for some of the topic areas (and their potential issues) to overlap with that for other topics. The following pages first lists the topic area of interest and then describes potential issues associated with that area in more detail, followed by discussion of why these issues are of potential interest to DOE sites and facilities.

1. **Unknown or Inadequately Characterized Hazards.** Facilities awaiting deactivation often suffer from a lack of information on the types, extent, and levels of contamination. Lack of this information hinders the effort to plan technical approaches and to develop adequate project cost and schedule estimates and results in the need for assumptions and factors that cause the best estimates of cost and schedule to have very broad ranges. These ranges, at best, vary by a factor of four.
2. **Conflicting and Overlapping Requirements and Regulations.** No clearly defined regulatory strategy exists for transitioning facilities from operation to shutdown to safe storage to final disposition. However, DOE facilities and sites must be in compliance with applicable laws, regulations, and agreements, which includes following not only DOE Orders but federal and state regulations. It is not unusual for these laws, regulations, and agreements to overlap or even conflict. Being in regulatory compliance is even more challenging when the requirements of the regulations are not clearly defined, when the regulations are continually changing, and when approval authority is not clear. The following paragraphs discuss these issues and obstacles in more detail.

Wide Variety of Regulatory Requirements. DOE sites and facilities must comply with a wide variety of regulatory requirements. However, environmental regulations differ with respect to philosophy, intent, and specific requirements. Examples of potential regulations that will affect waste disposal facility closure options include RCRA, CERCLA, Clean Water Act (CWA), Federal Facilities Amendments (FFA), Federal Facilities Compliance Act (FFCA), Clean Air Act (CAA), Safe Drinking Water Act (SDWA), NEPA, DOE Orders (especially DOE Order 5820.2A), Toxic Substance Control Act (TSCA), state laws, OSHA, and Comp Orders.

Other issues include the following:

- reconciliation of land-use planning with NEPA and CERCLA,
- no "how clean is clean" standards defined in regulations,

- no clear conception of how to meet all regulatory requirements without "swamping" funding (funding limitations may prevent full compliance),
- no agreement on definitions of "Below Regulatory Concern" (BRC) and "acceptable risk" in regulations, and
- lack of a basis for present regulations on human-health and environmental risks.

No Common Interpretation of Requirements. Regulatory requirements are interpreted differently from site to site and facility to facility. This includes the level of documentation required and the classification of wastes into low-level radioactive, transuranic (TRU), hazardous, or mixed waste categories.

An example of an area for which questions are being asked is the application of technical specifications and unreviewed safety question concepts to shutdown and safe storage activities. What are the safety documentation requirements and where and what should be used as guidance in DOE facilities? Should safety analysis, Environmental Protection Agency (EPA), and Occupational Health and Safety Act (OSHA) activities be integrated?

Changing Requirements. One of the major concerns with future transitioning activities involves changing regulatory requirements. There are regulatory actions under way at the NRC, EPA, and DOE that may significantly impact DOE's transitioning programs. EPA believes that it is necessary to be seen as a strong regulator to enhance its credibility, and new EPA directions include (1) using risk to set priorities, (2) shifting from a command-and-control approach to cooperation, and (3) shifting from a focus on remediation towards pollution prevention.

EPA's Office of Radiation Programs is also setting standards for residual activity. Some policies related to these standards have been issued, including (1) NEPA reviews for nuclear facilities must consider decommissioning, (2) priority should be given to setting limits for release of land and buildings, and (3) limits are to be set for unrestricted use only. Currently, EPA is collecting information on the extent of the problem (i.e., inventorying contaminated materials); identifying options for recycling and available technology; existing rules; conducting a preliminary assessment of costs and benefits; reviewing risk models; and developing a work plan.

Another issue is that regulatory developments are outstripping compliance capabilities; thus, technologies and methods to support compliance are not keeping pace.

3. **Technology Development or Enhancement Needs.** One of the major issues for large transitioning programs is the lack of technologies to handle the scale of upcoming transitioning projects. Technologies and techniques currently available for safe storage and decommissioning activities generate large amounts of liquid waste and uncontaminated materials that must be disposed of, create industrial hazards, and take time. The tendency has been to dispose of large components intact when these are difficult to decontaminate and/or dismantle. To be truly successful, ways to make the transitioning process more

efficient must be found. In addition, a mechanism to consolidate descriptions of the technologies, including those from the commercial sector and decommissioning projects, must be found and made available to personnel responsible for transitioning activities.

Specific DOE technology needs have been identified and include the following:

Characterization. Automated dose mapping; in situ characterization technologies; faster instrumentation; field screening machine for contamination testing; optical, RF, and ultrasonic techniques; improved characterization equipment to reduce personnel exposure; reduced sample analysis turnaround times and cost; and technologies deployable in the field and compatible with remote-handling techniques.

Decontamination (for those activities required to place a facility into safe storage). Self-contained scabbling machine with dust abatement; scabbling techniques; contaminant removal techniques (abrasive, thermal, and high-intensity radiant energy); cleaning methods for inside ducts and pipes; portable, cleanable containment systems with rounded corners; non-RCRA cleaning solutions; environmentally acceptable decon chemicals; environmentally acceptable substitute for freon; dry and wet vacuum systems; nonphosphoric-based electropolishing solutions; innovative, larger-scale concrete scabbling equipment; metal surface decontamination techniques; and improved decontamination technology to minimize secondary waste and maximize free release fraction.

Remote Systems. Radiation-hardened industrial robots; self-contained mobile platforms; sensor platform reconfigurable for many sensors; automated operations programs for robotics; better human/machine robotics interface; system integration techniques and improved robotics mobility, control, and manipulation; improved remote operations; delivery systems for remote instruments; remote sampling techniques; and adaptation of existing remote or robotic technologies to facilities designed for hands-on maintenance.

Waste Disposal. Technologies for waste minimization; secondary waste minimization; and mixed waste minimization.

Other. Portable high-efficiency particulate air (HEPA) filtration systems; portable erector systems; small and large tool removal systems; emergency eye wash and shower system with collection and hot water systems; decommissioning construction technology; characterization and decontamination methods that reduce staffing; better approaches and equipment for very large projects using minimal staff; HEPA-ESP systems; and storage and transportation containers.

4. **Risks at a Transitioning Facility.** Facilities in safe storage present a different set of hazards than those that are present at an operating facility (and are typically addressed in a safety analysis). Facilities without function or that are not in use tend to be of low priority and can become a significant risk to surveillance and maintenance personnel. The obvious risks are those dealing with residual hazardous inventories that need to be safely

contained or confined, but the not-so-obvious risks are industrial hazards that tend to increase because of deterioration, configuration, and neglect. It has been observed that the industrial hazards can, in time, become unacceptable.

A facility in safe storage needs a transitional or deactivation process that looks into the foreseeable future and helps establish priorities and timing for transitioning activities. This type of risk-driven process includes setting cleanup standards, developing integrated site activities, and developing specific implementation programs. An important part of this process includes establishing the basis for risk acceptance, especially with regard to nonradiation hazards (e.g., chemical and carcinogenic hazards). There is also a need for guidance on hazard assessment and accident analysis, that is, a need to determine what requires exhaustive analysis and what is acceptable for qualitative or bounding analysis. In addition, there is a need to determine the short-term and long-term risks of a nonfunctioning facility, that is, to identify the range of potential accidents common to transitioning activities and the special or unique contributors to risk uncertainty.

5. **Cost Increases and Uncertainties.** To be successful, the transitioning process needs to develop an effective cost/risk benefit analysis that can be used to help develop approaches to minimizing staff levels and keeping surveillance and maintenance costs low. It will also be important to maintain adequate funding over the long time required to complete transitioning activities. It is not unusual for funds to be moved to other, more critical needs, which leads to funding uncertainties.

Other issues include accurately estimating the costs associated with the transitioning process. The waste packaging and disposal/storage costs are constantly changing. In addition, with radioactive waste disposal costs increasing by 10% to 30% a year and decommissioning costs doubling every two to three years, why place a facility into safe storage? Placing a facility into safe storage for 60 or more years does not buy a whole lot to reduce exposure, but comparative costs will dramatically increase for decommissioning.

6. **Management/Programmatic.** Sufficient infrastructure needs to be in place to plan and manage mission activities through effectively estimating, developing, and providing the human-resource and capital investment requirements needed for the transitioning activities. Issues include the following:

- limited time to identify a plan for resource needs,
- inability to set staffing requirements,
- organizational inertia interfering with reallocation of personnel consistent with a changing mission,
- continuing difficulty in recruiting qualified staff, and
- program oversight problems because of high contractor to staff ratios.

A means of efficiently using resources needs to be found, and this will involve aggressively pursuing innovative approaches to development, acquisition, and management of resources. Issues include the following management concerns:

- although they are continually improving, insufficiently developed program management capabilities that inhibit effectiveness,
- obstacles to timely reallocation of resources, which adversely affect program operations, and
- research and development contributions to program efficiencies that are limited by the discretionary nature of funding.

7. **Stakeholder Concerns.** The development of effective communication programs with state and local governments, the public, concerned individuals, and the work force may help alleviate inaccurate perceptions by helping these external stakeholders understand EM's mission and the issues it is facing. It is important to build public confidence in the transitioning process. One of the major obstacles to building this confidence is that the public does not accept the concept of "relative risks," making support for a risk-based approach hard to obtain from Congress, states, Indian tribes, and local governments.

A specific issue that may be of concern to DOE facilities is how to involve local DOE representatives from the start of the transitioning process.

8. **Recycle and Reuse Opportunities.** Recycling is a critical need for the transitioning of facilities to safe storage and to final disposition. DOE facilities contain large amounts of strategic metals that will result in very large volumes of waste if recycling is not available. For example, the Oak Ridge National Laboratory K-25 site contains nickel worth over \$1 billion. However, for large scale recycling to be used, regulatory changes must occur. There is a critical need for unrestricted release criteria for residual radioactivity as well as for restricted use as is the case of slightly contaminated drums. However, development of such criteria requires both public and regulatory acceptance. Public perception may be the crux of the problem. The public does not always accept the government's determination of safe radiation levels because of a tendency to focus on the hazard versus the probability of occurrence, lack of control over the risk, and a belief that any additional exposure is an unnecessary degradation of the environment.

Other issues to be considered with respect to recycling include (1) the need for accurate, reliable, and economical assay technologies, (2) management of secondary wastes, and (3) availability of markets for contaminated materials and products. Legal considerations include the potential that states could require land disposal versus recycling of contaminated materials and EPA could set contamination limits that reduce the materials eligible for recycling.

Finally, the uses of recycled materials may need to be controlled by defining first-use restrictions, limiting them to specific users, or restricting them from certain products.

9. **Industry Involvement.** It is anticipated that one of the major questions faced by DOE will be how to get industry participation in the transitioning challenge. This will involve developing mechanisms for involving industry and smoothing the procurement process. There is a strong desire for industry to be involved; however, it is also important to be sure that the technologies offered by industry are of value, not solutions in search of problems. There is also a need to find a way to communicate with industry so that there is a clear understanding of what DOE means by faster, cheaper, better, safer. Industry wants to know: "Faster than what? Cheaper than what? Better than what? Safer than what?" Establishing baselines or goals that define "better, cheaper, faster, safer" would help clear the way for industry involvement.

Private sector participation is also being solicited through cooperative research and development agreements (CRADAs) and program research and development announcements (PRDAs), with particular emphasis on scrap metal recycling; metal, concrete and equipment decontamination; and dismantlement technologies for metal and concrete structures.

10. **Waste Minimization and Avoidance of Mixed-Waste Generation.** There is concern that waste minimization and avoidance of mixed-waste generation will be major concerns as the transitioning process proceeds (and grows).

1.3.3 Commercial Nuclear Experience Questionnaire

To facilitate gathering of information from commercial nuclear utility decommissioning experience a questionnaire was developed. Specific questions were created based on the topics and associated issues summarized in the previous section. The questionnaire was used during the site visits to focus interviews and discussions on those subject areas felt to be of most interest to DOE. The questionnaire is presented in Figure 2.

1. **Unknown or Inadequately Characterized Hazards**
 - A. How did you characterize the hazards and what problems did you have in doing this? How did you handle poorly characterized areas?
 - B. Any suggestions for improving the hazard evaluation process?
 - C. How did this process affect the accuracy of your cost and waste volume estimates?
 - D. What ALARA practices did you use?
 - E. What "lessons learned" can you share? If you had to do this deactivation project again, what changes would you make How would you prioritize the activities? Which tasks should have an increased or decreased scope or be completely eliminated?
2. **Management/Programmatic**
 - A. How did you establish your deactivation plans? How did you decide the order in which the overall deactivation activities should be performed?
 - B. Explain how deactivation activities were managed and controlled.
 - C. How did you determine necessary staffing levels, skills, training, retraining (including outplacement), and implementation schedules?
 - D. What work activities (i.e., cleanout, equipment removal, equipment deactivation, decontamination, etc.) were or are being undertaken to achieve SAFSTOR?
 - E. Discuss the decision process employed to choose between decontamination and SAFSTOR? What drove your decision? How did you integrate the deactivation or decontamination activities with other ongoing site activities?
 - F. What influence did your final D&D plans have on deactivation planning?
 - G. How are you maintaining plant systems that you plan to use in deactivation and SAFSTOR?
 - H. What "lessons learned" can you share? If you had to do this deactivation project again, what changes would you make?

Figure 1. Commercial Nuclear Experience Questionnaire

3. **Conflicting and Overlapping Requirements and Regulations**

- A. How did you define SAFSTOR and the regulations and requirements to achieve this condition?
- B. What federal, state, and other entities set policies/requirements affecting SAFSTOR?
- C. What requirements were overlapping or in conflict and how was this resolved?
- D. What approach or system did you use to ensure compliance with all regulatory requirements?
- E. How did you handle changing regulations during the deactivation process?
- F. How did you define the radiological and hazardous material exposure limits for the SAFSTOR "endpoint"? Or, how clean was "clean enough"?
- G. What requirements in the following areas did you have to meet for SAFSTOR and how were these determined?
 - maintenance
 - surveillance
 - quality assurance
 - radiation monitoring
 - hazardous, radioactive, and mixed-waste management
 - security
 - safety analysis documentation (accident analysis) and tech specs
 - worker safety and health requirements (such as health and safety plans, 29 CFR 1910.120 - OSHA Hazard Communication Standard)
 - facility decontamination
 - deactivation activities documentation
 - operation
 - emergency planning
- H. How did you translate operational Tech Specs to SAFSTOR operation and maintenance requirements and update your safety basis documentation?
- I. What "lessons learned" can you share?

Figure 1. (continued)

4. Risks at a Transitioning Facility

- A. Did you use a risk-based methodology when you developed your deactivation plans?
- B. What did you do to minimize risks during deactivation and SAFSTOR? What specific engineering and administrative controls do you use?
- C. For facilities placed into safe storage, what set of hazards (in general) has been identified?
- D. How can facilities placed into safe storage become a significant risk to surveillance and maintenance personnel?
- E. Did or do you have any residual radioactive or hazardous inventories that need to be safely contained or confined? Have they presented any problems? Explain.
- F. Are there any industrial hazards that tend to increase because of deterioration, configuration, and neglect? Explain.
- G. Do or did you have a transitional or deactivation process (i.e., risk-based or other) in place that looks into the foreseeable future and helps establish priorities and timing for transitional activities? Explain.
- H. How did you determine what level of risk assessment was sufficient?
- I. How did you determine if the hazard assessment and accident analysis requires exhaustive analysis or a qualitative or bounding analysis?
- J. Have you identified potential accidents common to transitioning activities and special or unique contributors to risk uncertainty? What are they?

5. Cost Increases and Uncertainties

- A. What cost uncertainties did you encounter, and how did you handle them?
- B. What were the causes and associated magnitudes of your cost uncertainties?
- C. What are the (cost) impacts of long-term, on-site storage of spent fuel and other radioactive, hazardous, and mixed waste?
- D. What are your SAFSTOR operation and maintenance costs, and how were they estimated in advance?
- E. What, if any, are the costs and benefits associated with the SAFSTOR method because of time-related reduction in radioactivity levels? Are there any other costs and benefits associated with SAFSTOR? Explain.
- F. What decommissioning funding alternatives did you consider? How did you fund your program?

Figure 1. (continued)

- G. What are the costs and benefits of decontamination procedures that reduce regulatory classification (Class "C," Class "B," Class "A," Below Regulatory Concern)?
 - H. What economic considerations (especially for prematurely shutdown plants) influenced your decommissioning decisions?
 - I. In developing your plans for SAFSTOR, did you consider or include activities that would potentially help reduce final D&D costs? Explain.
 - J. What "lessons learned" can you share?
6. **Stakeholder Concerns**
- A. How did you communicate with and encourage stakeholder participation in site use and D&D planning?
 - B. To what extent did stakeholder participation affect your deactivation activities?
 - C. How did you identify stakeholders and determine their concerns?
 - D. Which stakeholders had the greatest impacts, and how did you resolve their concerns?
 - E. What "lessons learned" can you share?
7. **Waste Minimization and Avoidance of Mixed-Waste Generation**
- A. What waste minimization procedures did you follow in your deactivation activities to reach SAFSTOR?
 - B. What type of mixed waste issues did you have to face in your deactivation activities to reach SAFSTOR?
 - C. How did you minimize the efforts (i.e., documentation, labor, verification, and costs) associated with packaging, and storing or transporting wastes?
 - D. What "lessons learned" can you share?
8. **Industry Involvement**
- A. What contractors did you use to support your deactivation activities and how did you identify them?
 - B. What expertise did they provide? How were their credentials validated?
 - C. What activities did they perform?

Figure 1. (continued)

- D. How do you share contractor results with others?
- E. What, if any, outside courses/training did you find useful?
- F. What "lessons learned" can you share?

9. Recycle and Reuse Opportunities

- A. What, if any, alternatives for site utilization after decommissioning did you consider?
- B. Was there any potential for recycling or reuse of structures, components, and materials (i.e., fuel, plant equipment)? Explain.

10. Technology Development or Enhancement Needs

- A. For each of the following areas, what technical approaches did you find most useful in your efforts to deactivate your facilities?
 - characterization
 - decontamination
 - remote/robotic systems
 - waste disposal
 - demolition
 - radiation monitoring
 - fuel handling
 - fuel storage
- B. For major and high radiation level structures and components, what decontamination and deactivation techniques did you use? Which of these were the most effective?
- C. What types of mobile or transportable systems were used during deactivation?
- D. Were any specialized processes or tooling used to facilitate deactivation?
- E. What techniques were used to deactivate below ground structures and components (such as foundations, piping, tanks, cables, and ductbanks) and characterize and/or remediate soil and groundwater?
- F. What radiological measurement and monitoring methods and assessments were used during characterization and deactivation?
- G. How was an inventory of materials (concrete, steel, aluminum, copper, plastics, lubricants, asbestos, hazardous materials, etc.) maintained, and how accurately was it tracked?
- H. Were any reactor clean-up or other systems used in the decontamination effort?

Figure 1. (continued)

- I. What technical problems did you encounter during deactivation and how did you solve them?
What additional technologies did you wish were available?
 - J. Were the hazards associated with the technologies chosen for the deactivation activities evaluated
with respect to their potential to cause environmental or safety problems?
 - K. What "lessons learned" can you share? If you had to do this deactivation project again, what
changes would you make?
11. **Feedback**
- A. What have we missed? Are there other questions that we should have asked?
 - B. What questions should we eliminate or combine?

Figure 1. (continued)

1.4 Literature Review

An initial review of the open literature was performed by SNL and LANL. The data base survey included the following:

- Oak Ridge bibliographies on "Nuclear Facility Decommissioning and Site Remedial Actions,"
- DOE - Energy Science and Technology,
- Newsletters,
- Business Files, and
- Licensing Information Services (LIS) database of regulatory documents.

Selected documents from these data bases were ordered and a partial set of reports (mostly on microfiche) were screened for relevant information.

Other sources of information were identified and used as needed, including the following:

- Professional organizations that provide environmental or decommissioning short courses and reference material, such as:
 - Executive Enterprises, Inc.,
 - the Keystone Center,
 - Government Institutes, Inc., and
 - Oak Ridge (EH-231 mailing list).
- Listing of points of contact in federal agencies, such as the EPA, NRC, DOE, etc.) were identified from:
 - U.S. Government Manual,
 - Washington Information Directory,
 - Federal Yellow Book, and
 - State Executive Directory.
- Commercial facility decommissioning points of contact were identified (from previous personal contacts with assessment team members) for some of the facilities listed in Table 2. Contacts were made, and decommissioning plans (or similar technical information) were requested.

2.0 COMMERCIAL REACTOR HISTORY

In this section, a brief history of the Dresden, Fermi, Fort St. Vrain, Humboldt Bay, Pathfinder, Rancho Seco, Shippingport, Shoreham, Trojan and Yankee Rowe nuclear facilities is provided. These ten commercial nuclear facilities are those from which information was solicited.

2.1 Dresden 1

Dresden Nuclear Power Station Unit 1 (Dresden 1) is located in Grundy County, IL, approximately 50 miles southwest of Chicago near the confluence of the Des Plaines, Kankakee, and Illinois Rivers. The plant shares a site with two other boiling water reactors (Units 2 and 3) and is owned and operated by Commonwealth Edison Company (CECo).

Dresden 1 was the first nuclear power plant built by private industry and was operated from July 1960 to October 1978, with a gross output of 210 MWe. Dresden 1 was taken out of service in October 1978 for modifications and backfits to meet new federal regulations and to perform a chemical decontamination of major piping systems. While it was out of service, additional regulations were issued as a result of the March 1979 incident at Three Mile Island. The estimated cost to bring Dresden 1 into compliance with the new regulations was more than \$300 million.¹ CECo concluded that the age of the unit and its relatively small size did not warrant the investment.¹ The decision to decommission Dresden 1 was made in October 1984.

2.2 Enrico Fermi 1

In the early 1950s, the Korean War aggravated relations between the U.S., the USSR and China. The Defense Department wanted assurance that it could secure more plutonium for a weapons buildup. One way to assure this was for industry or government to build dual-purpose nuclear plants. The military would have first call on the plutonium produced by the plants; electric utility owners could utilize the heat for power generation. The decision to build the Fermi plant fitted ideally into the atmosphere and perceived needs of the times. Not only would this plant demonstrate the technical and economic aspects of breeder reactors, but it would provide high-grade plutonium that could be used for military weapons or as fuel for reactors.⁴

On January 10, 1955, the U. S. Atomic Energy Commission (AEC) announced its Power Reactor Demonstration Program inviting private enterprise to present plans for building nuclear power reactors in cooperation with the AEC. On March 30, 1955, the Detroit Edison Company, on behalf of itself and eight other companies, offered to participate in the U. S. program by designing, constructing, and operating an experimental fast-neutron breeder reactor electric power plant. The nine companies formed the Power Reactor Development Company (PRDC) as a nonprofit organization. The plant was to be called the Enrico Fermi Atomic Power Plant (later known as Fermi-1) to commemorate the work of the late Enrico Fermi, the first atomic scientist to produce a chain reaction.⁴

Fermi-1, designed for operation at 150 MWe, was the first large nuclear power plant having as its heat source a sodium-cooled fast breeder reactor. The Fermi-1 heat transport system used three cooling loops to remove heat by natural circulation using intermediate heat exchangers and steam generators.⁴

On August 4, 1956, the AEC issued a construction permit for Fermi-1. The Fermi reactor and the associated steam-electric generating plant were built on a 915-acre site at Lagoona Beach, Frenchtown Township, Monroe County, MI, on the western shore of Lake Erie, about 30 miles from downtown Detroit and 25 miles from downtown Toledo. Cooling water was available from Lake Erie.⁴

The low-power operating license for Fermi was issued on May 10, 1963, and criticality was achieved on August 23, 1963. The low-power test program was successfully completed by December 1965. The full-power operating license was issued on December 17, 1965, and the high-power test program began on December 29, 1965.⁴

The early months of 1966 were devoted to a series of tests at incrementally-increasing power levels. On October 5, 1966, while in this testing phase, the plant experienced a fuel melting incident caused by one of six zirconium liners of the conical flow guard. Somehow this liner became detached and was thrust upward against the inlet flow nozzles of the affected fuel subassemblies by the force of the flowing liquid sodium coolant. The restricted flow of the liquid sodium coolant to these fuel subassemblies resulted in fuel melt. This incident resulted in a three-and-one-half year rehabilitation period, during which large costs were incurred.⁴

Fermi was repaired and successfully demonstrated electrical power generation at its core design level in 1969. The fuel melt incident precluded the reuse of a large number of fuel subassemblies, because that would have required an expensive and time-consuming test program to assure that they had not been damaged. This restriction shortened the useful life of the alloy core, since only two full core loadings of alloy subassemblies were fabricated. An effort was made to raise the \$54 million necessary for new oxide fuel and plant revisions. Many companies worldwide responded, but only \$44 million could be raised. On November 27, 1972, the Executive Committee of PRDC reluctantly decided to decommission the plant, which was successfully accomplished by the end of 1975 at a cost of \$7 million.⁴

Data from this decommissioning project were put into a computerized data-handling system, MAPPER, which was intended to allow for flexible data accumulation, manipulation, and retrieval. The purpose of this was to provide the NRC and its licensees with comparative data in the areas of ALARA (as low as reasonably achievable) responsiveness, cost-estimate accuracy, schedule adherence, project labor hours and costs, exposure accountability, and radwaste generation and disposition, to assist them in their assessment of decommissioning alternatives and ALARA methods for future decommissioning projects.³ Unfortunately, when this report was retrieved on microfiche, the computer printout was largely illegible, much of the data was not available, and there was little text to summarize the available information.

2.3 Fort St. Vrain

The Fort St. Vrain Nuclear Generating Station (FSV) is the first and only High-Temperature Gas-Cooled Reactor (HTGR) in the U.S. commercial nuclear industry. It was a 330-MW electric generating station designed by General Atomics in the mid-1960s for Public Service Company of Colorado (PSC) as part of the AEC Reactor Demonstration Program.

FSV is located in the South Platte River Valley, in an agricultural area with gently rolling hills, approximately 35 miles north of Denver. The population density in the rural areas surrounding the plant is relatively low. The South Platte River and St. Vrain Creek pass through portions of the 2798-acre site. These two streams, which join near the northern tip of the site, are not large enough to be used for water transportation.

FSV used a uranium-thorium fuel cycle with helium as its primary coolant. A prestressed concrete reactor vessel (PCRVR) contained the total primary coolant system including the reactor, steam generators, and helium circulators. The reactor core was graphite moderated and reflected and was located in the upper part of the vessel. The reactor core consisted of over 5000 individual graphite blocks, including an active core of 1482 hexagonal fuel elements loaded with TRISO-coated uranium and thorium particles cast into cylindrical rods. The helium coolant was discharged from four helium circulators at 700 psia (100% of rated power) and passed down through the core, removing heat from the fission process. This heat was then distributed equally through 12 steam generator modules.

The initial announcement to build FSV was made on March 13, 1965. The FSV construction permit was issued in September 1968, and construction was completed and the operating license was issued in December 1973. Initial criticality was achieved on January 31, 1974. Although FSV received a full-power operating license in 1973, extensive preoperational testing mandated by the NRC and the resulting engineering modifications delayed the commercial operation of the plant until July 1979. The plant operated sporadically from 1979 through 1988, with a historical capacity factor of less than 15% and less than 30% availability. For an extensive discussion of the FSV operational experiences, see an article written by H.L. Brey.⁵

In response to FSV's historically reduced levels of power generation, the Office of Consumer Counsel (OCC) filed a complaint with the Colorado Public Utilities Commission (CPUC) against PSC alleging that, in light of its operating history, FSV was not "used and useful" in rendering a utility service. In September 1986, PSC signed a settlement agreement with the CPUC and the OCC over several areas of litigation and long-term issues. Significant provisions of the settlement agreement included (1) removal of FSV from the rate base; (2) a provision for the sale of future energy produced at FSV to PSC customers at a rate of 4.8 cents per KWh; and (3) recovery over five years of \$11.5 million of decommissioning costs. Because of FSV's poor operational performance and the cost of fuel, PSC could not operate on the 4.8 cents allowed by CPUC. Attempts to obtain subsidies (both government and private) failed, and the plant operated at a \$25 to \$35 million dollar loss per year. Therefore, the utility decided in December 1988 to permanently cease FSV operation by June 30, 1990. However, on August

18, 1989, the plant was shut down because of control rod drive and steam generator problems, the repair of which would have required significant down time and capital investment. On August 29, 1989, the utility decided not to restart the reactor.

The utility filed a Preliminary Decommissioning Plan with the NRC in June 1989 based on SAFSTOR. However, in June of 1990, because of a desire to utilize the nonnuclear plant for continued power production, the utility went out for fixed price bids for decommissioning the reactor and repowering the plant with natural gas. This request also asked for entrepreneurial bids to decommission and repower the plant as an Independent Power Producer (IPP).

The utility decided to pursue the early dismantlement option based on the following major considerations:

- Future risks of the SAFSTOR process cannot be quantified (such as the regulatory environment, public attitude, and waste disposal).
- There are continuing long-term costs for the SAFSTOR option (maintenance, security, testing, etc.).
- Risks for early dismantlement are more quantifiable (fixed price bids, regulatory environment, public attitude, waste disposal).
- No continuing long-term costs for early dismantlement (FSV ceases to be a liability).

Although the utility pursued the DECON option, they retained the option to go to SAFSTOR.

In November 1990, PSC submitted to the NRC the FSV Proposed Decommissioning Plan (PDP), based on the DECON option. In February 1991, the NRC issued a POL. The POL confirmed the non-operating status of FSV and represented an intermediate step in the transition into the decommissioning phase of the facility.

The utility intended to begin defueling FSV and shipping the fuel to INEL in early 1991. However, because the Governor of Idaho refused to allow the fuel to enter Idaho, the utility had to construct an Independent Spent-fuel Storage Installation (ISFSI) at the FSV site. The utility received the license to operate the ISFSI in November 1991. The defueling of the reactor and movement of all fuel to the ISFSI were completed on June 15, 1992. On November 23, 1993, the NRC issued the Decommissioning Order for FSV. The current cost estimate for decommissioning FSV is \$124 million.

2.4 Humboldt Bay 3

The Humboldt Bay Power Plant (HBPP) Unit 3 is a General Electric natural circulation, single cycle boiling water reactor (BWR) rated at 65 MWe. The plant is located four miles southwest of Eureka, CA, and is operated by Pacific Gas and Electric Company (PG&E). The plant site also includes two fossil-fueled units and two gas-turbine-powered mobile emergency power plants.^{11,12}

HBPP Unit 3 was granted a construction permit by the AEC on October 17, 1960. The reactor achieved initial criticality on February 16, 1963, and began commercial operation in August of the same year. During the period from August 1963 to July 1976, HBPP Unit 3 generated more than 4.7 billion kWh of electricity and had a cumulative availability factor of 85.9%.¹¹

On July 2, 1976, the HBPP Unit 3 reactor was shut down for annual refueling and to conduct seismic modifications. In December 1980, it became apparent that the cost of completing required backfits might make it uneconomical to restart the unit, and work was suspended at that time. An updated economic analysis in 1983 indicated that restarting would probably never be economical, and in June 1983, the utility announced its intention to decommission the unit.¹¹

The alternatives that the NRC defined for decommissioning included shipment of spent fuel off-site, prior to an amendment of a POL. Because no U.S. facilities receive spent fuel and because no spent-fuel reprocessing facilities, away-from-reactor storage facilities, or geological repositories are operating or accepting uncontracted for spent fuel, the utility included spent-fuel storage at HBPP within its definition of custodial SAFSTOR. The utility has plans to place HBPP into custodial SAFSTOR for a dormancy period of as long as 30 years. The spent-fuel assemblies will be stored on site until a federal repository is operating and able to receive the spent fuel.¹¹

The fuel was removed from the reactor in early 1984. The spent-fuel pool contains 390 spent-fuel assemblies and 54 in-core fission chambers.¹² The reactor primary containment is located entirely below grade and consists of the drywell vessel, which houses the reactor, and a suppression chamber located concentrically around the drywell.¹¹

2.5 Pathfinder

The following information on the Pathfinder Atomic Power Plant is from the "Case Study: Pathfinder Decommissioning" paper written by John Closs¹⁵ and from interviews the authors of this document had with Northern States Power employees at the Pathfinder Plant. The lessons learned section highlights information that, in the opinion of the authors of this document, will provide valuable lessons to individuals and teams planning decontamination and decommissioning projects.

The Pathfinder Atomic Power Plant, built and operated by Northern States Power Company (NSP), is located six miles northeast of Sioux Falls, SD. The plant was part of the Atoms for Peace program. The AEC was looking for "unique" reactor designs and provided NSP the research and development necessary to build the plant as well as the fuel. NSP retained ownership of the plant and its subsequent decommissioning costs. The Pathfinder Plant was a demonstration BWR with a nuclear superheater. The plant's 66-MWe nuclear reactor first went critical in 1964. After several years of subcritical and low-power operations (equivalent to only 88 days of full power operation), the reactor underwent its final shutdown on September 16, 1967.

After establishing that the plant required structural and design upgrades because of the mechanical failure of the steam generators, NSP made an economic decision to keep the nuclear reactor permanently shut down. NSP began to repower the Pathfinder Plant with gas-fired boilers in 1968. The reactor was defueled and then placed in SAFSTOR during 1969 and 1970. Its operating license was surrendered for a by-product material possession license under the provisions of 10 CFR 30. Following conversion, Pathfinder was placed back into commercial operation as a fossil-fueled peaking plant and continues to operate.

Pathfinder's decommissioning phase began in the late 1980s when NSP examined the feasibility of completing its decommissioning work while LLW disposal sites were available and disposal costs were relatively low. Following NSP's decision to demolish the unused nuclear portions of the site, several conferences with the NRC were conducted to discuss the proposed project. In January 1990, the NSP decommissioning team arrived at the site, and in July 1990, they began to dismantle the nuclear portions of the plant.

The scope of the decommissioning phase included (1) the reactor building and its contents, including the reactor vessel, (2) the fuel handling building and its contents, and (3) the fuel transfer vault between the reactor building and the fuel handling building. Radioactive material and residual contamination contained in the fossil-fired plant was not included in the scope.

The Pathfinder reactor vessel was lifted out of the reactor building on May 14, 1991. NSP was granted a Certificate of Compliance by the NRC for shipping the reactor vessel as a Type A package. On August 7, 1991, the vessel was shipped in one piece to a commercial disposal facility near Richland, WA.

2.6 Rancho Seco

On June 6, 1989, the public voted to recommend that the Sacramento Municipal Utility District (SMUD) no longer operate the Rancho Seco Nuclear Generating Station as a nuclear power plant. However, the vote did not prohibit the sale to another qualified operator or operation. Plant operators shut down the plant on June 7, 1989. Reactor defueling was completed on December 8, 1989, and a total of 493 spent fuel assemblies are stored in the Spent-Fuel Pool in the Fuel Storage Building. During its lifetime, Rancho Seco operated for about 51,595 hours and generated about 44 billion kWh of electricity. At plant shutdown, the radioactivity inventory was estimated to be in excess of 9 million Ci.

Rancho Seco was a single nuclear generating unit designed and constructed by Bechtel; the pressurized water reactor was supplied by Babcock and Wilcox. The plant site is on 2480 acres of rolling farmland terrain with a low population density. The unit had a thermal output of 2772 MW and a net electrical output of 913 MW. SMUD received a construction permit in October 1968; actual site preparation began in March 1969. Construction was completed in August 1974 after six years and a total cost of \$350 million. The plant began commercial operation in April 1975.

Today the plant is in a custodial SAFSTOR phase with off-loaded fuel stored in the plant spent-fuel pool. The plant has an NRC POL and is operated by about 150 staff. Current plans are to store the fuel in dry casks in an on-site ISFSI. Custodial SAFSTOR will continue until the fuel is located at the ISFSI in about 1998, at which time the plant will move to a hardened SAFSTOR mode. DECON is expected to take place after 2009, subject to the availability of sufficient funds. Site restoration is expected sometime after 2011.

2.7 Shippingport

The Shippingport Atomic Power Station is located on the south bank of the Ohio River at Shippingport, PA, approximately 25 miles northwest of Pittsburgh. It was built on approximately seven acres of land leased from Duquesne Light Company (DLC) by the AEC.

The station was constructed during the mid-1950s as a joint project of the federal government and DLC. The project had several purposes; one was to develop and demonstrate pressurized water reactor (PWR) technology and the other was to generate electricity. The reactor and steam-generating portions of the station are owned by DOE; the electrical generating portion is owned by DLC.

The station achieved criticality in December 1957 and was operated by DLC under supervision of DOE-Naval Reactors (NR) until operations were terminated on October 1, 1982. End-of-life testing as well as reactor defueling were conducted in the following two years. The reactor utilized three cores of reactor fuel; the first two were PWR cores, and the third was a light water breeder reactor (LWBR) core. The LWBR core was installed in 1977 to demonstrate the thermal breeding principle in a light water reactor. Responsibility for the station was transferred from NR to Richland, WA, within DOE, on September 6, 1984. In addition, General Electric (GE) replaced DLC as the Operations Contractor. A summary of operational data can be found in Table 3. Table 4 displays a chronological sequence of operations at Shippingport.

Table 3. Summary of Operational Data for Shippingport		
	Total Operation Effective Full Power Hour	Total Gross Generation (kWh)
Core 1 (PWR)	27,780.9	1,793,581,700
Core 2 (PWR)	23,812.0	3,476,592,300
Core 3 (LWBR)	28,730.4	2,103,833,029
Totals	80,323.3	7,374,007,029

Table 4. Operations Chronology for Shippingport	
Pressurized Water Reactor Project Authorized	July 1953
Ground Broken	September 6, 1954
Construction Started	March 1955
Initial Core 1 Criticality	December 2, 1957
Core 1 Operations Complete	February 9, 1964
Initial Core 2 Criticality	April 9, 1965
Core 2 Operations Complete	February 4, 1974
Initial Light Water Breeder Reactor Criticality	August 26, 1977
Light Water Breeder Reactor Operations Complete	October 1, 1982
Defueling and End-of-Life Testing Complete	September 6, 1984
Turnover for Decommissioning	September 6, 1974

2.8 Shoreham

On May 15, 1968, the Long Island Lighting Company (LILCO), an investor-owned electric and gas utility serving a little over a million customers, formally applied to the AEC for a construction permit to build the first nuclear power station on Long Island. The plant, to be built in Suffolk County near the village of Shoreham, was expected to cost between \$65 million and \$75 million, and to be on-line by 1973.²⁶

LILCO had initially filed its licensing application documents with the AEC for a 540-MW GE BWR design with a MARK II containment. A cost analysis indicated that a 540-MW nuclear plant would be no more economical than a fossil-fuel plant at the same rating. Then, in the hot summer of 1968, electricity demand surged, and a study based on load-growth projections called for a plant with more capacity than 540-MW to be added by the mid-1970s. The study also indicated that a larger nuclear plant would be more economical than a comparable fossil-fuel plant at the same rating because it could take advantage of economies of scale. LILCO's architect-engineer advised LILCO that the bigger 820-MW reactor would fit within the reactor building already designed for the 540-MW reactor. Because of this change, LILCO had to refile much of the application to the AEC to reflect the design change.

The loss of the months required to rewrite and file the construction license application to reflect the bigger reactor ultimately caused significant delays in issuance of the construction permit. There were, of course, design changes necessary to upgrade the reactor from 540-MW to 820-MW, but in addition, the utility now faced strong public opposition to the reactor. The

hearings before the AEC lasted three years, the longest construction permit hearings ever held for a nuclear power plant. In July 1971, the U.S. Court of Appeals ruled that the AEC was not complying with the 1969 NEPA, a decision that applied to any plant that had not yet received a permit. This decision meant LILCO had to file a much more comprehensive environmental impact statement than before and enter into yet another set of hearings on NEPA. Because of these delays, the Shoreham construction permit was not issued until April 1973.²⁶

With the issuance of the construction permit, LILCO felt that the worst was behind them, a feeling soon reinforced by energy shortages in late 1973 that escalated into the energy crisis. Nuclear energy suddenly became favored as the means to energy independence in the United States.

However, as it turned out, LILCO's problems were only beginning. The AEC adopted American Society of Mechanical Engineers' (ASME) new piping codes, known as ASME III, just prior to LILCO's engineering shutdown in 1971, but LILCO did not implement them until 1973. As a result, LILCO suffered delays in construction while awaiting the new piping. More importantly, ASME III and other AEC regulations issued shortly after the project started up again in late 1972 directed nuclear reactor designers to guard against pipe breaks outside the containment building. Compliance with the new regulations meant that the already marginally sized reactor containment building at Shoreham became even more crowded with piping and restraints. Even worse, LILCO incorporated the corrective measures before submitting the proposed corrective measures for approval by the AEC in 1974. In 1976, the NRC rejected LILCO's proposed solution. Therefore, in 1977, LILCO had to make further modifications to satisfy the NRC after the plant was already four years into construction.²⁶

In 1973, GE's Mark III containment structure failed to pass verification testing for withstanding extreme hydrodynamic loads that might be experienced during an accident. This meant that the GE Mark II containment structure used at Shoreham also was not designed to withstand the hydrodynamic loads during an accident and had to be retrofitted to satisfy the AEC. The hydraulic load problem was not remedied until 1982.

In March 1979, when Shoreham was approximately three-quarters completed, the Three Mile Island (TMI) accident occurred. In the aftermath of TMI, the NRC was determined to prevent the reoccurrence of another accident like TMI and imposed more than 130 new regulatory requirements on the commercial nuclear power industry. This further impacted and delayed the completion of the Shoreham plant.

At approximately the same time as TMI, the Suffolk County and New York State governments withdrew their support for the plant. The PSC began investigating LILCO in 1981 for imprudence in the management of the Shoreham Plant project and, in 1985, voted to disallow \$1.4 billion of Shoreham's \$4.6 billion from the rate base.

In February 1983, one of the backup generators at Shoreham broke in two during testing and the incident made national headlines. Also in February 1983, the Suffolk County legislature

voted to withdraw its emergency evacuation plan for Shoreham, and New York Governor Mario Cuomo refused to intervene on LILCO's behalf. The county and state governments gave safety and emergency planning concerns as reasons for the withdrawal of support. Without an NRC approved emergency plan, issuance of a full-power license to LILCO for the operation of Shoreham became doubtful.

In mid-1985, the NRC granted LILCO a license to test its operation at 5% of full power. Shoreham was tested only briefly at low power. Due to this brief operating history, the extent of radioactive contamination at Shoreham is very limited. Aside from the nuclear fuel, which is stored in the spent-fuel pool. It is estimated that the total radioactive inventory at Shoreham is about 602 curies, almost all of which is located in the reactor pressure vessel and its internals. The radioactive inventory of the remaining structures and systems is about 3 millicuries.²⁴

After receiving a full power operating license on April 21, 1989, the Shoreham Nuclear Power Station shut down in June 1989 pursuant to an agreement between the State of New York and LILCO. The agreement provided that LILCO would cease operations at Shoreham and sell the facility to the Long Island Power Authority (LIPA), a New York state agency, for decommissioning. Soon thereafter, LILCO removed all fuel from the reactor, stored the fuel in the spent-fuel pool as permitted under its full-power license, and, under regular procedures, began to seek a series of license amendments and exemptions to allow it to reduce staffing and other requirements applicable to operation. In February 1992, the LIPA team was formally organized to decommission Shoreham. The license was transferred the same month to LIPA, which received the decommissioning order from the NRC in June 1992.²⁵

DECON was the decommissioning alternative chosen for Shoreham. The DECON alternative involves the immediate dismantling and removal of contaminated equipment, structures, and portions of the facility containing radioactive contaminants. The DECON alternative was selected over the SAFSTOR and ENTOMB alternatives because Shoreham had developed relatively low radiation levels over its brief operating history.²⁵ LIPA has estimated the cost of decommissioning Shoreham as \$186 million in 1991 dollars.²⁴ Decommissioning was substantially completed with segmentation of the reactor vessel by the end of 1992.

2.9 Trojan

The Trojan Nuclear Power Station is located in Columbia County, in the State of Oregon, 42 miles north of Portland. The site consists of 623 acres incorporating a recreational area/park and various office buildings along with an industrial complex enclosed by a security fence. Surrounding the site is land used for residential, commercial, and agricultural purposes. The cooling water supply for the site is from the Columbia River. Drinking water is supplied from on-site wells.

The plant is jointly owned by Portland General Electric (PGE), Pacific Power (PG&E), and the Eugene Water and Electric Board. The plant was designed by Bechtel Power Corporation as

a single generating unit with a PWR supplied by Westinghouse Corporation. The nuclear steam supply system was capable of a thermal output of 3423-MWt with a net electrical output of 1170-MWe. The Trojan Nuclear Plant received its operating license on November 21, 1975, was declared commercial on December 24, 1975, and formally began commercial operation on May 20, 1976.

The PGE board of directors voted to close the Trojan Plant permanently on January 4, 1993. This decision was based on the results of least cost planning, regulatory uncertainty, and steam generator tube defects identified during the 1991 refueling shutdown, which were noted again in 1992. The plant was forced off-line on November 9, 1992, because of a steam generator tube leak. PGE received a POL for the Trojan plant on May 5, 1993. The plant is currently in SAFSTOR awaiting a decision on possible future uses.

2.10 Yankee Rowe

Construction of the Yankee Rowe Nuclear Power Station (YNPS) began in 1956. YNPS was placed into commercial operation in 1960. YNPS's original license expiration date was November 4, 1997; however, in 1988, the term of the license was extended to July 9, 2000, to reflect recapture of the construction period.

During its lifetime, YNPS, which was rated at 185-MWe, generated over 30 billion kwh. While operating, YNPS ranked among the top performing nuclear plants in the world by maintaining a lifetime capacity factor of over 70%.

YNPS permanently ceased power operation on February 26, 1992, mainly because of the economic outlook for the plant and the uncertainty associated with the resolution of reactor vessel integrity issues and restart of the plant. YNPS voluntarily shut down on October 1, 1991, as a result of NRC's concern regarding the unresolved reactor vessel integrity issues. The Yankee Atomic Electric Company (YAEC) indicated that it made more economic sense to close the plant than to shoulder the multi-million dollar cost of proving to the NRC that the unit's radiation weakened reactor pressure vessel could withstand a severe accident. In addition, a glut of relatively cheap power in New England made continued operation of the unit uneconomic. YAEC claimed that shutting the unit would save consumers more than \$130 million. On March 27, 1992, YAEC requested that the license for the Yankee plant be amended to a POL. On August 5, 1992, the NRC approved the requested POL amendment.

Prior to NRC approval of the POL amendment, YAEC requested and received regulatory relief on containment testing, off-site emergency planning, FSAR annual updates, shift staffing, and training and qualification of operators. Subsequent to issuance of the POL, the NRC approved technical specification amendments that allowed for the transfer of fire protection technical specifications to a manual and revision of technical specification requirements regarding the Plants Operations Review Committee.

YAEC also submitted to the NRC proposed emergency and security plans for a defueled plant, and a technical specification amendment, which transferred radiological effluent requirements into a manual. YAEC has also submitted a letter to the NRC stating that the requirements of 10 CFR 171.15 (annual fees) no longer apply. YAEC intends to submit additional regulatory relief requests regarding deletion of chemistry requirements for the main coolant system and secondary water monitoring program, and property insurance. YAEC is continuing to evaluate applicability of the financial protection requirements of Part 140, as well as other regulatory requirements to YNPS.

To support the regulatory relief requests and changes to the emergency plan and security plan, YAEC evaluated all plant systems to identify the availability and classification requirements corresponding to the permanently shutdown and defueled status. All transient analyses were reviewed to determine which design basis events applied to the permanently shutdown and defueled status and to determine what the potential consequences of such an accident would be. In addition, YAEC evaluated the likelihood and potential consequences of a loss of spent-fuel pool inventory. For purposes of the Defueled Security Plan, YAEC conducted additional radiological sabotage event analyses.

In late November 1993, YAEC took a major step toward decommissioning Yankee Rowe by shipping two of four steam generators to Chem Nuclear Systems low level radioactive waste disposal facility at Barnwell, SC. YAEC planned to move all steam generators, the pressurizer, and reactor internals to Barnwell before June 1994.

YAEC intended to submit a Decommissioning Plan to the NRC by February 1994.

3.0 RESULTS OF PLANT REVIEWS AND LESSONS LEARNED

To facilitate summarizing the results of the on-site interviews and document reviews, the results, or lessons learned, have been summarized using the same ten categories (topic areas) as those identified in the questionnaire.

3.1 Hazard Characterization

Deactivation, safe storage, and decontamination work activities required are determined by the hazard characterization.

Before appropriate deactivation, safe storage, and decontamination activities can be chosen, site characterization must be done. The importance of characterization was emphasized by every facility. The determination of the potential final resting places for the hazards and the type of packaging required cannot occur until the hazard is clearly identified and classified. For example, if a contaminated material at a site is classified as Class A Low Level Waste (LLW), it can be placed in a Type A container. The Dresden Nuclear Power Station found it likely that radioactive hazardous waste will be the "bottleneck" for their decontamination activities.

There is not enough money or time to be absolutely certain that characterization of every area at a site has been done; therefore, an intelligent system must be developed to characterize a site effectively.

The Pathfinder Atomic Power Plant viewed the first step in any SAFSTOR or decommissioning project to be characterizing the site and that sufficient time and expense to survey the site must be allotted. However, there is not enough money or time to be *absolutely certain* that every possible area at a site has been characterized. Therefore, it is important to use intelligence when selecting survey points. The Pathfinder Plant used a grid and color code system for its survey points; areas anticipated to be contaminated used a smaller grid (and different color) than those areas that were unlikely to be contaminated. However, surprises must still be anticipated and accommodated.

Fort St. Vrain (FSV) hazards were characterized by taking 35,000 radiological data points. A bar code system was used to track the information, which made information retrieval relatively easy. Environmental characterization (such as EPA-type hazards and mixed waste) was also done. One of the changes that the FSV personnel would have made with respect to hazard characterization was to collect fewer data points. In reality, only 10,000 to 15,000 points were needed. However, plant personnel felt that, based on the hazard characterization, the decontamination activities were correctly prioritized.

A site radiological plan was developed to guide in the characterization of the Trojan Nuclear Power Station. The characterization activities were divided into four major areas - environment,

structures, plant systems, and activated systems. The environmental area included outside areas such as roads, ponds, and yards. For the environmental area, background radiation levels were measured, soil/sediment/water samples were taken, and ambient radiation dose rates were computed. The structural area included all buildings on-site. Plant personnel determined background radiation levels and surveyed for fixed and loose radioactive material.

The plant systems area was divided into four categories. The C1 category was *known contaminated*; these areas were surveyed to characterize the activity present. The C2 category was *potentially contaminated* based on previous data. The I category was *indeterminate*; therefore, these areas had to be surveyed and data obtained to determine the actual status. The N category was *clean systems*. However, the clean systems were surveyed to verify cleanliness, and smears and direct radiation readings were taken at selected locations. The activated systems area included those components that had been subjected to neutron flux such as the reactor vessel and shielding. Computer codes were used to verify activity and dose rates. The code output was then verified with actual surveys.

If short-lived radioactive isotopes are present, a safe storage period will result in a significant reduction in radiation and contamination levels.

For the Pathfinder Atomic Power Plant, approximately 20 years in SAFSTOR resulted in significantly reducing radiation and contamination levels. This was based on the short-lived radionuclides present at the plant.

The key decision to defer major decontamination during deactivation to SAFSTOR until years later, during DECON, reduced the worker dose at the Rancho Seco Nuclear Generating Station. Because of natural decay processes, the final worker dose is anticipated to be less, even though less knowledgeable workers will be involved in final decontamination activities.

To reduce radiation levels outside the Trojan refueling water storage tank (RWST), the tank is kept full of water. Inside containment, all ventilation and lighting is off. Prior to anyone entering containment, the building ventilation system is turned on for a day. There was no real incentive to do any up-front decontamination prior to entering SAFSTOR. About 4% of the facility was contaminated prior to SAFSTOR; the level in 1993 was around 3% and decreasing because of natural decay processes.

Use existing and enhanced radiological surveys to determine the radiation hazards present at a site. Subsurface soil sampling can be used to determine the depth (and type) of contamination.

At both the Rancho Seco Nuclear Generating Station and the Shippingport Atomic Power Station, existing and enhanced radiological surveys were used to establish the radiation hazards.

The Shippingport Plant found two isotopes, cobalt-60 and cesium-137 during a surface survey. However, the expected iodine-125 was not found. At Shippingport, on-site concrete surfaces were surveyed, and cobalt-60 made up more than 99% of the measured activity. The Rancho Seco Plant analyzed concrete and asphalt core bores, which showed that most of the activity at the site was located in the top 1/4 inch. At Shippingport, subsurface soil sampling was done; fifty 10-cm holes were drilled to depths ranging from 0.5 to 4 meters. Sb-125 was detected in these samples.

At FSV, the activation depth of the steel reinforced concrete containment top was found to be 11 ft instead of 3 ft as previously estimated. This meant that significantly more contaminated concrete had to be disposed of. The concrete blocks supporting the core were found to be 1000 times radiologically "hotter" than the decommissioning team had estimated.

The bulk of the waste at the nuclear power plants is LLW. The two most common sources of hazardous materials are asbestos insulation and equipment contaminated with PCBs.

At the Dresden Nuclear Power Station the primary source of radioactive hazardous materials is anticipated to be from asbestos insulation on contaminated piping and components. Other potential sources of hazardous materials include asbestos insulation on noncontaminated piping and components and transformers contaminated with PCBs.

Hazardous material identified at the Trojan Nuclear Power Station included some asbestos, and chemicals such as NaOH, hydrazine, and sulfuric acid. The total volume of mixed waste was small and included freon and freon filters, some oxalic acidem permanganates and chromium. The bulk of the waste at the plant, approximately 400,000 ft³, was considered to be Class A radwaste and included trash, concrete, piping, etc. Class C waste included resins and filters; Class B included various metals. Greater than Class C waste included the fuel and some portions of the reactor internals.

Measure background radiation levels at other sites that were built at the same time and that are similar in construction before committing to final background radiation levels.

At the Pathfinder Atomic Power Plant, NSP committed to a less than 5 microRem/h background radiation level. Because the plant was radiologically clean, NSP felt that this background level would be attainable. However, proof of this level could become very expensive. Background levels at the county courthouse, which was built at the same time and is similar in construction to the Pathfinder Plant, were measured at 8 microRem/h. In fact, the cleanest air in the area around the plant was at the air filters in the plant, not outside the plant, since radon is present in the area.

In establishing radiological clean-up levels for a facility or site, the Sacramento Municipal Utility District (SMUD) utilized Aerial Gamma Surveys performed by DOE before the plant was built to identify or establish the basis for pre-existing radiation levels.

Estimate the expected radiation exposures when planning a job. Have a system in place to ensure that the expected exposures are realistic and to ensure that specific actions that may be taken to reduce exposures have been considered.

The Humboldt Bay Power plant (HBPP) committed to maintaining ALARA exposures. An ALARA committee was created whose purpose was to review:

- radiation exposures for routine operations and maintenance and recommend future exposure reduction goals,
- planned jobs where potential exposures might exceed 500 mRem total for the job or 100 mRem for any individual and establish exposure limits and person-Rem goals for that job,
- completed jobs for achievement of goals and determination of future improvements,
- plant radiation and contamination levels annually and recommend future exposure reduction goals, and
- plant design changes and plant procedures for ALARA considerations.

Before the ALARA committee review of a proposed job, the individuals planning the job estimate the expected radiation exposures based on radiation surveys conducted in the area where the job will be performed and estimates of the time required to perform the job based on prior experience. These estimates are reviewed by the Radiation Protection Department. If the thresholds of 500 mRem for the total job or 100 mRem for any individual are expected to be exceeded, an ALARA checklist is completed for review by the ALARA Committee to document the consideration of specific actions that may be taken to reduce radiation exposures.

At the Shippingport Atomic Power Station, the Decommissioning Plan estimated that a 1000 man-Rem total radiation exposure for the work force would occur during the decommissioning project. The actual total personnel exposure accumulated was 155 man-Rem. Although the original estimate was conservative, dramatic reductions in exposures were because of good planning and ALARA practices.

Use training to indoctrinate workers with respect to safety; make it the responsibility of the worker to follow procedures and safety rules.

All radiation workers at HBPP receive, as part of their radiation protection training, an indoctrination in the principles of ALARA radiation exposure control. In this training, the responsibility of the individual worker to follow procedures and safety rules and to maintain individual exposure ALARA is emphasized. The principles of minimizing the duration of

exposure, maintaining distance from the source, and reducing source term are included in training.

3.2 Management/Programmatic Issues

Have a well-established facility endpoint before planning deactivation, SAFSTOR, and decommissioning activities.

Utility experience indicates that planning should be from the perspective of "what is needed" rather than "what is not needed." The more future use options left open, the more impact on deactivation planning. A good framework for SAFSTOR and decommissioning activities must be developed at the start of the project to allow efforts to be focused and approvals to be anticipated. Recognize up front that the facility will not be returned to "Greenfield." If possible, begin planning for facility decommissioning when the facility is still in operation. To improve the decommissioning planning process, one needs to identify "up front" where the facility will go, and focus on the plan without getting distracted.

After the decision was made to shut down the plant, SMUD established system lay-up plans to allow for possible future startup. The initial effort was to allow for plant preservation, and so wet chemical lay-up, similar to that used during outages, was employed. In addition, dry air was pumped through the secondary side of the plant. When it was certain that the plant would never be restarted, planning took place to evaluate decommissioning options. Because of limited funds and the lack of suitable high-level waste (HLW) storage facilities, the decision was made to transition to custodial SAFSTOR, build the independent spent fuel storage facility (ISFSF), transition to hardened SAFSTOR, and, finally, transition to decommissioning. To satisfy the NRC, SMUD committed to running the containment exhaust fans.

There is no unique defined SAFSTOR "end point."

During SAFSTOR all utility service to Pathfinder, except for a single breaker, was terminated. During the decommissioning phase, power was restored by running new lines. Battery-powered emergency lights were also installed. It was clear what to remove and what to leave alone - all new systems were painted orange, which meant *do not touch*. There were no other active systems in the decommissioning areas. The sequence used during the decommissioning phase was to remove asbestos, hazardous material, cables, piping, equipment, concrete, and structures.

There was no real incentive for Portland General Electric (PGE) to do any up-front decontamination prior to entering SAFSTOR.

Dresden 1 preparations for SAFSTOR include the following:

- Drain, de-energize, and secure all noncontaminated, nonessential systems;

- Remove filter elements and demineralize resin beds for shipment and burial;
- Drain reactor vessel (reactor vessel internals remain in place);
- Drain, de-energize, and secure all contaminated systems and decontaminate as required;
- Prepare the spent-fuel storage pool for long-term storage of fuel and provide for maintenance of fuel pool water chemistry;
- Maintain lighting, fire protection, heating, ventilation and air conditioning (HVAC), and alarm systems, as required, for continued use during SAFSTOR;
- Clean loose surface contamination from building access pathways; and
- Control access to radioactive or contaminated areas in accordance with normal station procedures.

During the plant's 30-year dormancy period, activities required include maintenance of a guard force, preventive/corrective maintenance on lighting and HVAC, general building upkeep, maintenance of structural integrity, and an environmental and radiological monitoring program. During the plant's dormancy phase, minimal radioactive waste is expected to be generated and will be disposed of at the other operating units (i.e., Dresden 2 and 3).

Systems and equipment not required by the HBPP Unit 3 operating license for the cold shut-down mode and not required to support deactivation activities were secured in preparation for SAFSTOR. Preparations included unloading the reactor core; draining, flushing, and securing systems; de-energizing instruments and controls no longer required; and isolating nonoperational from operational systems.

During deactivation to SAFSTOR at HBPP, systems no longer required by the revised technical specifications are secured and isolated. Systems required to support deactivation activities but not required during SAFSTOR are secured upon the completion of those activities. The objectives of the system lay-up are as follows, to:

- drain systems containing fluids to the maximum extent practical,
- remove or shield significant sources of radiation in areas routinely accessible during SAFSTOR,
- seal connections between secured and operating systems by either using blank flanges or by cutting and capping the lines to prevent operating system leakage from refilling a system that has been drained, and
- de-energize motors, valves, instrumentation and other electrical components associated with secured systems.

The primary drivers leading to the decision to go to SAFSTOR are economic.

The decision made by Northern States Power (NSP) to switch the Pathfinder nuclear power plant from a nuclear facility to a fossil-fueled plant was primarily economic. The costs for modifications to bring the plant up to code with respect to new safety requirements were prohibitive. In addition, in 1964, NRC specifications were constantly changing, and NSP saw

that *many* regulations would be added to the nuclear industry in the future, which would lead to cost increases.

HBPP selected the SAFSTOR alternative because (1) it was the most cost-effective alternative because of the lack of a federal repository for spent fuel, i.e., the fuel pool was needed for on-site storage of spent fuel, and (2) it allowed radionuclide decay so that when fuel dismantling takes place, occupational radiation exposures will be reduced. The use of SAFSTOR includes the temporary storage of the spent-fuel assemblies in the spent-fuel storage pool.

During the SAFSTOR period at HBPP, and until initiation of the final decommissioning program, necessary plant systems will be operated and maintenance performed on structures, systems, and components, as required, to ensure continued safe conditions within the plant. The maintenance program established for the safe storage period is a modified version of the plant maintenance program and includes both preventive and corrective maintenance.

The preventive maintenance program at HBPP provides for a regularly scheduled series of inspections, tests, and services for structures, systems, and components. The frequency of preventive maintenance is established on the basis of prior experience, ongoing operational use, plant conditions, and, where applicable, technical specification requirements. The objective of the preventive maintenance program is to ensure continued, reliable performance of necessary structures, systems, and components (equivalent to or better than the reliability existing at the beginning of the SAFSTOR period).

The corrective maintenance program at HBPP provides for analysis and appropriate action to be taken when performance of structures, systems, and components is determined to be degraded. Adequate stores of spare parts and servicing equipment are maintained to ensure that corrective action can be taken within the time frame required by the technical specifications.

Dresden 1 will be maintained in the SAFSTOR mode for as long as 30 years, or until Units 2 and 3 are decommissioned and dismantled. Since Dresden 1 is a shared site with operational Units 2 and 3, it can be safely and inexpensively maintained while allowing decay time, which will result in lower personnel exposures during dismantling. There is an expected savings in disposal costs for the highly activated components (i.e., the reactor vessel and internal components) because of the decay of short-lived isotopes. However, a delay in decommissioning reduces (but does not eliminate) the radionuclide inventory, and, at the end of its dormancy period, the facility will require extensive decontamination.

Because the plant was shut down prematurely, Trojan has collected only about \$33 million of the estimated \$400 to \$415 million needed to decommission the site. Therefore, considerable effort has gone into repowering and other alternate site uses.

One of the biggest disadvantages of placing a plant in SAFSTOR is the unavailability of knowledgeable station operations personnel at the time of actual decommissioning.

Commonwealth Edison Company (CECo) recognized that one of the biggest disadvantages of placing the plant in SAFSTOR is the unavailability of knowledgeable station operations personnel at the time of actual decommissioning. Therefore, a complete data base will be necessary for the preparation of engineering and the planning of decommissioning activities.

NSP recognized that it was fortunate to have some experienced personnel available to assist with the Pathfinder decommissioning. To avoid the loss of this invaluable experience, NSP recommended a SAFSTOR period of less than 20 years.

In the process of transitioning to SAFSTOR, utilities with only one nuclear unit (SMUD and PGE) provided financial incentives to retain experienced personnel during deactivation and SAFSTOR.

Staffing needs at Trojan are continually being re-evaluated as equipment and systems are taken out of service. Initial large decreases in personnel were handled via layoffs. For example, security personnel went from 175 in 11/92 to 25 in 12/93. Because of the limited availability of jobs within PGE, redeployment was limited to approximately 100 people, most of whom were moved laterally or demoted. Currently, there are monthly layoffs as the staff levels are approaching the near-term equilibrium level of about 200. A large number of licensed operators were able to move to Tennessee Valley Authority (TVA) facilities.

PGE's initial staffing plan was based on a compromise between staffing data obtained from Rancho Seco and Yankee Rowe, as well as the staffing needs requested by individual managers. Considerable discussion occurred among the senior managers regarding the final staff size and composition. The initial large layoffs were based on the curtailment of power generation and the need to continue to satisfy regulatory requirements. Later layoffs were based on receiving specific license changes. To encourage people to stay for four years, a retention plan was introduced that amounted to a bonus of 30% per year for each of the four years. However, staff using this plan *took their chances*.

A draft long-term Trojan plant organization chart shows that about 102 people are needed to maintain the plant in SAFSTOR. About 60 people are required for operations, maintenance, and radiation protection, 23 for security and administration, plus 19 in licensing and quality assurance (QA).

Staffing levels at SMUD were based on the estimated reduction in work load consistent with the reduction in technical specification requirements. Current staffing is about 150 (i.e., for custodial SAFSTOR). In 1998, when the plant achieves hardened SAFSTOR, employment will be down to about 30 people, about six of those will be security personnel.

Initially, low morale was a problem. Amazingly, SMUD never had to lay anyone off, even though site employment dropped from nearly 1000 in 1989 to about 150 today. SMUD was able to transfer people to other jobs within the utility or allow them time to find a suitable job elsewhere. Management provided financial incentives to certain key people to encourage them to stay to help with various deactivation phases. Other people were given one- or two-year contracts. Other incentives were the continuation of the operational nuclear pay bonus as well as a four-day work week.

Deactivation activities used normal staff personnel and operable systems. The attempt to keep all FSV staff was quite successful, only one person left when knowledge of the plant shutdown became known. The staff at the plant is much smaller now than when it was operating, but outplacement to other locations within the company avoided layoffs.

Multiple Unit Sites can provide for reduced surveillance and maintenance costs during SAFSTOR.

Dresden 1 will be maintained in the SAFSTOR mode for as long as 30 years, or until Units 2 and 3 are decommissioned and dismantled. Since Dresden 1 is a shared site with operational Units 2 and 3, it can be safely and inexpensively maintained while allowing decay time, which will result in lower personnel exposures during dismantling.

During the plant's dormancy phase, minimal radioactive waste is expected to be generated and will be disposed of at the other operating units (i.e., Dresden 2 and 3). Security forces will be personnel employed at Dresden Units 2 and 3 to prevent unauthorized entry. Detection and notification systems will be operated according to the station Security Plan. Maintenance will be provided by the full-time utility maintenance staff already employed at the site. The environmental program is a modified (i.e., abbreviated) version of the one used for normal operations.

Utilize the existing facility operating/maintenance infrastructure with some streamlining to manage deactivation and decontamination activities.

Personnel are familiar (and comfortable) with the existing facility work control processes, that is, the procedures, safety review processes, "plan-of-the-day" meetings, etc. Changing the existing work processes, even though they may seem cumbersome, may create more operational problems than the change attempts to solve. For example, preventive maintenance procedures should not be rewritten.

During decommissioning, utilize the same administrative infrastructure that was in use during operations, that is, procedures, QA plan, etc.

NSP had three levels of management at the site, which meant that one *always knew whom to call* when a problem developed. NSP Headquarters stayed in the background, providing funding and then trusting personnel at the site to get the job done. Site personnel resolved the details. NSP managed Pathfinder decommissioning with its own employees rather than hiring a contractor. The on-site crew remained lean throughout the project. When in-house labor was not available, NSP hired outside labor for the duration of the need. This management philosophy resulted in considerable savings to NSP.

During deactivation and SAFSTOR, both Pacific Gas and Electric Co (PG&E) and SMUD have chosen to retain the Site and Independent Safety Review panels in accordance with operating technical specifications.

Decommissioning was treated as little more than a typical outage at one of NSP's operating nuclear plants. However, stringent operational requirements were relaxed and adapted to the less stringent decommissioning environment.

The SMUD plant organizational structure consists of a Nuclear Plant Closure Manager with three direct reportees: an Operations and Maintenance Superintendent, an RP and Chemistry Superintendent, and a Quality/Licensing/Administrative Superintendent. These individuals manage all remaining operational activities.

Develop a Defueled SAR and technical specifications consistent with the facility SAFSTOR "end state" to provide a well-established "design basis" for deactivation.

Immediate cost savings are possible through reductions in the scope of the emergency, fire protection, security, training and insurance programs.

Shoreham will keep the reactor building ventilation system operable during decommissioning.

Trojan went from 146 technical specifications to four. The NRC approved "Certified Fuel Handler" program, which does not require licensed operators or simulator training, was adopted. In fact, only general employee training is provided to employees at this time.

Review TVA, EPRI, Navy and INPO experiences on system lay-up, that is, corrosion processes, galvanic concerns, passivation, chemistry, etc.

Utilities appear to employ different lay-up processes for facility piping.

A major effort at Trojan went into laying up the turbine and steam generators because these portions of the plant had commercial value if the plant could be repowered. The plant elected to maintain chemistry in the steam generators; therefore, wet lay-up was used. The reactor vessel was filled with water, thus providing shielding. Both TVA and the Institute of Nuclear

Power Operations (INPO) provided good sources of information on how to preserve and lay-up components, corrosion processes, galvanic issues, etc. The Electric Power Research Institute (EPRI) was a good source of information on how to preserve turbine and oil systems. To lay-up the turbine, fans and heaters were installed to keep the systems dry and minimize corrosion.

3.3 Requirements and Regulations Issues

Know the current regulatory requirements, standards, and guidance for deactivation, safe storage, and decommissioning phases and activities.

Dresden 1 decommissioning will be performed in accordance with current regulatory requirements, standards, and guidance prescribed by the NRC, DOT, EPA, and the State of Illinois. The worst case radiological release (from the stored spent fuel) was compared to the guidelines in 10 CFR 100. The applicable regulations¹ are 10 CFR 19, 10 CFR 20, 10 CFR 30, 10 CFR 40, 10 CFR 50, 10 CFR 51, 10 CFR 70, 10 CFR 61, 10 CFR 71, 10 CFR 73, 10 CFR 140, 10 CFR 150, 10 CFR 170, Regulatory Guide 1.86, Proposed Rule (Decommissioning criteria (2/11/85) for nuclear facilities), DOT Regulations 49 CFR 170-190, U.S. regulations 40 CFR 190, and 29 CFR 1910.

To determine the regulations and requirements applicable to the FSV site, letters were written to regulators discussing the decontamination process and requesting guidance. This seemed to work well. In addition, FSV worked with the EPA and the state on water quality issues, and there were letter agreements with the state on tritium releases (based on the water flow) to ensure that there was no misinterpretation. FSV has pages of regulations applicable to SAFSTOR and decommissioning (see Appendix B).

The radiological conditions at HBPP Unit 3 at the start of the safe storage period are in compliance with the Standards for Protection Against Radiation, 20 CFR 20. These standards do the following:

- Discuss the control of releases of radioactive materials to the environment and limitations of radiation doses to workers and the public,
- Provide limits on air and water effluent concentrations of approximately 250 radionuclides,
- Set limits of radiation exposure for individuals in both restricted (worker) and unrestricted (general public) areas,
- Describe ALARA (ICRP 26), and
- Remain applicable to HBPP Unit 3 until the license is terminated.

The waste management requirements applicable to the HBPP are as follows:

- 10 CFR 61, which sets forth the acceptance criteria of radioactive waste for land disposal. The NRC's technical position papers on radioactive waste classification and

waste form give guidance for determining compliance with Part 61. This regulation is applicable to all shipments of radwaste from Unit No. 3 to LLW disposal sites.

- 10 CFR 71, which establishes the standards of Type B, Fissile Class I, II, and III packages for packaging of radioactive material for transport and transportation of radioactive material.
- 40 CFR 260: Hazardous Waste Management System General; 40 CFR 261: Identification and Listing of Hazardous Wastes; 40 CFR 262: Standards Applicable to Transporters of Hazardous Waste.

HBPP also discovered that under the DOT Act of 1966, DOT has regulatory responsibility for safety in the transportation of hazardous and radioactive material. 49 CFR addresses packaging requirements, shipping papers, radiation level limitations, contamination control, labeling, placarding, storage, and transportation. Certain states have established agreements with the NRC and adopted 49 CFR regulations for intrastate shipments. Under certain conditions, the containers for radioactive waste must have a state's approval before transport within or across that state's boundaries.

Other applicable regulations include the following:

- 40 CFR 61 - National Emissions Standards for Hazardous Air Pollutants
- 40 CFR 122 - National Pollutant Discharge Elimination System
- 40 CFR 129 - Toxic Pollutant Effluent Standard
- 40 CFR 141 - National Interim Primary Drinking Water Regulations
- 40 CFR 190 - Radiation Protection Standards for Nuclear Power Operations
- 40 CFR 260 - The Resource Conservation and Recovery Act (RCRA) of 1976

OSHA has set standards limiting worker exposures to toxic substances, but these standards do not extend to the public. In addition to specifying permissible exposure limits for substances previously encountered, for example, metals, chromates, sodium hydroxide, sulfuric acid, solvents, and asbestos, additional regulations specify requirements for medical examinations, monitoring, methods to minimize airborne contamination, personal protective equipment, personal hygiene, signs and labels, access control, training, and waste disposal. 29 CFR 1910 also regulates radiological exposure and directly references 10 CFR 20. California OSHA regulations are consistent with 29 CFR 1910.

Develop acceptable site release criteria and methodology for release of the site (and the materials present at that site) for unrestricted use.

During decommissioning planning at FSV, significant focus was directed toward the development of the site release criteria and methodology for both release of the site for unrestricted use and materials off-site. The U.S. does not have a lower "limit" for radioactivity. It was important to develop an acceptable methodology that would receive regulatory acceptance since the dismantlement/decontamination approach selected would not result in a

"bare walls" plant after completion of physical decommissioning. An educated guess was made on what reasonable exposure limits were for radiological and hazardous material, and then the appropriate regulatory agency was contacted to verify it.

Most often cited in the Shippingport literature with respect to requirements and regulatory issues was the lack of a complete set of reasonable and acceptable criteria that covered the release of materials. The decommissioning contractor for the plant was asked to estimate the cost trades for reducing future doses from the site to no more than 100, 25, and 10 mRem/year to the public. One of the interesting goals of this site release criteria effort was to develop a criterion that would result in low cost of remediation and a low dose to the public. The studies for Shippingport indicated that doses to the public could be limited to 10 mRem/year. The release criterion was finally established for the site based on a dose of 100 mRem/year to maximum exposed individuals plus ALARA (to 10 mRem/year).

As soon as possible after a shutdown decision, revise work processes, technical specifications, and the SAR to be consistent with the new status of the facility.

Once the Trojan Plant was granted its POL, PG&E revised the emergency and fire protection plans to be consistent with the new defueled condition of the plant. There was a lot of monetary savings related to reducing the scope of these plans. No off-site emergency plans, sirens, or support were kept. The SAR was reissued and technical specifications were prepared for the new plant status. The revised SAR or Defueled Safety Analysis Report (DSAR) provides a revised "design basis" for the plant on which the 10 CFR 50.59 change process can be based.

Trojan went from 146 technical specifications to four. The NRC-approved "Certified Fuel Handler" program, which does not require licensed operators or simulator training, was adopted. In fact, only general employee training is provided to employees at this time.

In the area of fire protection, PG&E went from an Appendix R program to an NFPA industrial program. Property insurance for the Trojan Plant averages \$4000 per day, which PG&E is attempting to change because the hazards have been reduced significantly. PG&E believes that, after a three-year hold period, it may be able to get relief from Price Anderson Liability considerations. The Appendix B QA program has been maintained, again consistent with the plant status.

One of the activities undertaken at Rancho Seco to achieve SAFSTOR was a study of heat generation in the spent-fuel pool. The study concluded that there was no safety requirement for the emergency diesel generators or for a backup cooling system. The study also concluded that the auxiliary building exhaust fan must be placed into service if spent-fuel cooling is lost. This study required about 1.5 man-years of work. Throughout the planning process, SMUD had to fight the "nuclear safety mentality" to identify new design-basis accidents or to upgrade the importance of various systems, such as spent-fuel cooling.

<i>Evaluate the environmental impact of proposed activities.</i>
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The NRC requested that YAEC evaluate the environmental impact of the proposed activities relative to the conclusions in the NRC Final Generic Environmental Impact Statement (GEIS) (NUREG-0586). The important GEIS conclusions, as they relate to component removal activities being considered by YAEC, are as follows:

- The environmental impact of decommissioning nuclear facilities is similar to or less than those created during construction and operation.
- Both DECON and SAFSTOR are reasonable alternatives for decommissioning light water power reactors.
- The occupational exposure for DECON is higher than for SAFSTOR, but similar to routine operation.
- The higher DECON occupational exposure has marginal significance to health and safety.
- The LLW burial volume is typically less for SAFSTOR than DECON because of the decay of radioactivity from the time the plant shuts down until final dismantlement begins (burial volume reduction is recognized in the GEIS after a 50-year SAFSTOR period). This benefit is not uniquely compelling when selecting a decommissioning alternative.

YAEC provided the NRC staff with an Environmental Report (ER) which addressed all important aspects of the environmental impact from operation of YNPS, including plant modifications. The NRC environmental assessment included an evaluation of the following considerations:

- Radiological impacts of the hypothetical design basis accident,
- Radiological impacts - annual releases,
- Environmental impact of the uranium fuel cycle,
- Nonradiological impacts, and
- Plant modifications.

These licensing basis considerations are evaluated in the YAEC 10 CFR 50.59 design change process, which is being implemented for the component removal activities currently in progress. It is fully expected that the environmental impact of the component removal activities will be bounded by the conclusions in the EIS for the following reasons:

1. The GEIS conclusions are based in part on the assumption that programs and procedures to minimize environmental impact during plant operation are fully effective during decommissioning. YAEC will ensure that these programs are maintained during all phases of decommissioning.

- a. Occupational exposure at YNPS is controlled through existing programs and procedures. The design change process ensures that ALARA considerations are integrated into the final design and implementation plan from the outset. The Radiation Protection and ALARA programs used during plant operation will continue through all phases of decommissioning.
 - b. The YNPS Environmental Monitoring Program will continue to be implemented through all phases of decommissioning. Plant effluent discharges will continue to be controlled and monitored under existing programs and procedures.
 - c. Both liquid and solid radwaste processing, handling, packaging, and transportation will continue to be controlled by existing programs and procedures.
2. The potential environmental impacts of postulated accidents are thoroughly evaluated and documented during the design-change development process. The safety evaluation, conducted in accordance with 10 CFR 50.59, and in conjunction with the design-change development will ensure that the proposed activities requiring NRC approval prior to implementation are properly identified and documented.
 3. The activities under consideration have been completed under 10 CFR 50.59 by operation of facilities using a process similar to the YAEK design-change process.

When translating operational technical specifications to safe storage operation and maintenance requirements, evaluate systems by asking, "Does it make sense to keep this system tech speeded?"

When FSV looked at translating operational technical specifications to SAFSTOR operation and maintenance requirements, the systems involved were evaluated with respect to their technical specifications. The question asked for each system was, "Does it make sense to keep this system tech speeded?" Engineering judgment was used to classify whether the systems should or should not be tech speeded.

There is a lack of guidance for safe storage radiological limits.

As pointed out by the Rancho Seco Plant, one of the major problem areas for a nuclear power plant facing deactivation is the lack of guidance for SAFSTOR radiological limits. Each facility seems to be defining its own safe storage (SAFSTOR) state, consistent with its situation with NRC concurrence. Since there is no radiological guidance, SMUD chose basically to leave the plant as it was during operations for SAFSTOR. Similarly, Trojan saw no incentive to decontaminate the plant prior to entering SAFSTOR.

A cost/benefit analysis on current regulatory requirements can be effectively used with regulators to negotiate compromises.

If FSV were required to meet 10 CFR 50 Part 20 (Radiation Protection Guides), costs would be increased by 5%. A cost/benefit analysis was done for the allotted time periods and the results were presented to the regulators. The impact the regulations would have on the costs, etc. was clearly shown and a compromise was made.

The decision to switch the Pathfinder Plant from a nuclear facility to a fossil-fueled plant was primarily economic. The costs for modifications to bring the plant up to code with respect to new safety requirements were prohibitive. In addition, in 1964, NRC specifications were constantly changing and NSP saw that *many* regulations would be added to the nuclear industry in the future, which would lead to cost increases.

Passage of the 1980 Low Level Waste Act and its 1985 Amendment allowed burial surcharges. Plant owners were looking at losing access to LLW burial and the coming of time limits. The longer NSP waited to bury its LLW, the higher the cost. If disposal of the reactor vessel was postponed for a year, the cost increase was anticipated to be \$1 million. In addition, NSP would be required to use a Type B container, which would significantly increase costs.

The establishment of release criteria for the Shippingport Plant was not a "cut and dried" procedure based solely on regulations; maximum limits and ALARA should also be applied. However, the establishment of a release criterion could be the most sensitive parameter in the cost-benefit equation of any decommissioning site.

If a site has multiple units, evaluate all units with respect to potential releases.

Dresden 1 amended its facility license to include specifications for the SAFSTOR period. Although no iodine will be released from the shutdown of Unit 1, small releases could potentially occur from the adjacent Units 2 and 3 through the Unit 1 turbine building. Therefore, the Dresden 1 chimney will continue to be monitored. Airborne effluents from Unit 1 have been added to those from Units 2 and 3 and are included in the total site dose. Liquid radioactive effluents will not be released from Unit 1 to the environment but may be released from the radwaste systems for Units 2 and 3 and will meet applicable regulations.

Utilities can initiate preliminary decommissioning/deactivation activities prior to NRC approval of a Decommissioning Plan.

At FSV and Trojan, using 10 CFR 50.59 certain decommissioning activities were undertaken using plant operating Technical Specifications prior to US NRC review and approval of a Decommissioning Plan.

3.4 Risks at a Transitioning Facility

There are no significant radiological risks to surveillance and maintenance personnel because of placement of facilities in SAFSTOR. However, risks from degradation over time of equipment and facilities are of concern.

There were no significant risks to surveillance and maintenance personnel from the placement of the facilities in SAFSTOR at the Rancho Seco Plant. Hot spots continue to be a radiological concern that will reduce with time. Some potential for equipment degradation and leaks exists because of reduced preventive maintenance. SMUD knows that certain roofs leak, but no effort is being undertaken to improve the situation, and there are some problems with pigeons. As part of the SAFSTOR decision, SMUD chose to maintain containment ventilation to prevent the buildup of molds and fungi to avoid future health risks that might increase if things were welded shut. The only safety related equipment kept operational at the plant were those associated with operation of the spent-fuel pool.

For the Trojan Plant, PG&E worked with EPRI and a consultant (Decision Focus, Inc.) to employ a decision-analysis approach to prioritizing decommissioning alternatives. The prototype model performed a high-level economic analysis focused on timing and prioritizing decommissioning activities and understanding risks and uncertainties associated with decommissioning. Options such as SAFSTOR and DECON can be evaluated considering waste costs, timing of component removal, and radiation levels. The study also had the capability to evaluate transportation risk.

When developing the safety plan for the Trojan Plant, general considerations included the following:

- Retaining existing barriers and alarms and redesignating areas based on the contents,
- Keeping the boundaries the same for EP, RP, and security areas,
- Co-assigning duties,
- Reducing service levels (i.e., "on-call" rather than "always there"), and
- Working with OPS, RP, maintenance engineering, EP, etc.

As a result of the security plan, the staffing levels went from 175 to 110 to 36 to 25 (for fuel in wet storage). There was a minimal impact on work being performed at the site.

At the Pathfinder Plant, nothing that would deteriorate during the SAFSTOR period, as long as no water was present, was left. Even though very little water was present, some equipment did rust. However, it was never going to be used again so it was inconsequential. In case it became necessary during the SAFSTOR period to enter the areas in storage, a breaker was left in place.

Inside containment at the Trojan Plant, all ventilation and lighting are off. Prior to anyone entering containment, the building ventilation system is turned on for a day. PG&E felt that there was no real incentive to do any up-front decontamination before entering SAFSTOR. About 4% of the facility was contaminated prior to SAFSTOR; the level is now around 3% and is decreasing because of natural decay processes.

Evaluate the non-nuclear as well as nuclear hazards. Most accidents occurring during the SAFSTOR and decommissioning phases are normal industrial-type accidents.

FSV performed a PRA for nuclear and non-nuclear hazards. The main hazards identified included fires, tornadoes, and industrial-type accidents. When evaluating FSV's accident scenarios, fire was the most threatening with respect to radiological releases to workers and to the public. It was also more likely to occur. If a scenario had a likelihood of occurrence of less than $1E-4$ it was ignored. However, if its likelihood was greater than $1E-3$, design, surveillance, etc., were used to ensure that it would not occur. There were no significant radiological risks to surveillance and maintenance personnel, and primarily industrial-type risks are present.

At the Pathfinder Plant, the only accidents that occurred during the SAFSTOR and decommissioning phases were normal industrial-type accidents. Training and protective equipment (e.g., safety glasses and steel-toed boots) were used to help alleviate these types of accidents.

Potential accidents evaluated at HBPP during the SAFSTOR period have a low probability, are few in number, and are of minor consequence in comparison to accidents associated with reactor operations. The more severe accidents that could be credible during SAFSTOR operations were analyzed and are the following:

- Spent-fuel handling accident,
- Any event rupturing the spent-fuel storage pool,
- Heavy load drop into the spent-fuel storage pool,
- Uncontrolled release of radioactive liquid radwaste tankage to the environment, and
- Explosions, delayed ignition of flammable vapor clouds, release of toxic chemicals, or fire.

There were no significant risks to surveillance and maintenance personnel from placing the facilities into SAFSTOR. Hot spots will continue to be a radiological concern that will reduce with time. There is some potential for equipment degradation and leaks because of reduced preventive maintenance. SMUD knows that certain roofs leak, but no effort is being undertaken to improve the situation. There are some problems with pigeons. As part of the SAFSTOR decision, SMUD chose to maintain containment ventilation to prevent the buildup of molds and fungi and avoid future health risks that might increase if things were welded shut.

SMUD and the Rancho Seco Plant had some advice regarding accident analyses: do not spend time trying to "create or invent" new hazards or scenarios. Remember that the plant was licensed to operate, that bounding accident analyses were performed to obtain that operating license, and that long-term operation of the spent-fuel pool was considered in the operating license. The current safety basis is loss of spent-fuel pool inventory, dropped assembly, and station blackout or loss of off-site power.

Attempt to lower significant risk as much as possible during deactivation and decommissioning activities.

FSV attempted to lessen significant risk as much as possible during deactivation and decontamination activities. Fire doors were left in place, radiation monitoring and fire protection systems were operable, an *intelligent* maintenance program was still in effect, and component reliability was being tracked.

When looking at the SAFSTOR and decommissioning phases at the Pathfinder Atomic Power Plant, the activities that had the most risk, albeit small, were those involved in preparing the vessel for shipping and the shipping itself. Hospitals and emergency personnel were contacted along the shipment route to ensure that the vessel contents were known and that preparations could be made for potential accidents.

Look at the potential hazard implications of removing a system from service before deactivating it.

FSV looked at the potential hazard implications of removing a system from service before it was deactivated.

Limit the number of vital areas and access to them.

At the Pathfinder Atomic Power Station, one of the requirements for SAFSTOR was that an operator or a security person be present at the site 24 hours a day. NSP employed one operator during the day and security personnel for the remainder of the 24-hour period.

The security plan before the Trojan Plant was shut down encompassed a protected area and approximately 30 vital areas. There were approximately 10 areas established as "critical sabotage" targets. Once the plant shutdown was started, PGE reduced the number of vital areas (and access to them).

The choice of a particular decommissioning alternative is generally driven by the availability of funds to complete decommissioning, access to a HLW repository, the availability of an LLW disposal facility for decommissioning wastes.

As the Yankee Rowe Plant indicated, the choice of a particular decommissioning alternative is generally driven by the availability of funds to complete decommissioning and the availability of an LLW disposal facility for decommissioning wastes.

The availability of sufficient funds could adversely affect a licensee's ability to decommission the facility safely. It may be necessary to SAFSTOR the facility until adequate funds are available to ensure completion of the process. Although sufficient funds may be available to complete decommissioning, a LLW site may not be available for disposal of decommissioning waste. This was the primary reason for YAEC's decision to SAFSTOR YNPS until the year 2000. Until recently, access to all of the existing LLW burial facilities was closed to out-of-compact generators, such as YNPS, beyond January 1, 1993. The State of South Carolina recently indicated that the Barnwell facility will remain open to Massachusetts generators through June 30, 1994. This decision allowed YAEC to consider equipment removal and disposal activities designed to take full advantage of the burial site availability.

Appropriate controls, programs, procedures, systems, structures, and components necessary to preclude inadvertent public exposure or spread of contamination must be maintained until the site is released for unrestricted use.

The primary objective of the SAFSTOR alternative is to preclude inadvertent public exposure or inadvertent spread of contamination while awaiting final dismantlement. This objective remains as long as the plant contains radioactivity above residual levels permitting unrestricted use of the facility. This safety objective continues until the final radiation surveys are completed to demonstrate that the radioactivity has been removed to residual levels permitting unrestricted use of the facility. Therefore, appropriate controls, programs, procedures, systems, structures, and components necessary to preclude inadvertent exposure or spread of contamination must be maintained until the site is released for unrestricted use.

Removal of these components clearly does not foreclose the SAFSTOR option because the need to protect the worker, the public, and the environment will remain after the components are removed, and until the site has been restored to residual levels permitting unrestricted use of the facility and termination of the license.

Fundamental to this discussion is the fact that either decommissioning alternative, DECON or SAFSTOR, is acceptable provided it is implemented in such a way that protects the public, the worker, and the environment during execution, and ultimately results in release of the facility for unrestricted use. The choice of either alternative will generally be made because of

extenuating circumstances surrounding a licensee's unique situation at the time the decision is made to cease power operations and begin decommissioning.

During the safe storage period, mark, shield, or protect using physical barriers all accessible areas that have radiation levels above those deemed safe.

During the safe storage period for the Dresden Plant, all accessible areas within the facility that have radiation levels above 5mRem/h will be marked, shielded, or protected by physical barriers.

3.5 Cost Increases and Uncertainty

Prompt decontamination and dismantlement is the current least cost option for many single unit nuclear utilities given that adequate funding has been set aside and that a HLW repository is available. Lacking availability of a HLW repository and/or sufficient set-aside funding, SAFSTOR appears to be the only reasonable option.

Prompt decontamination and dismantlement is the current least cost option for Trojan given that adequate funding had been set aside and that an HLW repository was available. Prompt DECON utilizes existing personnel with specific knowledge. The attitude of PG&E staff was, "We built it, we can tear it down." This option takes advantage of known LLW costs.

FSV decided to pursue the early dismantlement option based on the following major considerations:

- Future risks of the SAFSTOR process cannot be quantified (such as the regulatory environment, public attitude, and waste disposal).
- There are continuing long-term costs for the SAFSTOR option (maintenance, security, testing, etc.).
- Risks for early dismantlement are more quantifiable (fixed price bids, regulatory environment, public attitude toward waste disposal).
- There are no continuing long-term costs for early dismantlement (FSV ceases to be a liability).

FSV concluded that the decreased radioactivity level of waste during SAFSTOR and the corresponding decrease in disposal costs would not outweigh potential increases in volumetric waste disposal charges.

The schedule developed for the Dresden Decommissioning Plan indicates that preparation for SAFSTOR will take one year to complete (from the date of NRC approval of the Decommissioning Plan) and cost \$18,424.8 (in thousands). The dormancy period will be approximately 17 years but will depend on the decommissioning schedule of Dresden Units

2 and 3. The expected end date is December 2017, and the estimated cost is \$98,247,400 (about \$6 million/year). The methodology used in the cost estimate included a 25% contingency and was based on the AIF/NESP-009 study report, "An Engineering Evaluation of Nuclear Power Reactor Decommissioning Alternatives" and the DOE "Decommissioning Handbook." The decommissioning schedule was prepared using Microsoft Project for Windows.

The actual decommissioning costs of the Pathfinder Plant were \$13 million. The cost breakdown amounted to about one third each for engineering and planning, waste disposal, and labor. Pathfinder Plant personnel emphasized how important it is to know what the disposal costs will be. Without knowledge of disposal costs, optimal decommissioning strategies cannot be chosen. The landfill costs charged by US Ecology were \$30/ft³ for burial plus a \$40/ft³ surcharge.

The 30-year delay for Dresden adds uncertainty to the decommissioning process. Since most of the decommissioning activities will occur 30 to 60 years after plant operations, cost estimates made now, based on current prices, technologies, and regulations are very susceptible to change.

Because of the premature shutdown of the Rancho Seco plant and the lack of funds set aside for decommissioning, a delay in final decommissioning was necessary. In addition, the lack of a final repository for the spent fuel necessitated a deferred decommissioning effort. SMUD chose not to do extensive decommissioning activities during deactivation to SAFSTOR to avoid what they considered to be unnecessary radiation exposure. Deferring decontamination activities until the actual decontamination phase will reduce overall exposure.

The major economic consideration that influenced SMUD's decommissioning decision was the lack of set-aside decommissioning funds to fund the effort properly and potential rate shock if an aggressive decommissioning were undertaken.

Transitioning HBPP into the custodial SAFSTOR mode is estimated to cost approximately 414 million. This total includes costs for the following activities:

- Surveys and analyses to perform radiological characterization,
- Preparation of the SAFSTOR Decommissioning Plan, Environmental Assessment Report, and Draft Dismantlement Plan,
- Labor and materials associated with the unloading of fuel from the reactor vessel and the securing of plant systems no longer required by the operating license, and
- Processing, packaging, shipment, and disposal of radioactive wastes at the site.

Cost estimates were prepared based on the detailed work breakdown schedule developed at the outset of the project. Estimates were based on experience in performing similar activities at HBPP and known plant labor and material costs. Costs to perform the SAFSTOR

decommissioning of HBPP have been included in PG&E's Nuclear Plant Operations budget and the project.

During the SAFSTOR period, funds will be required to maintain the unit in accordance with the POL and associated technical specifications. Maintenance and surveillance activities during the SAFSTOR period will be similar to activities conducted during operation, but reduced in scope. Funds for SAFSTOR costs will be allocated in the HBPP annual operations and maintenance budget. CPUC has authorized that the operation and maintenance expenses, including certain expenditures of SAFSTOR activities, be recovered in rates.

LLW burial costs represent the major portion of, and uncertainty in, projected decommissioning costs.

Uncertainties in LLW costs are the major factor in the overall decommissioning of Rancho Seco. Original estimates were \$1.00/ft³. Current estimates exceed \$440/ft³ at Ward Valley, assuming a 1996 opening. Based on an estimated 7300 yd³ of LLW, SMUD estimates about \$100 million for LLW disposal costs and recognizes that costs might go higher. If funding were available and if the DOE high-level storage facility were available, they would prefer to decontaminate immediately. This is the lowest cost option.

To address further the uncertainties associated with LLW storage, SMUD constructed a \$5 million LLW storage building in case Ward Valley does not open or is delayed. The present capacity is 50,000 ft³, which should be sufficient for five years.

To reduce SAFSTOR costs, SMUD is planning to build an on-site ISFSI to store the reactor fuel in dry casks that in the future would be transportable to a permanent DOE high-level storage facility. SMUD wants the dry storage casks to be certified to 10 CFR 71 for transport and final storage. SMUD estimates that it will cost \$16 million to build the ISFSI. The ISFSI operating costs will be about \$2.6 million/yr as compared with \$10.6 million to keep the spent-fuel pool operating. The major cost savings will be in operating and maintenance personnel.

SMUD used an experienced contractor to provide cost estimates for the entire decommissioning effort, including custodial and hardened SAFSTOR. For custodial SAFSTOR, TLG estimated \$10.6 million/yr in 1991 dollars. For hardened SAFSTOR, TLG estimated \$2.5 million/yr in 1991 dollars.

The cost of LLW disposal and storage for Trojan is increasing. In February 1993, the rate charged by US Ecology was \$52.65/ft³; the rate at the time the authors of this document received documentation was \$55.52/ft³. Future burial costs may be impacted by NUREG 1307, "Escalation of Decommissioning Waste Disposal Costs at Low-Level Waste Burial Facilities." Barnwell will add a fee of \$12.60/ft³ effective on January 1, 1994, for a Site Closure Fund. US Ecology's rates currently include a Perpetual Care and Maintenance Fee of \$1.75/ft³.

PGE has four steam generators and a pressurizer classified as Large Component Removal, with a burial volume of 48,000 ft³ (which is approximately 13% of the total decommissioning volume) and a cost estimate of \$15 million.

Decommissioning cost uncertainties at Trojan are caused by the rate of escalation of burial costs, the storage period for the spent fuel, and changing NRC and other requirements. The largest cost uncertainties are associated with LLW. In 1993 dollars, the burial costs of the LLW at the Trojan Plant are \$30 million. As time passes, this estimate increases.

Despite the fact that FSV was essentially radiologically clean, the cost estimate was \$186 million. Burial costs for the estimated 79,000 ft³ of waste were set at \$240/ft³ (1992 costs).

Cost estimates at FSV were based on the AIF/NESP "Guidelines for Producing Commercial Nuclear Power plant Decommissioning Cost Estimates," the PNL report "Technology, Safety, and Cost of Decommissioning a Reference Boiling Water Reactor Power Station," RG 1.159 "Assuring the Availability of Funds for Decommissioning Nuclear Reactors," and the DOE "Decommissioning Handbook."

The total costs in 1974 for the 36-month Fermi Decommissioning project were \$7,164,988. Approximately 44.2 million of the decommissioning costs were paid to the AEC for core reprocessing, blanket reprocessing, and use charges during decommissioning. The personnel exposure was 28.04 man-Rem or \$255,527 per man-Rem. It was estimated that 5,000 Ci were handled during decommissioning for a cost of approximately \$1422 per curie or 178.3 Ci per man-Rem.

Even though decommissioning Fermi took longer than anticipated, the additional expense was offset by the rapid reduction in work force. The final cleanup in 1975 was accomplished with a very small work force. Retiring buildings and equipment as soon as they were not needed resulted in savings in property taxes and insurance.

A major contributor to the cost of decommissioning Dresden is the disposition of radioactive wastes. The cost study assumed that a burial site will be available in the Central Midwest Compact within 375 miles of Dresden 1. The base burial rate was estimated on current costs and projections for the Central Midwest Compact site with the surcharge structure of the existing operating burial ground (Barnwell, SC). The cost of burial at this future site was based on an assumed burial rate of \$350/ft³ rate schedule and supplemental costs provided by Chem-Nuclear for its site in Barnwell, SC. Historically, costs for LLW disposal have risen at a higher rate than inflation. Shipping costs are sensitive to fuel-cost changes and distance to the disposal facility. Removal costs depend on the amount of remotely-operated equipment available in the future when dismantling occurs and the higher cost of that equipment versus the savings in labor costs.

With the passage of the 1980 LLW Act and its 1985 Amendment, the Pathfinder plant owners were looking at losing access to LLW burial and a significant increase in LLW burial costs

(which would continue to escalate as time passed). In addition, by waiting, it was highly possible that the reactor vessel could no longer be packaged in a Type A container. If a Type B container had been required, costs would have risen significantly, and transportation of the package by railcar would not have been possible. Significant analyses are required by requirements and regulations for waste packages.

Final decommissioning costs are dominated by the projected costs of LLW disposal. The escalation in LLW disposal costs as well as the uncertainty in future costs make it extremely difficult to plan and schedule. Federal and state leadership is needed to solve this problem. Fortunately, DOE facilities are not likely to be impacted by this.

The availability of cheap low-level radioactive waste storage must be considered in Decommissioning Plans.

A hazard evaluation should be performed as early as possible to assist with the planning process.

Pathfinder's experience indicates that it is important to perform the hazard evaluation process early, as part of the planning process. The decommissioning process cannot be determined until the hazards have been characterized. LLW costs are the cost driver. LLW is tied to high costs. The waste types and volumes must be known.

During SAFSTOR, the Price-Anderson Act liability continues.

At FSV, during SAFSTOR, the Price Anderson Act will require up to a \$79 million payment in the event of a catastrophic accident at another nuclear plant. With DECON, PSC's financial liability associated with the Price Anderson Act is minimized.

Significant differences in decommissioning costs for similar facilities are possible.

The decommissioning cost for Shippingport (1986-1989) was \$98 million while the cost to decommission Pathfinder in 1990-1991 was \$13 million. In both cases, the utilities were able to ship the reactor vessel intact to Hanford. Waste disposal costs varied significantly, i.e., \$5/ft³ for Shippingport versus \$70/ft³ for Pathfinder.

The decommissioning cost estimate for Shoreham, a radiologically clean facility (i.e., 602 curies, except for fuel), was estimated at \$186 million in 1991 dollars.

Contracting environmental monitoring tasks to specialists led to substantial cost savings (when compared to the costs of training and paying site personnel to perform the tasks).

At the FSV, during decontamination activities, site health physics personnel were used for radiation monitoring, and environmental monitoring was done by specialists. Contracting the environmental monitoring tasks to specialists led to substantial cost savings (when compared to the costs of training and paying site personnel to perform the tasks).

3.6 Stakeholder Concerns

Anticipate stakeholder reactions (and make contingency plans).

The removal of the spent fuel from the FSV was the responsibility of PSC even though DOE, as the owner, was committed to taking possession of the fuel and storing it. The utility intended to begin defueling and shipment of the fuel to INEL in early 1991. However, Governor Andrus, of Idaho, strenuously objected, and a series of legal maneuvers ensued. The fuel was scheduled to be removed and shipped to permit the start of decommissioning in January 1992, these complications delayed that schedule. However, the utility had foreseen this possibility and had moved ahead with construction of an ISFSI in February 1991 and received an operating license in November 1991.

The shipping of Yankee Rowe's two steam generators to Barnwell in November 1993 generated some public interest and concerns, as evidenced by about 50 protesters following the dedicated shipment train. Protestors were from the Citizens Awareness Network and Greenpeace International.

It is important to have an effective program for sharing information with the local community and government.

At FSV, groups from the local community were invited to visit the site, and children were included in these invitations. Senior FSV personnel went to meetings in the community to answer questions about what was being done and planned at the plant. News flyers were sent out quarterly to the local community sharing plant information, and discussions included what FSV was currently doing and what had been done. Communications with the nuclear community—local, society, industrial, and environmental groups—also occurred. Routes used to transport waste were not disclosed; however, studies done to determine "acceptable societal risk" with respect to these routes were discussed.

The Pathfinder Plant did not have large groups of public intervenors who were concerned about whether the plant was *doing it right* (i.e., performing appropriate decommissioning activities safely). However, a local woman, who was very concerned about the plant's activities, was

kept in the decommissioning information loop. She was shown around the plant, and time was taken to explain what was going to be done and why. A "written agreement" was made between her and the plant that was a commitment to work together to resolve concerns. Her concerns were basically the same as the plant's, so the only real change for the plant involved adding her name to the mailing list.

NSP's South Dakota Region personnel made considerable efforts to keep the Sioux Falls media fully informed on the decommissioning progress of the Pathfinder Plant. As a result, the shipment via railcar of the reactor vessel to its final storage destination started smoothly. The positive reporting by the media at the beginning of the transit resulted in keeping the whole shipment in perspective. NSP invited members of the Sioux Falls media to the Pathfinder site for the vessel sendoff. Later, during the transit, most television and radio stations knew that the train was coming through their town, so local news broadcasts carried a story about it. For the most part, the broadcasts contained factual and fair coverage of the event. Beyond Sioux Falls, outside interest was generally confined to curiosity seekers and passersby. The public treated the shipment for what it was: a big, heavy package that was not a problem. It was not a radiation threat and it did not endanger health and safety.

During shipment of the reactor vessel, a satellite tracking system was used to maintain contact with the train at all times. Courtesy and information calls were made before, during, and after the shipment to cognizant state and federal agencies. One question NSP was determined to be able to answer was, "Do you know where the train is right now?"

Another effective public relations tool for the Pathfinder Plant was through the use of decommissioning baseball caps. These caps were given out to the involved public and seemed to help the public feel more like an *owner* in the project.

NSP believes that the lack of concern exhibited during transport can be attributed to advance publicity and communications. For over a year, state and local officials, as well as news media and the public, were kept informed on NSP's plans. Maps, pictures, descriptive data, question and answer sessions, local visits, and public meetings helped answer concerns and alleviate potential problems.

At the Rancho Seco Plant, SMUD held public meetings to discuss its decommissioning plans, but there was little public concern or interest. This was in contrast to the interest by the public and "anti-nuclear proponents" in shutting down the plant. SMUD also used newspaper advertisements to try to identify any public concerns.

The YAEC Public Affairs Department at the Yankee Rowe Plant is currently developing a comprehensive public information program for planned decommissioning activities. The program will include the following:

- Meetings with local, state, and federal elected officials,

- Meetings with representatives of federal, state, and local agencies that are responsible for public health and safety,
- Public information forum(s) held in the vicinity of the plant site,
- Briefings to the local, regional, and/or national news media, and
- Slide presentation(s), information packets, and news media kits.

YAEC will ensure dissemination of information to elected officials, the general public, and news media regarding activities that YAEC believes would elicit public interest. In addition, YAEC will be working with the administration of the Greenfield Community College to improve the organization and documentation access capabilities in the Public Document Room at the college.

Create a good working relationship with regulators.

There was considerable confusion resulting from an NRC request for a "safety analysis" for dismantlement of FSV. The term safety analysis was commonly used for analysis of off-site doses. After considerable internal discussions, staff concluded that what the NRC was probably looking for was the occupational radiation exposure estimates. Telephone conversations with the NRC were not successful in determining exactly what was required. Based on the concern that the right question was not being answered, and an inability to resolve the issue, utility upper management met with NRC management and arranged another meeting. An all-day presentation was prepared to "sell" the NRC on what was deemed appropriate. The meeting was a success, and it convinced the NRC that only a small number of decommissioning activities were of significant concern and required any detailed explanation. The meeting was more of a success, however, because it brought the involved NRC and FSV personnel together in a detailed discussion and convinced the NRC that FSV personnel were extremely knowledgeable and competent and that the type of details the NRC was interested in were being covered. The overall result of the meeting was creating a much better working relationship. In addition, NRC and FSV staff committed to weekly conference calls to answer questions and discuss the status of the plant. A significant level of NRC staff was involved in each telephone conference. The conference calls were extremely successful in expeditiously answering questions, explaining details, and, in many instances, eliminating time-consuming written responses.

The Pathfinder Plant emphasized the importance of public relations (PR). NSP PR personnel were involved in the decommissioning project from the beginning. The Governor of South Dakota and the head of the Department of Human Services (which is equivalent to the head of the Department of Health in other states) were invited to tour the plant. Plant personnel explained what was going on and future plans. The NRC was also present during these tours. Later, local officials were also invited to the plant. The plant tours helped alleviate concerns, and frequently the response on leaving the plant was, "So, what's the big deal?" Plant personnel also kept these individuals informed about decommissioning activities. Communications were set up with senators, NRC staff, reporters, and many others. These

individuals were contacted six months before an activity was to be performed to allow time for questions to be asked and answered. The NRC was very interested in making the decommissioning project a success, a branch chief consistently attended meetings. If there were problems, the NRC was there quickly. Plant personnel emphasized the importance of having the support of state and federal regulators and the importance of treating the public as a significant contributor. Also of importance is never to surprise the regulator.

An issue of great importance to PG&E with respect to the Trojan Plant is public acceptance and support for the Decommissioning Plan, especially getting environmental acceptance and regulatory support for the plan.

The Oregon Public Utility Commission guidelines require PGE to work with the customers, regulators, and citizens interested in energy/environmental policy. PGE is required to prepare a least cost plan to meet future power needs every two years. The planning process involved creating two advisory committees - one is a TAG and the second is a PPG. The TAG includes representatives from regulatory agencies, (industrial and residential) customer groups, the affected Indian nations, the Sierra Club, and other environmental groups. The PPG includes executives from the business and financial community, the electric utility industry, etc. These advisory committees provide technical input, policy advice, trade-offs, assumptions, etc., into the least cost plan. The least cost plan originally recommended a four-year phase-out of Trojan. However, the increased costs and loss of reliability of the plant because of steam generator tube degradation, dissenting regulatory opinion on the tube repair criteria, and increased availability and lower-than-anticipated cost of replacement power led to the immediate shutdown.

3.7 Waste Minimization and Avoidance of Mixed-Waste Generation

<i>Use cost-effective waste minimization and volume reduction activities.</i>

Waste minimization procedures used at FSV included compaction, smelting, re-use, and free-release (if it was cost effective). To minimize packaging, FSV looked at LSA boxes, liners, and packing as tight as possible. Additional cost savings were realized by preplanning loading and unloading, and using self-shielding for packaging.

To reduce waste at the Trojan Plant, PG&E proposed remelting stainless steel. In fact, PG&E approached DOE with a joint proposal to perform a feasibility study to remelt contaminated stainless steel and fabricate spent fuel containers. The effort included the Oregon Graduate Institute, Pacific Nuclear, and Teledyne Wah Chang. A portable unit to melt and fabricate on site was proposed.

Avoid generating mixed waste.

The first activity performed by the Pathfinder plant involved ensuring that there was no mixed waste potential at the site. If the potential to create mixed waste was found, it was eliminated as quickly as possible. In some cases, on-site decontamination was done. The main types of mixed wastes were mercury and lead. In addition, there was 4,000 ft³ of contaminated asbestos. However, after compaction, only 600 ft³ was left for burial at a local landfill.

The site survey performed at the Rancho Seco plant initially identified some 20 nonlisted EPA chemicals that were potential mixed-waste concerns. Eventually, only two materials appeared to be of concern. Some mercury that was used in manometers and was slightly contaminated was identified. However, the major concern was cartridge filters used in a freon tool decontaminating unit. SMUD has accumulated two 55-gallon drums of filters (20 mRem/h) that must be disposed of as mixed waste. EPA regulations require that once a listed 002 freon solvent has contacted a filter, the filter is always considered contaminated. Currently, SMUD has exceeded the EPA 90-day storage limit for these filters and SMUD feels that there needs to be some flexibility in the interpretation of EPA regulations.

There is strong intrinsic motivation to minimize both LLW and HLW.

As was pointed out by the Rancho Seco Plant, there are no approved sites to dispose permanently of LLW or HLW that SMUD can use without paying exorbitant surcharges.

The discussion of waste at the Shippingport Plant centers on how waste is likely be a much larger problem for any future decommissioning operations than it was for Shippingport. This is because of lower LLW storage costs in the past and the fact that Shippingport was "cleaner" than other similar facilities. It was also noted that waste disposal operations are highly sensitive to changes in regulation and are the area of decommissioning most likely to be affected by public opinion. All in all, in any decommissioning operation there is a strong intrinsic motivation to minimize LLW.

3.8 Industry Involvement

All utilities appear to employ the services of experienced engineering contractors to perform or independently validate cost estimates for decommissioning activities. In addition, contractor assistance is often used for radwaste management, to provide for decommissioning expertise, and to provide additional RP/HP support.

NSP managed and conducted the SAFSTOR and decommissioning activities, only hiring contractors and laborers when expertise or resources were not available within the company. Subcontractors used by NSP included BN for shipping, US Ecology for the landfill, some

specialty organizations, such as a specialty crane company for moving the reactor vessel to the railcar, and ESG for health physics. SMUD, Trojan, and Dresden all utilized an experienced engineering contractor to perform cost/benefit estimates and analysis of decommissioning options. Dresden indicated that throughout the entire decommissioning process, they plan to use specialty consultants and contractors to assist in document preparation, spot decontamination, waste packaging, and disposal services.

The sharing of experiences between facilities undergoing deactivation appears to be worthwhile.

The establishment of, and participation in, a decommissioning support group (e.g., NUMARC) where similar facilities undergoing decommissioning can share experiences, lessons learned, etc., is recommended.

3.9 Recycle and Reuse Opportunities

Salvage sales have limited potential to provide a significant income. The primary savings often appears to be avoidance of disposal costs.

At the Fermi Plant, decommissioning expenses were reduced, primarily because some of the Fermi 1 buildings could be used by the Detroit Edison Company for continued operation of the turbine generator using steam from a conventional oil-fired boiler adjacent to the Fermi 1 plant. The steam generator was sold to the Central Research Institute of Electric Power Industry of Japan for \$1.00 and was shipped to Japan at Japanese expense.

Because of the high volumetric cost for waste disposal, a large percentage of the metallic inventory at the Dresden Plant is presumed to be sent to a waste recovery vendor. It is expected that 80-90% of this material can be decontaminated to levels permitting unrestricted use, at a significant cost savings.

Contaminated materials from the Pathfinder Plant went to Allied Technology Group, based in Richland, WA. NSP paid Allied Technology to take the contaminated material, which was then decontaminated and sold or volume reduced and disposed of. Allied Technology had a base charge, based on weight, and noncontaminated materials were sold by the plant. NSP's goal was always to be economical.

Trojan has established a formal asset recovery team to sell and/or dispose of surplus assets. An asset recovery plan has been created and includes a formal marketing analysis and marketing plan. The asset recovery plan is optimistic, there is a limited market for used nuclear components. Plants similar to Trojan have been identified, and marketing efforts are being focused on those plants. Diablo Canyon is the plant closest to Trojan in design and age. The asset recovery plan formally established a hierarchy of decisions to maximize recovery of

Trojan's assets. This hierarchy was as follows:

1. Sell the item for reuse at current market value for reuse within PG&E.
2. Return it to the supplier for cost.
3. Sell it to employees, other plants, organizations, countries, commission dealers, brokers, or auction.
4. Donate it to educational or charitable organizations.
5. Scrap it.
6. Give it away.
7. Pay to dispose of it (as a last resort).

PG&E reduced the number of occupied buildings from five to one and is looking at other uses for the buildings. Potential uses of the unoccupied buildings include using them as a vocational technical school or environmental monitoring and training center. PG&E also has Columbia River water rights of 55,000 gpm, an extremely valuable asset.

The Rancho Seco Plant has had limited luck with its asset recovery program. Before implementing the program, SMUD studied similar efforts at other sites and determined that many times, people spent more money trying to dispose of materials than was gained through sales or through reductions in disposal costs. Therefore, the asset recovery program was approached on a low-key basis. Some equipment and bulk acid was sold to sister utilities. SMUD went out for bid on salvage; bidders included General Physics, Pacific Nuclear, Joe Boyle (an auctioneer), and American Export Co. (which sells salvage material overseas). In addition, SMUD hired a company that specializes in decontaminating equipment. Several companies will accept decontaminated materials and decontaminate and reuse them. These companies included Quadrex, ALARON, Scientific Ecology Group - Westinghouse at Oak Ridge (SEG), and Allied Technical Group in Richland, WA. SEG can incinerate wastes as well as smelt low level contaminated metals.

The scrap generated during decommissioning was not included as a credit in the cost estimates for the Dresden Plant. The scrap value was low and merely offset the associated removal and reprocessing costs. With decommissioning taking place so far in the future, all equipment left at the site will be worn and obsolete. Therefore, CECO plans on removing all easily removed items such as furniture, tools, and mobile equipment (including forklifts, trucks, and bulldozers).

<i>Determine alternate uses for a facility, and then look for re-use opportunities.</i>

PSC is planning to repower FSV using natural gas, since the turbine is only three years old and is worth \$50 million. Equipment and components not necessary for repowering are being sold to other plants. PSC is reusing as much of the on-site equipment as possible.

3.10 Technology Development or Enhancement Needs

Existing decommissioning techniques and methods appear to be sufficient to meet the needs of the commercial nuclear power industry.

Trojan management feels that there is little to be gained by waiting for new technologies to "reduce" decommissioning costs. The technology is at hand to cut up and remove large components and decontaminate components and structures.

NSP viewed decommissioning as a high volume of low technology work in a relatively clean environment.

Decontamination techniques to be employed by LIPA are consistent with those used routinely throughout the nuclear industry. In-situ chemical decontamination, ultra-high pressure water lancing, abrasive grit blasting, and a variety of manual techniques are all expected to be used by LIPA during the course of Shoreham's decommissioning. In addition, LIPA is closely evaluating off-site decontamination services.

LIPA similarly will apply industry-accepted and field-proven processes for the dismantlement of certain plant systems and structures. Such techniques will range from simple, manually operated power bandsaws used to sever small bore piping through more sophisticated techniques such as diamond wire saw cutting, which may be used to sever the large-bore piping connections to the RPV. The selected options, as well as LIPA's continued evaluation of available technology, will reflect careful consideration of the radiological conditions associated with their intended application.

Segmentation of the more highly activated reactor internals at Shoreham will be performed using underwater, semi-automatic plasma arc and metal disintegration machining equipment. The RPV will be severed into ring sections using the diamond wire saw. The ring sections will then be cut into pieces appropriately sized to permit their safe and efficient handling, packaging, and shipping using either the diamond wire saw or a thermal cutting technique.

Projected high LLW disposal costs may provide economic incentives to develop other disposal options, investigate new decontamination processes that reduce waste and encourage recycling, incineration, or reuse of equipment when possible.

Cooperation from various governmental regulatory bodies will be needed to promote success.

NSP relied on the TRANSCON system as its primary means of communication during the reactor vessel shipment. It provided accurate tracking and near-continuous two-way communications. Cellular phones were available for less than a third of the trip. IMTS, a one-way phone link available on the business car, was not functional, even though several attempts

to use the system were made. TRANSCOM was used often, even when the cellular phone was available.

4.0 CONCLUSIONS AND RECOMMENDATIONS

In this section, lessons learned and results of the nuclear plant reviews discussed in Section 3.0 are related to potential applications in the DOE environment. It is important not to be limited to the suggestions discussed in the following paragraphs. Individuals struggling with issues in the environmental remediation environment may perceive other insights from the information.

4.1 Hazard Characterization

As is the case for nuclear utilities, it is likely for DOE facilities as well, that the type and scope of deactivation, safe storage and decontamination activities will be determined by the facility hazards. Utilities found that the hazards present at a site must be relatively well characterized before any deactivation, safe-storage or decontamination activities are implemented. In general, utilities found that characterization activities must be undertaken in an intelligent manner - that is, they concluded there was not enough money or time to be *absolutely certain* that every nook and cranny had been adequately characterized.

Utilities used unique methods to guide characterization of their sites, many of which may work at DOE sites. An example is the grid and color code system used at the Pathfinder plant where areas anticipated to be contaminated used a smaller grid (and different color) for sampling those areas that were unlikely to be contaminated. Fort St. Vrain (FSV) took 35,000 radiological data points and used a bar code system to track this information. The Trojan Nuclear Power Station divided characterization into four major areas: environment (roads, ponds, yards, etc.), structures (all on-site buildings), plant systems, and activated systems. The plant systems area was divided into four categories: known contaminated, potentially contaminated, indeterminate, and clean systems. Each of these categories were characterized differently.

In some instances (i.e., for reactor fission and activation products), the safe-storage period will result in a significant reduction in radiation, contamination levels, and risk associated with future cleanup. There would appear to be less to gain for facilities with transuranics. Utilities found that a key consideration in making a decision to defer decontamination activities during deactivation to SAFSTOR until years later (at the end of the safe storage period) is the reduction in worker dose. However, this consideration has to be balanced against the loss of knowledgeable plant staff and operable process systems that may not be available in the future.

To establish background radiation levels for facilities, Aerial Gamma surveys as well as surveys at other nearby sites that were built at the same time as the facility being decommissioned are useful. Utilities stressed the importance of avoiding committing to background radiation levels that cannot be attained. For example, at the Pathfinder Atomic Power Plant, a commitment to a less than 5 micro Rem/h background radiation level was made. However, background levels at the county courthouse (which was built at the same time and is similar in construction to the Pathfinder Plant) were measured at 8 microRem/h. In fact, the

cleanest air in the area around the plant was at the air filters in the plant, not outside the plant, since radon is present in the area.

The bulk of the waste at the nuclear power plants was low level waste (LLW). The two most common sources of hazardous materials are asbestos insulation and equipment contaminated with PCBs. It is anticipated that DOE sites may have a similar experience. These waste types present unique problems.

If worker health or safety is perceived by the public to be neglected or poorly protected, public confidence in the deactivation and safe storage efforts at a site could be undermined. There is a well known linkage between worker health and safety and off-site health impacts. Therefore, it is important to address worker health and safety. One potential method for reducing radiation exposures is from the Humboldt Bay Plant (HBPP). Individuals planning a job at the HBPP estimate the expected radiation exposures based on radiation surveys conducted in the area where the job is to be performed and estimates of the time required to perform the job based on prior experience. These estimates are reviewed by a Radiation Protection Department. If thresholds of 500 mRem for the total job or 100 mRem for any individual are expected to be exceeded, consideration was given to specific actions that may be taken to reduce that exposure. At Shippingport good planning and ALARA practices resulted in small radiation exposures for the work force.

Training is an important part of worker health and safety. A training program that has been successful at the HBPP may also be appropriate for DOE sites. All radiation workers at the HBPP receive, as part of their radiation protection training, an indoctrination in the principles of ALARA radiation exposure control. In this training, the responsibility of the individual worker to follow procedures and safety rules and to maintain individual exposure ALARA is emphasized. The principles of minimizing the duration of exposure, maintaining distance from the source, and reducing source term are also included.

4.2 Management/Programmatic Issues

Utility experience demonstrates the importance of defining a well established facility endpoint before planning deactivation, safe storage or decommissioning activities. A wide variety of activities and associated technologies are necessary to take a site from its current state, through deactivation activities and finally to its maintenance in safe storage. The drivers of the management process are (1) the decision on disposition of the site and (2) the current hazards. This means that it is vital that management of a safe-storage project begin with the end in mind: every system, component, area, etc., must have a description of its safe-store condition established before any activities begin. Equally important is a clear knowledge of the hazards present. Basically, one must know where one is going and where one is so that the activities performed are always moving in the right direction.

Once the two endpoints are established - where one is and where one is going - the various paths that can be followed can be explored. Along each path are numerous activities. The task

of management is to evaluate and choose the best path (and its associated activities). When evaluating the various deactivation and/or decommissioning activities (and technologies), there are a number of factors to consider: (1) risks to human health and safety (both public and worker); (2) availability and costs; (3) potential to cause environmental damage; (4) concerns of stakeholders; (5) regulatory issues; (6) effectiveness of the technology in performance of deactivation and safe storage tasks; (7) interactions and integration between technologies and other activities performed at the sites; and (8) recycle and reuse opportunities. All of these factors were addressed by the commercial nuclear facilities; however, the scope of deactivation for these facilities is much smaller than that of DOE facilities.

Utility experiences that may be of use to DOE when planning for deactivation, safe storage and decommissioning includes information provided by the Pathfinder, Dresden, and Humboldt Bay Plants. During SAFSTOR all utility service to Pathfinder, except for a single breaker, was terminated. During the decommissioning phase, power was restored by running new lines. Battery-powered emergency lights were also installed. It was made clear what to remove and what to leave alone - all new systems were painted orange, which meant *do not touch*. There were no other active systems in the decommissioning areas. The sequence used during the decommissioning phase was to remove asbestos, hazardous material, cables, piping, equipment, concrete, and, finally, structures.

Dresden 1 preparations for SAFSTOR included:

- Draining, de-energizing, and securing all contaminated systems, and decontaminating (as required) to ensure safety during SAFSTOR;
- Maintaining lighting, fire protection, heating, ventilation and air conditioning (HVAC), and alarm systems, as required, for continued use during SAFSTOR;
- Cleaning loose surface contamination from building access pathways; and
- Controlling access to radioactive or contaminated areas, in accordance with normal station procedures.

During the Dresden plant's maintenance in the SAFSTOR mode (for as long as 30 years, or until Units 2 and 3 are decommissioned and dismantled) activities required include maintenance of a guard force, preventive/corrective maintenance on lighting and HVAC, general building upkeep, maintenance of structural integrity, and an environmental and radiological monitoring program. Since Dresden 1 is a shared site with operational Units 2 and 3, it can be safely and inexpensively maintained while allowing decay time, which will result in lower personnel exposures during dismantling. There is an expected savings in disposal costs for the highly activated components (i.e., the reactor vessel and internal components) because of the decay of short-lived isotopes. However, a delay in decommissioning reduces but does not eliminate the radionuclide inventory, and, at the end of its dormancy period, the facility will require extensive decontamination. During the plant's dormancy phase, minimal radioactive waste is expected to be generated and will be disposed of at the other operating units.

Systems and equipment not required by the HBPP Unit 3 operating license (for the cold shut-down mode) or to support deactivation activities were secured in preparation for SAFSTOR. Preparations included unloading the reactor core; draining, flushing, and securing systems; de-energizing instruments and controls no longer required; and isolating nonoperational from operational systems. During deactivation to SAFSTOR systems no longer required by the revised technical specifications were secured and isolated. Systems required to support deactivation activities but not required during SAFSTOR were secured upon completion of those activities. The objectives of the system lay-up are as follows, to:

- drain systems containing fluids to the maximum extent practical,
- remove or shield significant sources of radiation in areas routinely accessible during SAFSTOR,
- seal connections between secured and operating systems by using either blank flanges or by cutting and capping the lines to prevent operating system leakage from refilling a system that has been drained, and
- de-energize motors, valves, instrumentation and other electrical components associated with secured systems.

The primary drivers leading to utility decisions to go to SAFSTOR are (1) the lack of set aside funding for immediate decommissioning and (2) the lack of a high level waste (HLW) repository for spent fuel. Potential DOE drivers are (1) limitation in methodologies to prioritize facilities for deactivation or decommissioning and (2) insufficient funding to clean up the entire complex at once. Risk-based decision models are being developed to assist with the facility prioritization process however, they face a number of challenges. Major problem areas for risk-based models include keeping up with constantly changing and increasing numbers of regulations and specifications and how to prioritize across multiple sites located in different states.

As was identified by utility experience, the DOE may find that one big disadvantage of going to safe storage is the loss of knowledgeable personnel and the near total lack of knowledgeable people at the time the facility is actually decommissioned. Careful documentation of the plant configuration and locations of hazards at the time the plant is placed in safe storage helps make final decommissioning tractable.

Utilities found that utilizing the existing facility operating and maintenance infrastructure, with some streamlining to manage deactivation and decontamination activities, was the easiest and most cost effective approach. The preventive maintenance program at the HBPP provides for a regularly scheduled series of inspections, tests, and services for structures, systems, and components. The frequency of preventive maintenance is established on the basis of prior experience, ongoing operational use, plant conditions, and, where applicable, technical specification requirements. The objective of the preventive maintenance program is to ensure continued, reliable performance of necessary structures, systems, and components (equivalent to or better than the reliability existing at the beginning of the SAFSTOR period). Personnel are familiar (and comfortable) with the existing facility work control processes, that is, the

procedures, safety review processes, "plan-of-the-day" meetings, etc. Changing the existing work processes, even though they may seem cumbersome, may create more operational problems than the change attempts to solve. For example, the HBPP found that preventive maintenance procedures should not be rewritten. The corrective maintenance program at the HBPP already provides for analysis and appropriate action to be taken when performance of structures, systems, and components are determined to be degraded. In addition, adequate stores of spare parts and servicing equipment are maintained to ensure that corrective action can be taken within the time frame required by the technical specifications. This experience suggests that utilizing existing programs, procedures, management structures, etc. (with some streamlining) to perform deactivation and SAFSTOR activities will tend to be more successful than developing new processes.

Utilities experienced morale problems shortly after the decision was made to shutdown a plant. Naturally, employees were concerned for their jobs and families. Most utilities made special efforts to retain experienced personnel to help with deactivation and also to help transfer or place employees elsewhere.

Utilities found that it was very helpful to have individuals on-site who can make decisions during deactivation, safe storage, and decommissioning in order to provide timely responses to problems that develop.

An important note is that DOE's normal budgeting process may make the suggestions in this section difficult to implement. Projecting the facility/site decommissioning efforts may approximate the theme of what commercial experience suggests, however, Congress still provides the dollars on an annual basis.

4.3 Requirements and Regulatory Issues

Numerous regulatory requirements, standards, and guidance prescribed by the Nuclear Regulatory Commission (NRC), Department of Transportation (DOT), Environmental Protection Agency (EPA), Occupational Health and Safety Agency (OSHA) and states must be observed during the transition phase. Therefore, it is important to determine which requirements and regulations are applicable at each site. Utility experience has shown the importance of being very proactive with regulators and involving them in the planning and decision-making process. A technique used by FSV was to write letters to regulators discussing the decontamination process and requesting guidance. FSV also worked with the EPA and the state on water quality issues - there were letter agreements with the state on tritium releases (based on the water flow) to ensure that there was no misinterpretation.

Cost-benefit studies have also been successful in negotiations with state regulators. For example, the FSV plant showed that if they were required to meet Radiation Protection Guidelines (10 CFR 20), costs would be increased by 5%. A cost-benefit analysis was done

for the allotted time periods and the results were presented to the regulators. The impact the regulations would have on the costs, etc, was clearly shown and a compromise was made.

Worker considerations are also important. OSHA has set standards limiting worker exposures to toxic substances. In addition to specifying permissible exposure limits for substances previously encountered (such as, metals, chromates, sodium hydroxide, sulfuric acid, solvents, and asbestos) additional regulations specify requirements for medical examinations, monitoring, methods to minimize airborne contamination, personal protective equipment, personal hygiene, signs and labels, access control, training, and waste disposal.

Site and material release levels have not been determined, but draft rules have been developed by a joint NRC/DOE/EPA task force working on the site release criteria for sites licensed by the NRC. The EPA is expected to establish similar site release rules for DOE sites. During the period of this study however, there was no lower "limit" for acceptable radioactivity levels. SAFSTOR radiological endpoints appear to be determined by each utility on a site-by-site basis. At FSV, during decommissioning planning, significant focus was directed toward the development of the site release criteria and methodology for both release of the site for unrestricted use and materials off-site. It was important for them to develop an acceptable methodology that would receive regulatory acceptance since the dismantlement/decontamination approach selected would not result in a "bare walls" plant after completion of physical decommissioning. An educated guess was made on what reasonable exposure limits were for radiological and hazardous material, and then the appropriate regulatory agency was contacted to verify it. The decommissioning contractor for the Shippingport plant was asked to estimate the cost trades for reducing future doses from the site to no more than 100, 25, and 10 mRem/year to the public. One of the interesting goals of this site release criteria effort was to develop a criterion that would result in low cost of remediation and a low dose to the public. The studies for Shippingport indicated that doses to the public could be limited to 10 mRem/year. The release criterion was finally established for the site based on a dose of 100 mRem/year to maximum exposed individuals plus ALARA (to 10 mRem/year).

Utility experience suggests that it is advantageous to revise the facility Safety Assessment Report (SAR), Operational Safety Requirement's (OSR's), Technical Specification (tech spec) Requirements, etc. to be consistent with the revised status of a facility as soon as possible after shutdown. Considerable cost savings are possible through reduced training, maintenance and surveillance efforts and the associated reduced staffing requirements. When translating operational technical specifications to safe storage operation and maintenance requirements, it helps to evaluate systems by asking, "Does it make sense to keep this system tech speced?" Another suggestion is automatic tech spec shedding via "Application Statements," i.e., when the hazardous condition no longer exists, then TSR is not involved. For a facility going through decommissioning this may be simpler than for facilities that are "at power" versus "down for refueling or maintenance" with the intent to "return to power."

The NRC requested that the Yankee Atomic Electric Company (YAEC) evaluate the environmental impact of proposed activities relative to the conclusions in the NRC Final Generic Environmental Impact Statement (GEIS) (NUREG-0586). The important GEIS conclusions, as they relate to component removal activities being considered by YAEC, are as follows:

- The environmental impact of decommissioning nuclear facilities is similar to or less than those created during construction and operation.
- The occupational exposure for DECON is higher than for SAFSTOR, but similar to routine operation.
- The higher DECON occupational exposure has marginal significance to health and safety.
- The LLW burial volume is typically less for SAFSTOR than DECON because of the decay of radioactivity from the time shutdown occurs until final dismantlement begins (burial volume reduction is recognized in the GEIS after a 50-year SAFSTOR period). However, this benefit is not uniquely compelling when selecting a decommissioning alternative.

4.4 Transitioning Facility Risk Issues

Utilities felt that there were no significant radiological risks to surveillance and maintenance personnel during SAFSTOR. Because of the reduction or elimination of preventative maintenance, however, risks from degradation of equipment and facilities over time are of concern. At the Rancho Seco Plant, some potential for equipment degradation and leaks exists because of reduced preventive maintenance. The Sacramento Municipal Utility District (SMUD) knows that certain roofs leak, but no effort is being undertaken to improve the situation, and there are some problems with pigeons. As part of their SAFSTOR decision, SMUD chose to maintain containment ventilation to prevent the buildup of molds and fungi to avoid future health risks that might increase if things were welded shut. The only safety related equipment kept operational at the plant were those associated with operation of the spent-fuel pool. Utilities stressed the importance of evaluating the potential hazard implications of removing a system from service before deactivating it.

Potential accidents evaluated at HBPP during the SAFSTOR period have a low probability, are few in number, and are of minor consequence in comparison to accidents associated with operations.

SMUD and the Rancho Seco Plant had some advice regarding accident analyses: do not spend time trying to "create or invent" new hazards or scenarios. Remember that the plant was licensed to operate, that bounding accident analyses were performed to obtain that operating license, and that long-term operation of the spent-fuel pool was considered in the operating license. The current safety basis is loss of spent-fuel pool inventory, dropped assembly, and station blackout or loss of off-site power.

The Trojan plant, used a decision-analysis approach to prioritize decommissioning alternatives. The prototype model performed a high-level economic analysis focused on timing, prioritizing decommissioning activities, and understanding risks (including transportation risks) and uncertainties associated with decommissioning. Alternative approaches were evaluated considering waste costs, timing of component removal, and radiation levels.

When developing the safety plan for the Trojan Plant, general considerations included the following:

- Retaining existing barriers and alarms and redesignating areas based on the contents,
- Keeping the radiological and security boundaries the same,
- Co-assigning duties,
- Reducing service levels (i.e., "on-call" rather than "always there"), and
- Working with operations, reactor protection, maintenance engineering, etc.

As a result of the security plan, the staffing levels were dramatically reduced with minimal impact on work being performed at the site.

At the Pathfinder Plant, nothing that would deteriorate during the SAFSTOR period, as long as no water was present, was left. Even though very little water was present, some equipment did rust. However, since it was never going to be used again it was inconsequential. In case it became necessary during the SAFSTOR period to enter the areas in storage, a breaker was left in place.

Inside containment at the Trojan Plant, all ventilation and lighting are off. Prior to anyone entering containment, the building ventilation system is turned on for a day. There was no real incentive to do any up-front decontamination before entering SAFSTOR. About 4% of the facility was contaminated prior to SAFSTOR, at the time of this study the level was around 3% and decreasing because of natural decay processes.

Utilities attempted to lower significant risk as much as possible during deactivation and decommissioning activities. At FSV, fire doors were left in place, radiation monitoring and fire protection systems were operable, an *intelligent* maintenance program was still in effect, and component reliability was being tracked.

When looking at the SAFSTOR and decommissioning phases at the Pathfinder Atomic Power plant, the activities that had the most risk, albeit small, were those involved in preparing the vessel for shipping and shipping itself. Hospitals and emergency personnel were contacted along the shipment route to ensure that the vessel contents were known and preparations could be made for potential accidents.

For many of the DOE facilities shut down for long periods of time, there is likely to be significant degradation of the physical plant, which may need to be upgraded as part of activities to achieve SAFSTOR. Utility experience indicates that most accidents occurring

during SAFSTOR and decommissioning are normal, industrial-type accidents. FSV performed a probabilistic risk assessment (PRA) for nuclear and non-nuclear hazards. The main hazards identified included fires, tornadoes, and industrial-type accidents. Fire was the most threatening potential accident with respect to radiological releases to workers and to the public. It was also more likely to occur. Overall, at FSV, if a potential accident scenario had a likelihood of occurrence of less than 1 in 10,000 yrs, it was ignored. However, if its likelihood was greater than 1 in 1,000 yrs, mitigative actions (design, surveillance, etc.) were used to reduce its likelihood.

At the Pathfinder Plant, the only accidents that occurred during the SAFSTOR and decommissioning phases were normal industrial-type accidents. Training and protective equipment (e.g., safety glasses and steel-toed boots) were used to help alleviate these types of accidents. Other means of reducing potential accidents include: limiting access to hazardous areas, continuing to maintain security personnel at the site at all times, and keeping appropriate controls, programs, procedures, systems, structures, and components necessary to preclude inadvertent public exposure or spread of contamination until the site is released for unrestricted use.

Unfortunately, there are numerous unique radiological hazards at many of the DOE facilities which means that it is likely that they will have to be addressed on a site-by-site basis.

For commercial nuclear plants, the FSAR and Tech Specs provided a basis from which to identify the plant systems that should be maintained during SAFSTOR. In general, for the older DOE facilities, safety and related documentation is lacking which will present a challenge to the facility operator in placing the facility in SAFSTOR or in decommissioning. Appropriate administrative controls, programs, procedures, systems, structures, and components necessary to preclude inadvertent public exposure or spread of contamination need to be in place during deactivation, SAFSTOR and decommissioning.

4.5 Cost Increases and Uncertainty

Every utility contacted felt that prompt decontamination and dismantlement was the least cost decommissioning option, provided that adequate funding and low level and high level waste repositories were available. Lacking sufficient funding and/or the availability of waste repositories, SAFSTOR was the only feasible option. Utilities recognized that there was risk associated with SAFSTOR, including the loss of knowledgeable plant workers, uncertainty regarding future risks of the SAFSTOR process (such as an increasingly complex regulatory environment and public attitude), probable increases in LLW disposal costs, continuing long-term liability and the cost for plant insurance, surveillance and maintenance. The utilities anticipated some cost-savings as a result of the decay of fission and activation products during SAFSTOR, however, this will not be the case for facilities contaminated with long-lived transuranics. In addition, there was little cost benefit gained due to reduction in plant radiation levels during SAFSTOR. As was the case for utilities, for DOE waste disposal has the potential to be a significant problem. In addition, there is not sufficient funding to decommission every

shutdown facility, hence DOE has incentives to pursue other alternatives, such as SAFSTOR, reuse, etc. Another consideration with respect to placing a facility in safe storage is the decommissioning schedule of other facilities at the site. It may be cost effective to decommission all facilities at a site at the same time, i.e., as part of a single, continuous unit. The decision to place Dresden Unit 1 into a dormancy period for 17 years was dependent on the decommissioning schedule of Dresden Units 2 and 3, at which time all three units will be decommissioned as an integrated program.

Cost estimates for transitioning a site into safe storage must include the costs of all activities. Transitioning the HBPP into the custodial SAFSTOR mode is estimated to cost approximately \$414 million. This total includes costs for the following activities:

- Surveys and analyses to perform radiological characterization,
- Preparation of the SAFSTOR Decommissioning Plan, Environmental Assessment Report, and Draft Dismantlement Plan,
- Labor and materials associated with the unloading of fuel from the reactor vessel and the securing of plant systems no longer required by the operating license, and
- Processing, packaging, shipment, and disposal of radioactive wastes at the site.

Cost estimates were prepared based on a detailed work breakdown schedule developed at the outset of the project. Estimates were based on experience in performing similar activities at the HBPP and known plant labor and material costs. During the SAFSTOR period, funds will be required to maintain the unit in accordance with the possession only license (POL) and associated technical specifications. Maintenance and surveillance activities during the SAFSTOR period will be similar to activities conducted during operation, but reduced in scope. Funds for SAFSTOR costs will be allocated in the HBPP annual operations and maintenance budget.

Despite the fact that FSV was essentially radiologically clean, the cost estimate was \$186 million. Burial costs for the estimated 79,000 ft³ of waste were set at \$240/ft³ (1992 costs). Cost estimates at FSV were based on the AIF/NESP "Guidelines for Producing Commercial Nuclear Power plant Decommissioning Cost Estimates," the PNL report "Technology, Safety, and Cost of Decommissioning a Reference Boiling Water Reactor Power Station," RG 1.159 "Assuring the Availability of Funds for Decommissioning Nuclear Reactors," and the DOE "Decommissioning Handbook."

The total costs in 1974 for the 36-month Fermi Decommissioning project were \$7,164,988. The personnel exposure was 28.04 man-Rem or \$255,527 per man-Rem. It was estimated that 5,000 Ci were handled during decommissioning for a cost of approximately \$1422 per curie or 178.3 Ci per man-Rem. Even though decommissioning Fermi took longer than anticipated, the additional expense was offset by the rapid reduction in work force. The final cleanup in 1975 was accomplished with a very small work force. Retiring buildings and equipment as soon as they were not needed resulted in savings in property taxes and insurance.

For utilities, LLW disposal costs represent the major portion of - and uncertainty in - projected decommissioning costs. Historically, costs for LLW disposal have risen at a higher rate than inflation. At Rancho Seco, original LLW costs were \$1.00/ft³ and 1993 estimates exceeded \$440.00/ft³ at a LLW facility planned at Ward Valley, assuming a 1996 opening. Based on an estimated 7,300 yd³ of LLW, SMUD, the owner and operator of the Rancho Seco plant estimates about \$100 million for LLW disposal costs and recognizes that costs might go higher. To address the uncertainties associated with LLW storage, SMUD constructed a \$5 million LLW storage building in case Ward Valley does not open or is delayed. To reduce SAFSTOR costs, SMUD is planning to build an on-site Independent Spent Fuel Storage Installation (ISFSI), which SMUD estimates will cost \$16 million to build, with operating costs of about \$2.6 million/yr, as compared with \$10.6 million to keep the spent-fuel pool operating. The major cost savings will be in operating and maintenance personnel.

In addition to LLW internment costs are the shipping costs which are sensitive to fuel-cost changes and distance to the disposal facility. Removal costs depend on the amount of remotely-operated equipment available in the future when dismantling occurs and the higher cost of that equipment versus the savings in labor costs. All this leads to the statement that the availability of inexpensive LLW storage is vital to cost-effective decommissioning. DOE disposal costs have not been a problem in the past but with the new open environment stakeholders are more likely to object to new LLW repositories. The availability of inexpensive LLW storage is vital to cost-effective deactivation and decontamination.

Reviews of actual as well as estimated decommissioning costs for nuclear plants showed considerable differences in costs for similar plants. For instance, Pathfinder decommissioning costs (1990-1991) were \$13 million with waste disposal costs of \$70 per cubic foot, while for the similar size Shippingport plant (1986-1989), decommissioning costs were \$98 million with waste disposal costs of \$5 per cubic foot. In both cases, the reactor vessels were sent intact to Hanford for burial. The decommissioning cost estimate for Shoreham, a radiologically clean facility (i.e., 602 curies, except for fuel), was estimated at \$186 million (1991 dollars). Other similar plants exhibit similar differences. The U.S. NRC has recognized that for commercial nuclear plants the decommissioning cost estimates appear to be low. The utilities emphasized the importance of knowing what the disposal costs will be, without this knowledge optimal decommissioning strategies cannot be chosen.

It may be advantageous for DOE sites to perform a hazard evaluation as early as possible to assist in the planning process. Utility experience has shown that the waste types and their volumes will drive the planning process and the costs of deactivation, safe storage, and decommissioning. Another potential area for cost savings was suggested by Fort St. Vrain. At FSV, during decontamination activities, site health physics personnel were used for radiation monitoring, while environmental monitoring was done by specialists. Contracting the environmental monitoring tasks to specialists led to substantial cost savings (when compared to the costs of training and paying site personnel to perform the tasks).

4.6 Stakeholder Concerns

In contrast to the near total lack of stakeholder interest expressed after utilities shutdown nuclear plants, the DOE has experienced considerable continuing stakeholder interest at nearly all of its sites. Utility experience suggests that having an effective program for involving and sharing information with stakeholders, the local community and government officials is an important part of a smooth transitioning process. This allows a facility to anticipate stakeholder reactions and plan for contingencies. An example of this philosophy, which was employed by FSV, is illustrated by the removal of the spent fuel from FSV. The utility intended to begin defueling and shipment of the fuel to Idaho National Engineering Laboratory (INEL) in early 1991. Idaho Governor Cecil Andrus strenuously objected however, and a series of legal maneuvers ensued. The fuel was scheduled to be removed and shipped to permit the start of decommissioning in January 1992, these complications delayed that schedule. The utility had foreseen this possibility, however, and had moved ahead with construction of an ISFSI which subsequently was used to store the spent fuel.

Programs that have been effective for the utilities have many good ideas for sharing information with the public. At FSV, local community groups, including children, were invited to visit the site. Senior plant personnel attended these community meetings and answered questions about what was being done and planned at the plant. Quarterly news flyers were sent out to the local community to share plant information, discussions included what work was currently in progress and what had been done. Communications with the nuclear community — local, society, industrial, and environmental groups — also occurred. Routes used to transport waste were not disclosed; however, studies done to determine "acceptable societal risk" with respect to these routes were discussed.

The Pathfinder Plant did not have large groups of public intervenors who were concerned about whether the plant was *doing it right* (i.e., performing appropriate decommissioning activities safely). However, a local woman, who was very concerned about the plant's activities, was kept in the decommissioning information loop. She was shown around the plant, and time was taken to explain what was going to be done and why. A "written agreement" was made between her and the plant that was a commitment to work together to resolve concerns. Her concerns were basically the same as the plant's, so the only real change for the plant involved adding her name to the mailing list.

NSP's South Dakota Region personnel made considerable efforts to keep the Sioux Falls media fully informed on the decommissioning progress of the Pathfinder Plant. As a result, the shipment via railcar of the reactor vessel to its final storage destination started smoothly. The positive reporting by the media at the beginning of the transit resulted in keeping the whole shipment in perspective. NSP invited members of the Sioux Falls media to the Pathfinder site for the vessel sendoff. Later, during the transit, most television and radio stations knew that the train was coming through their town, so local news broadcasts carried a story about it. For the most part, the broadcasts contained factual and fair coverage of the event. Beyond Sioux Falls, outside interest was generally confined to curiosity seekers and passersby. The public

treated the shipment for what it was: a big, heavy package that was not a problem. It was not a radiation threat and it did not endanger health and safety.

During shipment of the reactor vessel, a satellite tracking system was used to maintain contact with the train at all times. Courtesy and information calls were made before, during, and after the shipment to cognizant state and federal agencies. One question NSP was determined to be able to answer was, "Do you know where the train is right now?"

Another effective public relations tool for the Pathfinder Plant was through the use of decommissioning baseball caps. These caps were given out to the involved public and helped make the public feel more like an *owner* in the project.

NSP believes that the lack of concern exhibited during transport can be attributed to advance publicity and communications. For over a year, state and local officials, as well as news media and the public, were kept informed on NSP's plans. Maps, pictures, descriptive data, question and answer sessions, local visits, and public meetings helped answer concerns and alleviate potential problems.

At the Rancho Seco Plant, SMUD held public meetings to discuss its decommissioning plans, but there was little public concern or interest. This was in contrast to the interest by the public and "anti-nuclear proponents" in shutting down the plant. SMUD also used newspaper advertisements to try to identify any public concerns.

The YAEC Public Affairs Department at the Yankee Rowe Plant developed a comprehensive public information program for planned decommissioning activities. The program includes:

- Meetings with local, state, and federal elected officials,
- Meetings with representatives of federal, state, and local agencies that are responsible for public health and safety,
- Public information forum(s) held in the vicinity of the plant site,
- Briefings to the local, regional, and/or national news media, and
- Slide presentation(s), information packets, and news media kits.

YAEC will ensure dissemination of information to elected officials, the general public, and news media regarding activities that YAEC believes would elicit public interest. In addition, YAEC will be working with the administration of the Greenfield Community College to improve the organization and documentation access capabilities in the Public Document Room at the college.

Protestors from the Citizens Awareness Network and Greenpeace International followed the dedicated shipment train for the two Yankee Rowe steam generators to Barnwell in November 1993.

In addition to creating and maintaining a trusting relationship with the public, there is a need to create a good working relationship with appropriate regulatory bodies. The success of deactivation and decommissioning activities at the utilities was significantly assisted by a good working relationship with regulators. At the Fort St. Vrain Plant there was considerable confusion resulting from an NRC request for a "safety analysis" for dismantlement of FSV. The term safety analysis was commonly used for analysis of off-site doses. After considerable internal discussions, staff concluded that what the NRC was probably looking for was the occupational radiation exposure estimates. Telephone conversations with the NRC were not successful in determining exactly what was required. Based on the concern that the right question was not being answered, and an inability to resolve the issue, utility upper management met with NRC management and arranged another meeting. An all-day presentation was prepared to "sell" the NRC on what was deemed appropriate. The meeting was a success, and it convinced the NRC that only a small number of decommissioning activities were of significant concern and required any detailed explanation. The meeting was more of a success, however, because it brought the involved NRC and FSV personnel together in a detailed discussion and convinced the NRC that FSV personnel were extremely knowledgeable and competent and that the type of details the NRC was interested in were being covered. The overall result of the meeting was creating a much better working relationship. In addition, NRC and FSV staff committed to weekly conference calls to answer questions and discuss the status of the plant. A significant level of NRC staff was involved in each telephone conference. The conference calls were extremely successful in expeditiously answering questions, explaining details, and, in many instances, eliminating time-consuming written responses.

The Pathfinder Plant emphasized the importance of public relations (PR). NSP PR personnel were involved in the decommissioning project from the beginning. The Governor of South Dakota and the head of the Department of Human Services (which is equivalent to the head of the Department of Health in other states) were invited to tour the plant. Plant personnel explained what was going on and future plans. The NRC was also present during these tours. Later, local officials were also invited to the plant. The plant tours helped alleviate concerns, and frequently the response on leaving the plant was, "So, what's the big deal?" Plant personnel also kept these individuals informed about decommissioning activities. Communications were set up with senators, NRC staff, reporters, and many others. These individuals were contacted six months before an activity was to be performed to allow time for questions to be asked and answered. The NRC was very interested in making the decommissioning project a success, a branch chief consistently attended meetings. If there were problems, the NRC was there quickly. Plant personnel emphasized the importance of having the support of state and federal regulators and the importance of treating the public as a significant contributor. Also of importance is never to surprise the regulator.

An issue of great importance to PG&E with respect to the Trojan Plant is public acceptance and support for the Decommissioning Plan, especially getting environmental acceptance and regulatory support for the plan. The Oregon Public Utility Commission guidelines require PGE to work with the customers, regulators, and citizens interested in energy/environmental policy.

PGE is required to prepare a least cost plan to meet future power needs every two years. The planning process involved creating two advisory committees - one is a TAG and the second is a PPG. The TAG includes representatives from regulatory agencies, (industrial and residential) customer groups, the affected Indian nations, the Sierra Club, and other environmental groups. The PPG includes executives from the business and financial community, the electric utility industry, etc. These advisory committees provide technical input, policy advice, trade-offs, assumptions, etc., into the least cost plan. The least cost plan originally recommended a four-year phase-out of Trojan. However, the increased costs and loss of reliability of the plant because of steam generator tube degradation, dissenting regulatory opinion on the tube repair criteria, and increased availability and lower-than-anticipated cost of replacement power led to the immediate shutdown.

4.7 Waste Minimization and Avoidance of Mixed-Waste Generation

The lack of availability of waste disposal sites and the variable, but generally high, disposal costs provide a strong motivation to utilities to minimize generation of radiologically contaminated waste. The high waste disposal costs provide incentive to the utilities to compact waste, decontaminate equipment or recycle, if possible. Waste minimization procedures used at FSV included compaction, smelting, re-use, and free-release (if it was cost effective). To minimize packaging, FSV looked at LSA boxes, liners, and packing as tight as possible. Additional cost savings were realized by preplanning loading and unloading, and using self-shielding for packaging. At the Pathfinder Plant, if the potential to create a mixed waste was found, it was eliminated as quickly as possible. In some cases, on-site decontamination was done. The main types of mixed wastes found at the site were mercury and lead. In addition, there was 4,000 ft³ of contaminated asbestos. However, after compaction, only 600 ft³ was left for burial at a local landfill.

The discussion of waste at the Shippingport Plant centers on how waste is likely be a much larger problem for future decommissioning operations than it was for Shippingport. This is because of lower LLW storage costs in the past and the fact that Shippingport was "cleaner" than other similar facilities. As was pointed out by the Rancho Seco Plant, there are no approved sites to dispose permanently of LLW or HLW that SMUD can use without paying *exorbitant* surcharges.

Waste disposal operations are highly sensitive to changes in regulation, as was noted by the Shippingport plant, and are the area of decommissioning most likely to be affected by public opinion. It appears that both the DOE and utilities have a common political problem with the treatment and disposal of mixed wastes. The utilities have made the identification and minimization of mixed wastes a high priority item in their SAFSTOR activities.

4.8 Industry Involvement

All utilities appear to use the services of experienced engineering contractors to perform or independently validate cost estimates for decommissioning activities. In addition, contractor

assistance is often used for radioactive waste (radwaste) management, to provide decommissioning expertise, and to provide additional radiation protection and health physics support. Many utilities plan to use specialty consultants and contractors to assist in document preparation, spot decontamination, waste packaging, and disposal services. The utilities experience seems to be most similar to the DOE Environmental Restoration Management Contractor (ERMC) approach.

Subcontractors used by NSP included BN for shipping, US Ecology for the landfill, some specialty organizations, such as a specialty crane company for moving the reactor vessel, and ESG for health physics. SMUD, Trojan, and Dresden all utilized an experienced engineering contractor to perform cost/benefit estimates and analysis of decommissioning options. Dresden indicated that throughout the entire decommissioning process, they plan to use specialty consultants and contractors to assist in document preparation, spot decontamination, waste packaging, and disposal services.

Similar to the utilities, DOE uses experienced contractors to manage and perform cost estimates for decommissioning activities. However, the DOE has a much larger personnel base upon which to draw, which can be both an advantage and a disadvantage. Part of DOE's responsibility may include assisting employees with finding other jobs when their jobs become obsolete or are eliminated. Of course, a potential option for DOE sites is to transfer personnel, whose jobs are eliminated as deactivation, safe storage and decommissioning activities proceed, to other sites where their experience will be of value. Another option is to assist employees in a manner similar to that used by private companies and universities. This would involve helping employees write resumes and providing both companies and employees with an information base that could be used to match jobs available with skills of employees. This leads to employees with jobs and private companies having unique expertise available without having had to invest the huge amounts of money and time necessary to train personnel.

If the types of technologies available in private industry are known, contact can be made with the company and a demonstration of that technology given to determine the applicability, reliability and safety associated with that technology. Technologies under development (by DOE or other organizations) that can be adapted for commercial use present an excellent opportunity for joint work agreements between the organization and private industry.

Utilities found that sharing experiences among facilities undergoing deactivation appeared to be worthwhile. The establishment of, and participation in, a decommissioning support group (e.g., Energy Facilities Contractors Group - EFCOG) where similar facilities undergoing decommissioning can share experiences, lessons learned, etc., is worthwhile.

4.9 Recycle and Reuse Opportunities

Commercial utility salvage efforts to date suggest that, in general, salvage sales and asset recovery programs have demonstrated limited potential to provide a significant income. The primary savings often appears to be avoidance of disposal costs, which has the potential to save

a fair amount of money. Some major components can be decontaminated and disposed of by a waste recovery vendor. In some cases, a large percentage of the metallic inventory can be sent to a waste recovery vendor and decontaminated to levels permitting unrestricted use at a significant cost savings. Even though scrap values may be low they offset the associated removal and reprocessing costs. Here the major savings would be associated with reduced waste disposal charges, which once again has the potential to save DOE money. Contaminated materials from the Pathfinder Plant went to Allied Technology Group, based in Richland, WA. NSP paid Allied Technology to take the contaminated material, which was then decontaminated and sold or volume reduced and disposed of. Allied Technology had a base charge, based on weight. Noncontaminated materials were sold by the plant.

The establishment of asset recovery programs has had limited success. However, the commercial nuclear facilities have much smaller volumes of potentially recyclable and reusable materials, equipment and facilities than DOE. Trojan has established a formal asset recovery team to sell and/or dispose of surplus assets. An asset recovery plan has been created and includes a formal marketing analysis and marketing plan. The asset recovery plan is optimistic since there is a limited market for used nuclear components. Plants similar to Trojan have been identified, and marketing efforts are being focused on those plants. The asset recovery plan formally established a hierarchy of decisions to maximize recovery of Trojan's assets. This hierarchy was as follows:

1. Sell the item for reuse at current market value for reuse within PG&E.
2. Return it to the supplier for cost.
3. Sell it to employees, other plants, organizations, countries, commission dealers, brokers, or auction.
4. Donate it to educational or charitable organizations.
5. Scrap it.
6. Give it away.
7. Pay to dispose of it (as a last resort).

As was the case for the Trojan Plant, the Rancho Seco Plant has had limited luck with its asset recovery program. Before implementing the program, SMUD studied similar efforts at other sites and determined that many times, people spent more money trying to dispose of materials than was gained through sales or through reductions in disposal costs. Therefore, the asset recovery program was approached on a low-key basis. Some equipment and bulk acid was sold to sister utilities. SMUD went out for bid on salvage; bidders included General Physics, Pacific Nuclear, Joe Boyle (an auctioneer), and American Export Co. (which sells salvage material overseas). In addition, SMUD hired a company that specializes in decontaminating equipment. Several companies will accept contaminated materials and decontaminate and reuse them. These companies included Quadrex, ALARON, Scientific Ecology Group - Westinghouse at Oak Ridge (SEG), and Allied Technical Group in Richland, WA. SEG can incinerate wastes as well as smelt low level contaminated metals.

Because of the high volumetric cost for waste disposal, a large percentage of the metallic inventory at the Dresden Plant is presumed to be sent to a waste recovery vendor. It is expected that 80-90% of this material can be decontaminated to levels permitting unrestricted use, at a significant cost savings. In general, at the Dresden Plant, even though the scrap values were low, they offset the associated removal and reprocessing costs.

Another valuable suggestion from the commercial nuclear industry is to look for reuse opportunities for buildings and equipment at a site. PG&E reduced the number of occupied buildings at the plant site from five to one and is looking at other uses for the buildings. Potential uses include a vocational technical school or environmental monitoring and training center. PG&E also has Columbia River water rights of 55,000 gpm, an extremely valuable asset. With decommissioning taking place so far in the future, all equipment left at the site will be worn and obsolete. Therefore, CECo plans on removing all easily removed items such as furniture, tools, and mobile equipment (including forklifts, trucks, and bulldozers).

Many utilities have considered alternate uses for their facilities, typically repowering is one of the most viable options since this option makes use of a major portion of a power plant. For example, PSC is planning to repower FSV using natural gas, since the turbine is only three years old and is worth \$50 million. Equipment and components not necessary for repowering are being sold to other plants. PSC is reusing as much of the on-site equipment as possible.

Some avenues available to private utilities are not really feasible options for government organizations such as the DOE, e.g., utilities can donate equipment or facilities to educational/charitable institutions and receive a tax deduction. However, to reduce/eliminate remediation costs, selling or paying a third party to take ownership of a facility, thereby eliminating SAFSTOR or decommissioning remediation costs may be a viable option.

In a similar manner, the DOE may be able to "reuse" facilities and on-site equipment for applications in the commercial sector. In many instances, government organizations at a site have a commitment to make every effort to maintain the local economy and provide jobs as the facility transitions. The utilities, in general, made a concerted effort to retain employees, transfer them, or compensate them if their jobs were eliminated, however the possible loss of utility jobs has considerable less economic impact than the shutdown of a major DOE facility.

4.10 Technology Development or Enhancement Needs

Existing deactivation and decommissioning techniques appear to be sufficient to meet the needs of the commercial nuclear industry. The Trojan management felt that the technology is at hand to cut up and remove large components and decontaminate components and structures. NSP viewed decommissioning as a high volume of low-technology work. Decontamination and disassembly techniques to be employed by LIPA are consistent with those used routinely throughout the nuclear industry (*in situ* chemical decontamination, ultra-high pressure water lancing, abrasive grit blasting. A variety of manual techniques are expected to be used by LIPA during the course of Shoreham's decommissioning. LIPA similarly will apply industry-accepted

and field-proven processes for the dismantlement of certain plant systems and structures. Such techniques will range from simple, manually operated power bandsaws used to sever small bore piping through more sophisticated techniques such as diamond wire saw cutting, which may be used to sever the large-bore piping connections to the RPV. The selected options, as well as LIPA's continued evaluation of available technology, will reflect careful consideration of the radiological conditions associated with their intended application. Segmentation of the more highly activated reactor internals at Shoreham will be performed using underwater, semi-automatic plasma arc and metal disintegration machining equipment. The RPV will be severed into ring sections using the diamond wire saw. The ring sections will then be cut into pieces appropriately sized to permit their safe and efficient handling, packaging, and shipping using either the diamond wire saw or a thermal cutting technique. The lesson here is *before developing new technologies, look at the technologies that are already available*. It is not uncommon to develop a technology (the solution) and then look for an application (the problem). This statement is not meant to discourage the development of new and innovative technologies, however, justification for the development of new technologies is recommended.

The minimization and stabilization of mixed wastes is an area that needs additional technology development.

4.11 Other Recommendations

A review of safe storage and/or decommissioning experiences at other facilities or sites (such as those on the National Priorities List (NPL) or almost, including private, DOE, DoD (Army, Navy, and Air Force) could provide valuable lessons learned that could benefit the DOE. As part of this review, setting up "information sharing" capabilities across the various government facilities (including contractor information) may be useful. In addition, approaches used at various sites to address regulatory requirements, management of work activities, endpoint criteria, and stakeholder involvement could be evaluated. Additional, in depth, reviews of projected and actual utility decommissioning costs could provide clarity to the perceived large differences in costs observed for similar nuclear facilities.

Processes, techniques and experiences used by other nuclear organizations (i.e., Europeans, Russians, IAEA, Japanese, etc.) to transition to decommissioning could also be evaluated for lessons learned. Documenting commercial nuclear and military experience with system lay-up (e.g., Navy, TVA, EPRI, and INPO) may also be useful.

Other ideas include developing a joint demonstration program between DOE and a selected utility (with respect to SAFSTOR) and a joint technical program between DOE and the nuclear utility industry to address issues of common interest (i.e., remelting, mixed waste).

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COMMERCIAL REACTOR EXPERIENCE

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A.1 Introduction

Appendix A contains summaries of the results of on-site interviews at and document reviews of the Fort St. Vrain, Pathfinder, Rancho Seco, Shoreham, and Trojan commercial nuclear facilities. Also included are limited document reviews of pertinent activities conducted at the Dresden, Fermi, Humboldt Bay, Shippingport, and Yankee Rowe plants. For each plant, some background information is presented followed by a discussion of 11 general topics. The first 10 topics directly correlate to the 10 areas addressed in the questionnaire (see section 1.3.3). The final topic is a summary of the lessons learned in each of the 10 general topic areas. Some of the plant information can be found in several topic areas, this is because information in one topic area is also of value in another area. The topic area format and redundancy in information was used so that individuals interested in a particular plant or topic could have access to that information quickly and easily.

A.2 Dresden 1

Dresden Nuclear Power Station Unit 1 (Dresden 1) is located in Grundy County, IL, approximately 50 miles southwest of Chicago near the confluence of the Des Plaines, Kankakee, and Illinois Rivers. The plant shares a site with two other boiling water reactors (Units 2 and 3) and is owned and operated by Commonwealth Edison Company (CECo).

Dresden 1 was the first nuclear power plant built by private industry and was operated from July 1960 to October 1978, with a gross output of 210 MWe. Dresden 1 was taken out of service in October 1978 for modifications and backfits to meet new federal regulations and to perform a chemical decontamination of major piping systems. While it was out of service, additional regulations were issued as a result of the March 1979 incident at Three Mile Island. The estimated cost to bring Dresden 1 into compliance with the new regulations was more than \$300 million.^{A-1} CECo concluded that the age of the unit and its relatively small size did not warrant the investment.^{A-1} The decision to decommission Dresden 1 was made in October 1984.

A.2.1 Dresden 1 Hazard Characterization

In August 1982, Pacific Northwest Laboratory (PNL) conducted a radiological survey (including core and sediment/soil samples) of Dresden 1 to estimate the residual radioactivity at the site. The estimates did not include neutron-activated parts of the pressure vessel and the biological shield, radioactivity in residues and resins in tanks and pumps, or the spent fuel stored on-site. Health physics personnel from CECo conducted another radiation survey in July and October 1985. In 1987, TLG Engineering, a consulting firm specializing in analysis of commercial reactor decommissioning, used the ORIGEN2 computer code to provide estimates for the neutron-activated components as shown in the Decommissioning Plan.^{A-1}

The primary source of radioactive hazardous materials is anticipated to be from asbestos insulation on contaminated piping and components.^{A-1} The estimated volume of this waste assumes that all the insulation contains asbestos. It is highly likely that the radioactive

hazardous waste will be the "bottleneck" for decontamination activities. The desire is to bury this waste in a commercial low-level, shallow land burial facility. The calculated costs for dealing with radioactive hazardous materials were based on this waste being packaged in the same burial containers as the associated piping and components.

Other potential sources of hazardous materials include asbestos insulation on non-contaminated piping and components and transformers contaminated with PCBs (polychlorinated biphenyls). Again, all insulation was assumed to contain asbestos, and both the main and substation transformers are assumed to contain PCBs. Since these materials are classified as hazardous under the Resource Conservation and Recovery Act (RCRA), they will be disposed of at approved hazardous waste disposal facilities. The PCBs are disposed of as part of an ongoing program at CECo, and remediation is expected to be completed prior to initiation of decommissioning.

Nonradioactive and nonhazardous wastes generated during the dismantling of Dresden 1 will consist of clean piping, components, structural steel, concrete rubble, and other trash. This material will be disposed of in local landfills, which may require a dumping permit and disposal fee. There are no federal regulations governing this waste.

A.2.2 Dresden 1 Management/Programmatic Issues

Since Dresden 1 is a shared site with operational Units 2 and 3, it can be safely and inexpensively maintained while allowing decay time, which will result in lower personnel exposures during dismantling. There is an expected savings in disposal costs for the highly activated components (i.e., the reactor vessel and internal components) because of the decay of short-lived isotopes.^{A-2} However, a delay in decommissioning provides only a reduction, not an elimination, in the radionuclide inventory, and at the end of its dormancy period, the facility will require extensive decontamination. The facility must be partially reactivated and/or replacement capabilities provided. Needed refurbishment activities include crane requalification and reactivation of electrical, lighting, air handling, and other service systems. Waste processing systems would either have to be reactivated or procured. One of the biggest disadvantages of the SAFSTOR alternative is the lack of knowledgeable station operations personnel at the time of decommissioning, who would be invaluable to support and assist in the decommissioning operations.^{A-2} A complete data base is necessary for the preparation of engineering and the planning of decommissioning activities.

CECo identified a decommissioning project team to manage the program and prepare Dresden 1 for SAFSTOR. The Vice President Boiling Water Reactor (BWR) Operations is responsible for the authorization and approval of the decommissioning project and has the authority to commit personnel and resources to prepare for SAFSTOR safely, on schedule, and within budget. This individual reviews the Decommissioning Plan, proposed possession only license (POL) amendments, and revised technical specifications.

The Project Manager reports to the Vice President BWR Operations and is responsible for on-site and general project staff as well as all subcontractors. This individual is also responsible for developing the Decommissioning Plan and POL amendment application with revised technical specifications. This includes identifying and coordinating project team members, developing a Decommissioning Plan schedule and budget and a decommissioning program cost estimate and schedule, preparing for and obtaining CEC approval of the Decommissioning Plan and then meeting with the Nuclear Regulatory Commission (NRC) and other agencies to obtain their approval.

The on-site project team prepares and reviews the revised technical specifications and reviews the Decommissioning Plan. This team is also responsible for implementing the plant preparations for SAFSTOR.

The general office project team prepares the POL amendment for the NRC and develops the Decommissioning Plan, cost estimates and schedule, funding plan, and the Environmental Report.

Specialty consultants and contractors are used to assist in document preparation, spot decontamination, waste packaging, and disposal services.

Dresden 1 will be prepared for decommissioning by maintaining it in the SAFSTOR mode for up to 30 years, or until Units 2 and 3 are decommissioned and dismantled. At the end of the SAFSTOR period, Dresden 1 will be decommissioned by dismantling (DECON). The objectives of the decommissioning process (which encompasses SAFSTOR operations to site restoration) are as follows, to:^{A-1}

- maintain Dresden 1 systems and structures needed to support operation of Units 2 and 3,
- secure all nonessential Unit 1 systems and structures to prevent deterioration and ensure that there will be no potential for release of contained radioactivity,
- dispose of radioactive and hazardous wastes remaining on-site in preparation for the SAFSTOR dormancy period,
- store spent fuel temporarily on-site until a federal repository is available for permanent disposal,
- decontaminate plant floors and areas enroute to, or adjacent to, operating equipment or repetitive survey/monitoring locations,
- prepare a radiological baseline characterization of the plant and a monitoring and surveillance program for the SAFSTOR dormancy period, and
- devitalize all areas no longer containing vital equipment and amend the Security Plan accordingly.

The decommissioning process is organized into five periods:

1. SAFSTOR Operations,
2. Dormancy,

3. Delayed Dismantling Engineering & Preparations,
4. Decommissioning Operations & License Termination, and
5. Site Restoration.

The Period 1 activities include engineering and planning efforts necessary to revise the Dresden 1 technical specifications for the SAFSTOR period and to obtain a POL amendment to the operating license.

Dresden 1 preparations for SAFSTOR include the following activities:^{A-1}

1. Drain, de-energize, and secure all noncontaminated, nonessential systems.
2. Remove filter elements and demineralize resin beds for shipment and burial.
3. Drain reactor vessel (reactor vessel internals will remain in place).
4. Drain, de-energize, and secure all contaminated systems and decontaminate as required.
5. Prepare the spent-fuel storage pool for long-term storage of fuel and provide for maintenance of fuel pool water chemistry.
6. Maintain, as required, lighting, fire protection, heating, ventilation and air conditioning (HVAC), and alarm systems for continued use during SAFSTOR.
7. Clean loose surface contamination from building access pathways.
8. Control access to radioactive or contaminated areas in accordance with normal station procedures.

The Period 2 activities required include maintenance of a guard force, preventative/corrective maintenance on lighting and HVAC, general building upkeep, maintenance of structural integrity, and establishment of an environmental and radiological monitoring program. During the plant's dormancy phase, minimal radioactive waste is expected to be generated and will be disposed of at the other operating units (i.e., Dresden 2 and 3).

Security will be provided by personnel employed at Dresden Units 2 and 3 to prevent unauthorized entry. Detection and notification systems will be operated according to the station Security Plan. Maintenance will be provided by the full-time utility maintenance staff already employed at the site. The environmental program is a modified (i.e., abbreviated) version of the one used for normal operations.

Period 3 work is presumed to occur concurrently with, or sequentially to, the decommissioning of Dresden Units 2 and 3. In general, all reactor dismantling planning, engineering, and site preparations will occur during this period. Management staffs for the utility and decommissioning operations contractor will be selected and brought on-site. Specifications and detailed procedures will be developed. Preparations will include specialty contractor and tooling selection, arrangements for radioactive waste disposal, and temporary facilities for the decommissioning work force.

During Period 4, decommissioning operations will occur. All radioactivity will be removed from systems, components, and structures. Only a small amount of chemical decontamination will be necessary because most short-lived isotopes will have decayed to levels low enough to permit removal with low occupational doses. The reactor vessel and internals will be segmented, packaged, and shipped to a burial site. Although the dose levels from cobalt-60 will have decayed significantly during the dormancy period, the reactor vessel and its internals will still require remote segmentation. Corrosion products on piping and components are also likely to require remote removal processes. The steam drum, steam generators, and associated pumps will be buried. All currently contaminated systems are assumed to require decontamination. The final activity in Period 4 will be to survey the facilities to certify removal of radioactivity. The license will then be terminated.

Period 5 is the site-restoration phase, which includes demolition and removal of remaining structures. The steel building shell will be torch cut and released as scrap, building foundations will be backfilled, and site areas will be cleaned up, graded, and restored. The switchyard, transmission towers, canals, and site infrastructure will likely remain. A final dismantling report will then be prepared and submitted to the NRC.

A.2.3 Dresden 1 Requirements and Regulatory Issues

A POL amendment to the operating license was issued by the NRC in accordance with Title 10 of the Code of Federal Regulations, Parts 30, 50, 51, and 70. The POL was obtained for Dresden 1 in July 1986 when Operating License No. DPR-2 was amended to a possess-but-not-operate status (Amendment No. 36).

Dresden 1 amended the facility license to include specifications for the SAFSTOR period. Although no iodine will be released from the shutdown Unit 1, small releases could potentially occur from the adjacent Units 2 and 3 through the Unit 1 turbine building; therefore, the Dresden 1 chimney will continue to be monitored. Data on airborne effluents from Unit 1 have been added to those from Units 2 and 3 and are included in the total site dose. Liquid radioactive effluents will not be released from Unit 1 to the environment, but may be released from the radwaste systems for Units 2 and 3, and will meet applicable regulations.

In modifying the technical specifications, Dresden proposed to delete the requirements for auxiliary electrical systems, including two 138 KV lines, an operable diesel generator with starting batteries, and substation and station batteries. The stored, irradiated fuel had decayed until the heat load no longer required active cooling, and the cooling system has been out of service since 1983. Only occasional water additions are necessary to offset evaporation losses in order to maintain the water shielding level. Minimum pool level and water quality requirements have been established.

During the safe storage period, all accessible areas within the facility that have radiation levels above 5 mRem/h will be marked, shielded, or protected by physical barriers.^{A-1}

During decommissioning, all structures and components with radioactivity levels above U.S. NRC Regulatory Guide 1.86 Table 1 limits will be removed.^{A-1} The criteria for determining the disposition of radioactive materials removed from the site for unrestricted use are either 5 mR/h above background at 1 m from the surface or 10 mRem/year above background, considering reasonable proximity and occupancy. The criteria for disposition and disposal of hazardous and toxic wastes, including asbestos, will follow Environmental Protection Act (EPA) Title 40, Part 61.^{A-1}

Dresden 1 decommissioning will conform to current regulatory requirements, standards, and guidance prescribed by the NRC, Department of Transportation (DOT), EPA, and the State of Illinois. The worst-case radiological release (from the stored spent fuel) was compared to the guidelines in 10 CFR 100. The applicable regulations are:^{A-1} 10 CFR 19, 10 CFR 20, 10 CFR 30, 10 CFR 40, 10 CFR 50, 10 CFR 51, 10 CFR 70, 10 CFR 61, 10 CFR 71, 10 CFR 73, 10 CFR 140, 10 CFR 150, 10 CFR 170, Regulatory Guide 1.86, Proposed Rule (Decommissioning criteria (2/11/85) for nuclear facilities), DOT Regulations 49 CFR 170-190, U.S. regulations 40 CFR 190, and 29 CFR 1910.

A.2.4 Dresden 1 Transitioning Facility Risk Issues

No information on transitioning facility risk issues was available.

A.2.5 Dresden 1 Cost Increases and Uncertainty

A 30-year delay adds uncertainty to the decommissioning process. Since most of the decommissioning activities will occur 30 to 60 years after plant operations, cost estimates made now, based on current prices, technologies, and regulations are very susceptible to change.^{A-2}

In the November 1991 Decommissioning Plan, costs were estimated for each period of the program in a site-specific cost estimate.^{A-1} A financial plan was developed to assure that decommissioning funds will be available to decommission and dismantle the Dresden 1 site safely. CECO submitted a report to the NRC indicating how reasonable assurance will be provided that funds will be available to decommission all its nuclear generating facilities in compliance with 10 CFR 50.33(k) and 50.75. An internal funding method was used prior to 1989. Currently, an external funding method is used that satisfies the State of Illinois requirements in Public Act 85-1400 and the related Order No. 88-0298 of the Illinois Commerce Commission, the qualified nuclear decommissioning fund provision of Section 468A of the Internal Revenue Code, and 10 CFR 50.75.

The schedule developed for the Decommissioning Plan, indicates that Period 1 (SAFSTOR - Mothballing) will take one year to complete from the date of NRC approval of the Decommissioning Plan. Period 2 (Dormancy) will be approximately 30 years but will depend on the decommissioning schedule of Dresden Units 2 and 3; the expected end date is December 2017. Period 3 (Delayed Dismantling Preparations) will last 0.5 year and be completed in June 2018. Period 4 (Decommissioning Operations) will take 4.5 years and be finished in December

2022. The final phase, period 5 (Site Restoration), will last for 1.5 years, and expected completion is June 2024.

The decommissioning schedule was prepared using the Atomic Industrial Forum/National Environmental Studies Project (AIF/NESP)-009 study, with changes for recent experience. The schedule and work force estimates were prepared using Microsoft Project for Windows.^{A-2} The durations reflect the actual man-hour estimates, with the schedule output adjusted by stretching some activities over their slack range and moving other activities to the end of their slack range.

The costs for the five periods were estimated in November 1985 by TLG Engineering. The costs include a 25% contingency (for all periods).^{A-1} Also included are all management, engineering, planning, decontamination equipment, structure removal, packaging, shipping, and burial costs. Collateral costs, which were also accounted for, include equipment rental, health physics supplies, nuclear liability insurance, plant energy, site property taxes, and staff relocation. The total cost estimate for Dresden 1 was \$110 million.

In a January 1993 TLG Engineering report, "Final Decommissioning Cost Estimate for the Dresden Nuclear Power Station - Unit 1, "the costs and schedule were reported as follows:^{A-2}

	Cost, 92\$ <u>(thousands)</u>	Schedule <u>(months)</u>
Period 1: SAFSTOR Operations	18,424.8	12.0
Period 2: Dormancy	98,247.4	215.8
Period 3: Preparation	12,427.5	17.9
Period 4: Decommissioning Operations	144,261.6	26.9
Period 5: Site Restoration	25,527.7	7.6
Total Cost	298,888.9	280.2

The costs by calendar year were also provided:^{A-2}

	<u>Cost, 92\$ (thousands)</u>	<u>Calendar Years</u>
Period 1: SAFSTOR Operations	10,802.5	1993
	7,622.3	1994
Subtotal Period 1	18,424.8	
Period 2: Dormancy	98,247.4	1994-2012
Period 3: Preparation	4,506.6	2012
	7,920.9	2013
Subtotal Period 3	12,427.5	
Period 4: Decommissioning Operations	7,762.4	2013
	67,694.8	2014
	60,807.8	2015
	7,996.6	2016
Subtotal Period 4	144,261.6	
Period 5: Site Restoration	25,527.7	2016
Total Cost	298,888.9	

The costs represent the cost in 1992 dollars to decommission Dresden 1, and the dormancy period was selected to coincide with the scheduled shutdown of Unit 2. The cost study^{A-2} did not address removal of spent fuel from the site, but assumed that it would be removed in a timely fashion to a government repository such that it would not affect the overall schedule.

The cost report^{A-2} breaks down costs in each period of the Decommissioning Plan. In Period 1, the estimated personnel radiation exposure is 58.6 man-Rem, and the total craft labor requirements are 69,521.5 man-hours. During decommissioning Period 4, the estimated labor requirements are 27,974 man-hours, and the worker exposure is estimated at 974 man-Rem. For the entire project, the total labor requirements are estimated at 615,109 man-hours with a worker exposure of 1,039.8 man-Rem.

A major contributor to the cost of decommissioning is the disposition of radioactive wastes. The cost study^{A-2} assumed that a burial site will be available in the Central Midwest Compact within 375 miles of Dresden 1. The base burial rate was estimated on current costs and projections for the Central Midwest Compact site with the surcharge structure of the existing operating burial ground (Barnwell, SC). The cost of burial at this future site was based on an assumed burial rate of \$350/ft³ (rate schedule and supplemental costs provided by Chem-Nuclear, for their site in Barnwell, SC).^{A-2}

The major factors considered in determining this cost estimate were as follows:^{A-2}

1. Dresden 1 drawings, equipment, and structural specifications, including construction details, which were provided by CECO.
2. Representative regional employee salary and craft labor rates for site administration, operations, construction, and maintenance personnel were developed by TLG Engineering for the positions identified for overseeing and performing the decommissioning activities.
3. Engineering services such as writing activity specifications, detailed procedures, detailed activation analyses, structural modifications, etc., are assumed to be provided by contractors. These services could, however, be provided by utility personnel.
4. Material and equipment costs for conventional demolition and/or construction activities were taken from R.S. Means.
5. Rates for shipping radioactive wastes were provided by a radioactive waste transportation company that publishes tariffs for this cargo.
6. The estimate of low-level radioactive waste (LLW) disposal costs relied upon the surcharges (e.g., on total curies, weight, special handling requirements, etc.) in effect at the Barnwell, SC, LLW-management facility operated by Chem-Nuclear Systems, Inc. The base burial charge was developed as an estimate for the Central Midwest Compact.
7. Costs in this estimate are in 1992 dollars; that is, no adjustment has been made to reflect the effects of either interest or escalation in the amounts over the funding period.
8. This study does not address the removal or disposal of spent fuel from the site. Any costs for such activities will take place during Period 2, but are not included in this study.
9. This study follows the principles of ALARA (as low as reasonably achievable) through the use of work duration adjustment factors that incorporate such items as radiological protection instruction, mock-up training, and 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.
10. This study was performed in accordance with the Atomic Industrial Forum/National Environmental Studies Project report AIF/NESP-036, "Guidelines for Producing Commercial Nuclear Power Plant Decommissioning Cost Estimates." These guidelines were prepared under the review of a task force of representatives from utilities, state regulatory commissions, architectural/engineering firms, the Federal Energy Regulatory Commission, the NRC, and the National Association of Regulatory Utility Commissioners.

The methodology used in the cost estimate^{A-2} was based on the AIF/NESP-009 study report, "An Engineering Evaluation of Nuclear Power Reactor Decommissioning Alternatives," and

the DOE *Decommissioning Handbook*. A unit cost factor is used in these references. TLG Engineering developed unit cost factors for concrete removal, steel removal, and cutting from labor and material cost information.

Activity-dependent costs were also estimated. The activity-duration critical path determined the total decommissioning schedule. The program schedule was used to determine the period-dependent cost for program management, administration, field engineering, equipment rental, quality assurance, and security. Nuclear liability and property insurance premium cost estimates were provided by CECo.

This study used contingency percentages for each category from the AIF/NESP-036 study. With extremes in issues related to costs, such as storage time of the spent fuel to cost projections for low-level-waste disposal, instead of using a standard average contingency, a contingency analysis was prepared that evaluated each line-item cost by its level of uncertainty and its contribution to the total cost. The average contingency for this estimate was 15.94%.^{A-2}

The reactor pressure vessel and internals will be segmented and shipped in DOT-approved, currently available, shielded truck casks. The recirculation pumps will be lifted out intact and shipped in their own containers by truck to the disposal site. The exteriors of the steam generators will be decontaminated and penetrations sealed. The generators will also be removed intact and shipped by railcar to the disposal site. The steam drum will be decontaminated and penetrations sealed. It will then be segmented, have cover plates and lifting lugs welded in place, and be shipped by railcar. The drum shell will serve as its own burial container. The turbine will be dismantled conventionally. The rotors and shafts will be packaged and shipped as radioactive waste, and the main condensers will be segmented, shipped, and disposed of as low-level radioactive waste along with other components.

There may be some radioactive waste generated that is greater than 10 CFR Class C quantities (i.e., highly activated sections of the reactor vessel internals). This waste will likely be disposed of as high-level waste (HLW) in the DOE's deep geological repository unless an alternative is approved by the NRC. The cost of this disposal, unlike that of the spent fuel, is not covered by DOE's 1 mill/kWh surcharge, and was estimated from information on disposal costs for highly radioactive Type C waste.^{A-2}

The decommissioning and utility staff costs and removal costs are the largest percentage of the total cost, which reflects the labor-intensive nature of the decommissioning process. Radioactive waste disposal is the next most costly item. Historically, costs for low-level-waste disposal have risen at a higher rate than inflation. Shipping costs are sensitive to fuel cost changes and distance to the disposal facility. Removal costs depend on the amount of remotely operated equipment available in the future when dismantling occurs and on the higher cost of that equipment versus the savings in labor costs.

A.2.6 Dresden 1 Stakeholder Concerns

The documentation available did not discuss how stakeholder concerns will be addressed.

A.2.7 Dresden 1 Waste Minimization and Avoidance of Mixed-Waste Generation

The documentation available did not discuss any potential waste minimization activities or how the generation of mixed waste will be avoided.

A.2.8 Dresden 1 Industry Involvement

During the entire decommissioning process, specialty consultants and contractors will be used to assist in the document preparation and in spot decontamination, waste packaging, and disposal services.

During Period 3 (Delayed Dismantling Engineering & Preparations) of the decommissioning process, management staffs for the utility and decommissioning operations contractor will be selected and brought on-site. Specifications and detailed procedures will be developed. Preparations will include specialty contractor and tooling selection, arrangements for radioactive waste disposal, and temporary facilities for the decommissioning work force.

A.2.9 Dresden 1 Recycle and Reuse Opportunities

The scrap generated during decommissioning is not included as a credit in the cost estimates.^{A-2} The scrap value is low and merely offsets the associated removal and reprocessing costs, which are not included in the cost estimates. With the decommissioning taking place so far in the future, all the equipment will be worn and obsolete. CECo will remove all easily removable items such as furniture, tools, and mobile equipment, including forklifts, trucks, and bulldozers.

Because of the high volumetric cost for waste disposal, a large percentage of the metallic inventory is presumed to be sent to a waste recovery vendor. It is expected that 80 to 90% of this material can be decontaminated to levels permitting unrestricted use, at a significant cost savings.^{A-2}

A.2.10 Dresden 1 Technology Development or Enhancement Needs

No technology development or enhancement needs were discussed in the documentation available to the authors.

A.2.11 Dresden 1 Lessons Learned

Dresden 1 will be maintained in the SAFSTOR mode for as long as 30 years, or until Units 2 and 3 are decommissioned and dismantled. Since Dresden 1 is a shared site with operational Units 2 and 3, it can be safely and inexpensively maintained while allowing decay time,

resulting in lower personnel exposures during dismantling. There is an expected savings in disposal costs for the highly activated components (i.e., the reactor vessel and internal components) because of the decay of short-lived isotopes. However, a delay in decommissioning provides only a reduction, not an elimination, in the radionuclide inventory, and at the end of its dormancy period, the facility will require extensive decontamination. One of the more significant disadvantages of placing the plant in SAFSTOR is the lack of knowledgeable station operations personnel at the time of actual decommissioning. They would be invaluable to support and assist in the decommissioning operations. Therefore, a complete data base will be necessary for the preparation of engineering and the planning of decommissioning activities.

Dresden 1 preparations for SAFSTOR include the following activities:

1. Drain, de-energize, and secure all noncontaminated, nonessential systems.
2. Remove filter elements and demineralize resin beds for shipment and burial.
3. Drain reactor vessel (reactor vessel internals will remain in place).
4. Drain, de-energize, and secure all contaminated systems and decontaminate as required.
5. Prepare the spent-fuel storage pool for long-term storage of fuel and provide for maintenance of fuel pool water chemistry.
6. Maintain, as required, lighting, fire protection, HVAC, and alarm systems for continued use during SAFSTOR.
7. Clean loose surface contamination from building access pathways.
8. Control access to radioactive or contaminated areas in accordance with normal station procedures.

In addition, as soon as possible, adjust requirements and regulations to reflect the plant's SAFSTOR status.

During the plant's 30-year dormancy period, activities required include maintenance of a guard force, preventive/corrective maintenance on lighting and HVAC, general building upkeep, maintenance of structural integrity, and an environmental and radiological monitoring program. During the plant's dormancy phase, minimal radioactive waste is expected to be generated and will be disposed of at the other operating units (i.e., Dresden Units 2 and 3).

Security forces to prevent unauthorized entry will be provided from personnel employed at Dresden Units 2 and 3. Detection and notification systems will be operated according to the station Security Plan. Maintenance will be provided by the full-time utility maintenance staff already employed at the site. The environmental program is a modified (i.e., abbreviated) version of the one used for normal operations.

A 30-year delay adds uncertainty to the decommissioning process. Since most of the decommissioning activities will occur 30 to 60 years after plant operations, cost estimates made now, based on current prices, technologies, and regulations are very susceptible to change.

The schedule developed for the Decommissioning Plan indicates that preparation for SAFSTOR will take one year to complete (from the date of NRC approval of the Decommissioning Plan) and will cost \$18,424,800. The dormancy period will be approximately 30 years but will depend on the decommissioning schedule of Dresden Units 2 and 3. The expected end date is December 2017, and the estimated cost is \$98,247,400. The methodology used in the cost estimate was based on the AIF/NESP-009 study report, "An Engineering Evaluation of Nuclear Power Reactor Decommissioning Alternatives" and the DOE *Decommissioning Handbook*. The decommissioning schedule was prepared using the AIF/NESP-009 study, with changes for recent experience. The schedule and work force estimates were prepared using the "Microsoft Project for Windows" computer program.

A major contributor to the cost of decommissioning is the disposition of radioactive wastes. The cost study assumed that a burial site will be available in the Central Midwest Compact within 375 miles of Dresden 1. The base burial rate was estimated on current costs and projections for the Central Midwest Compact site with the surcharge structure of the existing operating burial ground (Barnwell, SC). The cost of burial at this future site was based on an assumed burial rate of \$350/ft³, rate schedule and supplemental costs provided by Chem-Nuclear, for its site in Barnwell, SC. Historically, costs for LLW disposal have risen at a higher rate than inflation. Shipping costs are sensitive to fuel cost changes and distance to the disposal facility. Removal costs depend on the amount of remotely operated equipment available in the future when dismantling occurs and the higher cost of that equipment versus the savings in labor costs.

The scrap generated during decommissioning is not included as a credit in the cost estimates. The scrap value is low and merely offsets the associated removal and reprocessing costs, which are not included in the cost estimates. With the decommissioning taking place so far in the future, all the equipment will be worn and obsolete. CECo will remove all easily removable items such as furniture, tools, and mobile equipment, including forklifts, trucks, and bulldozers.

Because of the high volumetric cost for waste disposal, a large percentage of the metallic inventory is presumed to be sent to a waste recovery vendor. It is expected that 80 to 90% of this material can be decontaminated to levels permitting unrestricted use, at a significant cost savings.

A.3 Enrico Fermi 1

In the early 1950s, the Korean War aggravated relations between the U.S. and the USSR and China. The Defense Department wanted assurance that it could secure more plutonium for a weapons buildup. One way to assure this was for industry or government to build dual-purpose nuclear plants. The military would have first call on the plutonium produced by the plants; electric utility owners could utilize the heat for power generation. The decision to build the Fermi plant fitted ideally into the atmosphere and perceived needs of the times. Not only would this plant demonstrate technical and economic aspects of breeder reactors, but it would provide high-grade plutonium that could be used for military weapons or as fuel for reactors.^{A-4}

On January 10, 1955, the U. S. Atomic Energy Commission (AEC) announced its Power Reactor Demonstration Program inviting private enterprise to present plans for building nuclear power reactors in cooperation with the AEC. On March 30, 1955, the Detroit Edison Company, on behalf of itself and eight other companies, offered to participate in the program by designing, constructing, and operating an experimental fast-neutron breeder reactor electric power plant. The nine companies formed the Power Reactor Development Company (PRDC) as a nonprofit organization. The plant was to be called the Enrico Fermi Atomic Power Plant (later known as Fermi-1) to commemorate the work of the late Enrico Fermi, the first atomic scientist to produce a chain reaction.^{A-4}

Fermi-1, designed for operation at 150 MWe, was the first large nuclear power plant having as its heat source a sodium-cooled fast breeder reactor. The Fermi-1 heat transport system used three cooling loops to remove heat by natural circulation using intermediate heat exchangers and steam generators.^{A-4}

On August 4, 1956, the AEC issued a construction permit for Fermi-1. The Fermi reactor and the associated steam-electric generating plant were built on a 915-acre site at Lagoon Beach, Frenchtown Township, Monroe County, MI, on the western shore of Lake Erie, about 30 miles from downtown Detroit and 25 miles from downtown Toledo. Cooling water was available from Lake Erie.^{A-4}

The low-power operating license for Fermi was issued on May 10, 1963, and criticality was achieved on August 23, 1963. The low-power test program was successfully completed by December 1965. The full-power operating license was issued on December 17, 1965, and the high-power test program began on December 29, 1965.^{A-4}

The early months of 1966 were devoted to a series of tests at incrementally-increasing power levels. On October 5, 1966, while in this testing phase, the plant experienced a fuel melting incident caused by one of six zirconium liners of the conical flow guard. Somehow this liner became detached and was thrust upward against the inlet flow nozzles of the affected fuel subassemblies by the force of the flowing liquid sodium coolant. The restricted flow of the liquid sodium coolant to these fuel subassemblies resulted in fuel melt. This incident resulted in a three-and-one-half year rehabilitation period, during which large costs were incurred.^{A-4}

Fermi was repaired and successfully demonstrated electrical power generation at its core design level in 1969. The fuel melt incident precluded the reuse of a large number of fuel subassemblies, because that would have required an expensive and time-consuming test program to assure that they had not been damaged. This restriction shortened the useful life of the alloy core, since only two full core loadings of alloy subassemblies were fabricated. An effort was made to raise the \$54 million necessary for new oxide fuel and plant revisions. Many companies worldwide responded, but only \$44 million could be raised. On November 27, 1972, the Executive Committee of PRDC reluctantly decided to decommission the plant, which was successfully accomplished by the end of 1975 at a cost of \$7 million.^{A-4}

Data from this decommissioning project were put into a computerized data-handling system, MAPPER, which was intended to allow for flexible data accumulation, manipulation, and retrieval. The purpose of this was to provide the Nuclear Regulatory Commission (NRC) and its licensees with comparative data in the areas of ALARA (as low as reasonably achievable) responsiveness, cost-estimate accuracy, schedule adherence, project labor hours and costs, exposure accountability, and radwaste generation and disposition, to assist them in their assessment of decommissioning alternatives and ALARA methods for future decommissioning projects.^{A-3} Unfortunately, when this report was retrieved on microfiche, the computer printout was largely illegible, much of the data was not available, and there was little text to summarize the available information.

A.3.1 Fermi 1 Hazard Characterization

Samples were taken from the secondary sodium cooling loop and were analyzed for radioactivity and impurities by PRDC, Hanford Engineering Development Laboratory, and the University of Michigan. The beta radioactivity levels were no higher than naturally occurring isotopes found in commercial-grade clean sodium. This sodium was drained into Department of Transportation (DOT) No. 17 E Type 1 55-gallon drums and was shipped to Fike Chemical Company in Nitro, WV, to be processed into sodium methyllate.^{A-4}

A.3.2 Fermi 1 Management/Programmatic Issues

Following the decision to decommission Fermi-1, PRDC submitted the rudiments of the Decommissioning Plan to the AEC. The major activities initially planned to decommission Fermi-1 included the following:^{A-4}

- return of leased enriched uranium to the AEC,
- disposition of blanket subassemblies,
- disposition of radioactive and nonradioactive sodium,
- passivation of residual sodium,
- disposal of other contaminated equipment and materials,
- decontamination and sealing of contaminated areas, and
- surveillance.

The second revision of the Decommissioning Plan detailed the major tasks required and requested approval for two proposals that would result in a significant cost savings: on-site storage of radial blanket subassemblies and on-site storage of all radioactive sodium. In addition, the second revision included the following:^{A-4}

- off-site burial of the axial blanket segments,
- removal of sodium from the secondary system for sale, and passivation of the residual sodium so that secondary system components could be salvaged or scrapped,

- reactor auxiliary and fuel handling systems to be cleaned of significant contamination or the access to such systems to be restricted,
- fencing of the facility to be left as is or rerouted for easier access to uncontaminated areas,
- retention of legally required and other significant documents, and
- establishment of administrative controls for authorized entry to restricted areas and for preparation of environmental, unusual events, and annual status reports.

The AEC issued a directive that the Decommissioning Plan include the removal and off-site disposal of primary and secondary sodium and blanket materials. A finalized Decommissioning Plan was submitted and approved by the AEC, one year after the decision was made to decommission the plant.^{A-4}

The 25.6% enriched fuel was assigned to the reactor project under an AEC lease agreement. Since no private company could reprocess it to UF_6 with diffusion plant purity specifications, the AEC accepted the fuel at the Savannah River Plant (SRP) for a reprocessing fee of \$1.78 million plus shipping costs. As of 1979, the fuel was residing in fuel storage pools at SRP awaiting reprocessing.^{A-4}

The blanket subassemblies contained plutonium bred in the fuel pins, so neither the AEC nor Detroit Edison would allow them to remain on-site. Neither could they be buried at a commercial radioactive waste site. Therefore, the PRDC sought relief from the AEC, which agreed to take the blanket subassemblies for an estimated disposal fee of \$1.2 million, under the hypothetical reprocessing provision of 33 CFR 30. Because of an index in this provision, when payment was made to the Energy Research and Development Administration (ERDA) it had increased to almost \$1.6 million in 1975. The blanket subassemblies were shipped in Philadelphia Electric Company Model PB-1 shipping casks to the Idaho Chemical Processing Plant (ICPP).^{A-4}

Nozzle segments were shipped to the Nuclear Engineering Company (NECO) burial site in Morehead, KY. Other radioactive components were buried at Morehead, KY; Sheffield, IL; and Beatty, NV. Some materials were donated or sold to other licensed organizations.^{A-4}

The radioactive primary sodium met the standards for reactor-grade sodium. The AEC was contacted concerning the use of this sodium at the Fast Flux Test Facility (FFTF), but it was rejected because of a significant cost penalty.^{A-4} PRDC also tried to dispose of the radioactive sodium at NECO's Beatty, NV, or Richland, WA, disposal sites. NECO could not obtain approval for this disposal. Since PRDC was directed by the AEC to remove the radioactive sodium from the Fermi site, but then denied burial at the AEC-regulated disposal sites, it again sought relief from the AEC.^{A-4}

The AEC proposed two options: ship the metallic sodium to Richland and pay for its conversion to a salt suitable for burial or convert the sodium to a caustic or salt suitable for Richland. These were both very expensive options, which were not planned for in the original

\$4 million decommissioning reserve. A number of problems were encountered in trying to convert the sodium using commercial vendors. The PRDC again suggested to the AEC that the sodium be reused instead of disposed of as waste. It was decided to store the sodium for use in the Clinch River Breeder Reactor Project (CRBRP). The sodium was to remain on-site at Fermi-1 under Detroit Edison's supervision. Part of the sodium was drummed and stored in the reactor building, and drained sodium systems were passivated using carbon dioxide. Funds to provide insurance, surveillance, drumming, and shipping were placed in escrow.^{A-4}

The reactor vessel was sealed within the primary shield tank, and outlying components were also sealed. The reactor building was used as an isolation structure against personnel access. The building, reactor vessel, major sodium piping, and other auxiliary facilities were left intact.^{A-4}

A.3.3 Fermi 1 Requirements and Regulatory Issues

No AEC guidelines were available concerning the decommissioning of a sodium-cooled reactor, even though other sodium or sodium-potassium-cooled reactors [i.e., HALLAM, SEFOR, and Experimental Breeder Reactor-I (EBR-I)] had been or were being decommissioned.^{A-4} Studies had to be made by both the AEC and PRDC to determine what to do with the irradiated blanket elements and the radioactive primary system sodium. These studies resulted in a long decommissioning period.^{A-4} Decisions had to be made concerning the administration of a site that still contained some level of radioactivity.

A.3.4 Fermi 1 Transitioning Facility Risk Issues

No information on transitioning facility risk issues was available.

A.3.5 Fermi 1 Cost Increases and Uncertainty

The total decommissioning costs in 1974 for the 36-month project were \$7,164,988. The personnel exposure was 28.04 man-Rem or \$255,527 per man-Rem. It was estimated that 5000 Ci were handled during decommissioning for a cost of approximately \$1433 per curie or 178.3 Ci per man-Rem.^{A-3} Approximately \$4.2 million of the decommissioning costs was paid to the AEC for core reprocessing, blanket reprocessing, and use charges during decommissioning.^{A-4}

Decommissioning took longer than anticipated, but this additional expense was offset by the rapid reduction in work force as personnel could no longer be effectively used. The final cleanup in 1975 was accomplished with a very small work force. Retiring buildings and equipment as soon as they were not needed resulted in savings in property taxes and insurance.^{A-4}

The final decommissioning costs were itemized as follows:^{A-4}

Core Fuel Processing	\$ 418,000.
Includes transferring subassemblies from the reactor and other storage areas, steam cleaning, underwater segmenting, loading in casks, and shipping to Savannah River; it also includes the material and fabrication cost of the No. 2 shipping cask and modifications to the No. 1 cask.	
AEC Core Fuel Processing	\$1,783,000.
Includes basic processing and conversion charges, processing and conversion losses, and use charges during the processing period.	
Blanket Subassembly Processing	\$ 67,000.
Includes transferring subassemblies from the reactor and other storage areas, steam cleaning, and storage in the cutup pool.	
Blanket Subassembly Processing for Disposal at Idaho	\$ 386,000.
Includes licensing and rental of two casks, design and purchase of special basket and container assemblies, round-trip shipping charges, and cutting and disposing of some nozzles.	
AEC (ERDA) Blanket Subassembly Processing	\$1,594,000.
Payment for blanket accepted by ERDA under reprocessing provisions of 33 CFR 30.	
Sodium and Cold Trap Disposal	\$ 250,000.
Includes transferring primary sodium from all systems to storage tanks, constructing a sodium-barreling facility, and dismantling and removing the primary cold trap for shipment to Beatty, NV. Includes \$75,000 allocated to the trust fund to barrel and ship primary sodium to PMC (for CRBRP) from 1981 to 1985.	
Sodium Piping and Contaminated Equipment Disposal	\$ 480,000.
Includes cutting and sealing pipes and equipment, decontaminating equipment, and packaging solid waste for burial.	
Plant and Administrative Expenses	\$1,999,700.
Includes plant and administrative expenses, nuclear insurance, property tax, regulatory charges, and AEC use charges. This amount is reduced by \$376,000 because of interest received on invested funds during the decommissioning period.	
Total Cost of Decommissioning	\$6,977,700.
Provision for Surveillance	\$ 187,288.
Total Cost for Decommissioning, Including Surveillance Fund	\$7,164,988.

In addition to the above surveillance amount, it was anticipated that the decommissioning reserve fund would be increased by \$350,000 over a 10-year period because of premium refunds from the National Energy Liability Insurance Association.^{A-4}

The sources of the funds used for the decommissioning project were as follows:^{A-4}

Cash and commitments as of Dec. 1, 1972 (decommissioning reserve fund)	\$4,113,826.
Member company contributions (1974-1975)	\$2,809,402.
Contribution from Atomic Power Development Associates	\$ 42,270.
Revenues from salvage sales	\$ 564,580.
Use charges, oxide core, construction, and other operating costs paid after Dec. 1, 1972, from the above funds	\$ -365,090.
Funds available and used for Decommissioning	\$7,164,988.

There was no mention of any funds in escrow for the eventual dismantling of the facility. The initial request by the AEC to the PRDC was to estimate costs based on a proposed plan for decommissioning and maintenance of the plant in perpetuity.^{A-4}

A.3.6 Fermi 1 Stakeholder Concerns

The documentation available did not discuss how stakeholder concerns were addressed.

A.3.7 Fermi 1 Waste Minimization and Avoidance of Mixed-Waste Generation

The documentation available did not discuss any potential waste minimization activities or how the generation of mixed waste was avoided.

A.3.8 Fermi 1 Industry Involvement

Industry involvement was not discussed in the documentation available.

A.3.9 Fermi 1 Recycle and Reuse Opportunities

Salvage sales provided significant income, primarily because some of the Fermi 1 buildings could be used by the Detroit Edison Company for continued operation of the turbine generator using steam from a conventional oil-fired boiler located adjacent to the Fermi 1 plant. The warehouse was used for the Fermi II project. The steam generator was sold to the Central

Research Institute of Electric Power Industry of Japan for \$1.00 and was shipped to Japan at Japanese expense.^{A-4}

A.3.10 Fermi 1 Technology Development or Enhancement Needs

No technology development or enhancement needs were discussed in the documentation available to the authors.

A.3.11 Fermi 1 Lessons Learned

Because of the limited amount of information available on the Fermi 1 decommissioning process, the lessons learned are very general in nature.

Characterization of the hazards present at the plant is important. Determining potential final resting places for the hazards and the type of packaging necessary cannot be done until the hazard is clearly identified and classified.

Creating a Decommissioning Plan helps to identify tasks that will result in significant cost savings. For example, Fermi 1 requested approval for two such tasks, on-site storage of radial blanket subassemblies and on-site storage of all radioactive sodium. The Decommissioning Plan also helps anticipate and deal with problem areas. For example, the enriched fuel assigned to Fermi 1 could not be reprocessed by a private company. The AEC ultimately accepted the fuel at the SRP for a reprocessing fee. There were no guidelines available from the AEC concerning the decommissioning of a sodium-cooled reactor. Studies had to be made by both the AEC and PRDC to determine what to do with the irradiated blanket elements and the radioactive primary system sodium. The blanket subassemblies contained plutonium bred in the fuel pins, so neither the AEC nor Detroit Edison would allow them to remain on-site. Nor could they be buried at a commercial radioactive waste site. Therefore, the PRDC sought relief from the AEC, which agreed to take the blanket subassemblies for an estimated disposal fee of \$1.2 million under the hypothetical reprocessing provision of 33 CFR 30. Due to an index in this provision, when payment was made to the ERDA it had increased to almost \$1.6 million in 1975. The blanket subassemblies were shipped in Philadelphia Electric Company Model PB-1 shipping casks to the ICPP.

The radioactive primary sodium met the standards for reactor-grade sodium. PRDC tried to dispose of the radioactive sodium at NECO's Beatty, NV, or Richland, WA, disposal sites. However, NECO could not obtain approval. Since PRDC were directed by the AEC to remove the radioactive sodium from the Fermi site, but then denied burial at the AEC-regulated disposal sites, PRDC again sought relief from the AEC. The AEC proposed two options: ship the metallic sodium to Richland and pay for its conversion to a salt suitable for burial or convert the sodium to a caustic or salt suitable for Richland. These were both very expensive options, which were not planned for in the original \$4 million decommissioning reserve. A number of problems were encountered in trying to convert the sodium using commercial vendors. The PRDC again suggested to the AEC that the sodium be reused instead of disposed

of as waste. It was decided to store the sodium for use in the CRBRP. The sodium was to remain on-site at Fermi 1 under Detroit Edison's supervision. Part of the sodium was drummed and stored in the reactor building. Funds to provide insurance, surveillance, drumming and shipping were placed in escrow.

The total decommissioning costs in 1974 for the 36-month project were \$7,164,988. Approximately \$4.2 million of the decommissioning costs were paid to the AEC for core reprocessing, blanket reprocessing and use charges during decommissioning. The personnel exposure was 28.04 man-Rem or \$255,527 per man-Rem. It was estimated that 5000 Ci were handled during decommissioning for a cost of approximately \$1433 per curie or 178.3 Ci per man-Rem.

Even though decommissioning took longer than anticipated, the additional expense was offset by the rapid reduction in work force. The final cleanup in 1975 was accomplished with a very small work force. Retiring buildings and equipment as soon as they were not needed resulted in savings in property taxes and insurance.

Salvage sales provided significant income, primarily because some of the Fermi 1 buildings could be used by the Detroit Edison Company for continued operation of the turbine generator using steam from a conventional oil-fired boiler located adjacent to the Fermi 1 plant. The steam generator was sold to the Central Research Institute of Electric Power Industry of Japan for \$1.00 and was shipped to Japan at Japanese expense.

A.4 Fort St. Vrain

The Fort St. Vrain Nuclear Generating Station (FSV) is the first and only High-Temperature Gas-Cooled Reactor (HTGR) in the U.S. commercial nuclear industry. It was a 330-MW electric generating station designed by General Atomics in the mid-1960s for Public Service Company of Colorado (PSC) as part of the AEC Reactor Demonstration Program.

FSV is located in the South Platte River Valley, in an agricultural area with gently rolling hills, approximately 35 miles north of Denver. The population density in the rural areas surrounding the plant is relatively low. The South Platte River and St. Vrain Creek pass through portions of the 2798-acre site. These two streams, which join near the northern tip of the site, are not large enough to be used for water transportation.

FSV used a uranium-thorium fuel cycle with helium as its primary coolant. A prestressed concrete reactor vessel (PCRv) contained the total primary coolant system including the reactor, steam generators, and helium circulators. The reactor core was graphite moderated and reflected and was located in the upper part of the vessel. The reactor core consisted of over 5000 individual graphite blocks, including an active core of 1482 hexagonal fuel elements loaded with TRISO-coated uranium and thorium particles cast into cylindrical rods. The helium coolant was discharged from four helium circulators at 700 psia (100% of rated power) and

passed down through the core, removing heat from the fission process. This heat was then distributed equally through 12 steam generator modules.

The initial announcement to build FSV was made on March 13, 1965. The FSV construction permit was issued in September 1968, and construction was completed and the operating license was issued in December 1973. Initial criticality was achieved on January 31, 1974. Although FSV received a full-power operating license in 1973, extensive preoperational testing mandated by the NRC and the resulting engineering modifications delayed the commercial operation of the plant until July 1979. The plant operated sporadically from 1979 through 1988, with a historical capacity factor of less than 15% and less than 30% availability. For an extensive discussion of the FSV operational experiences, see an article written by H.L. Brey.^{A-5}

In response to FSV's historically reduced levels of power generation, the Office of Consumer Counsel (OCC) filed a complaint with the Colorado Public Utilities Commission (CPUC) against PSC alleging that, in light of its operating history, FSV was not "used and useful" in rendering a utility service. In September 1986, PSC signed a settlement agreement with the CPUC and the OCC over several areas of litigation and long-term issues. Significant provisions of the settlement agreement included (1) removal of FSV from the rate base; (2) a provision for the sale of future energy produced at FSV to PSC customers at a rate of 4.8 cents per KWh; and (3) recovery over five years of \$11.5 million of decommissioning costs. Because of FSV's poor operational performance and the cost of fuel, PSC could not operate on the 4.8 cents allowed by CPUC. Attempts to obtain subsidies (both government and private) failed, and the plant operated at a \$25 to \$35 million dollar loss per year. Therefore, the utility decided in December 1988 to permanently cease FSV operation by June 30, 1990. However, on August 18, 1989, the plant was shut down because of control rod drive and steam generator problems, the repair of which would have required significant down time and capital investment. On August 29, 1989, the utility decided not to restart the reactor.

The utility filed a Preliminary Decommissioning Plan with the NRC in June 1989 based on SAFSTOR. However, in June of 1990, because of a desire to utilize the non-nuclear plant for continued power production, the utility went out for fixed price bids for decommissioning the reactor and repowering the plant with natural gas. This request also asked for entrepreneurial bids to decommission and repower the plant as an Independent Power Producer (IPP).

The utility decided to pursue the early dismantlement option based on the following major considerations:

- Future risks of the SAFSTOR process cannot be quantified (such as the regulatory environment, public attitude, and waste disposal).
- There are continuing long-term costs for the SAFSTOR option (maintenance, security, testing, etc.).
- Risks for early dismantlement are more quantifiable (fixed price bids, regulatory environment, public attitude, waste disposal).

- No continuing long-term costs for early dismantlement (FSV ceases to be a liability).

Although the utility pursued the DECON option, they retained the option to go to SAFSTOR.

In November 1990, PSC submitted to the NRC the FSV Proposed Decommissioning Plan (PDP), based on the DECON option. In February 1991, the NRC issued a possession only license (POL). The POL confirmed the non-operating status of FSV and represented an intermediate step in the transition into the decommissioning phase of the facility.

The utility intended to begin defueling FSV and shipping the fuel to INEL in early 1991. However, because the Governor of Idaho refused to allow the fuel to enter Idaho, the utility had to construct an Independent Spent-fuel Storage Installation (ISFSI) at the FSV site. The utility received the license to operate the ISFSI in November 1991. The defueling of the reactor and movement of all fuel to the ISFSI were completed on June 15, 1992. On November 23, 1993, the NRC issued the Decommissioning Order for FSV. The current cost estimate for decommissioning FSV is \$124 million.

A.4.1 FSV Hazard Characterization

Before appropriate decontamination activities were chosen, site characterization was done. To characterize the hazards at the plant, 35,000 radiological data points were taken. A bar code system was used to track the radiological information, which made information retrieval relatively easy. Environmental characterization (such as EPA type hazards and mixed waste) was also done. A 14-volume set of characterization information is available. According to NUREG 5849 and 2082, radiological surveys are required, including pathway analysis. After decontamination activities, an area is resurveyed to ensure successful decontamination.

One of the major problem areas for the FSV site characterization is inside the reactor vessel. Since there is no access at this time to the interior of the vessel, no characterization has been done. Removal of the vessel is planned for 1994.

One of the areas of most concern with respect to remediation was a fire-training pit used to simulate fires. Ten gallons of diesel fuel were periodically placed into the pit and ignited; fire-fighting personnel then practiced putting it out. Other than this site, the approximately 2700 acres that make up the plant site are relatively clean (except for shipping cask storage).

The radiological consequences of operating FSV have been exceptionally low. With the exception of tritium, noble gas airborne and liquid effluent releases from FSV were more than an order of magnitude below the average of the U.S. nuclear power industry. Higher than anticipated amounts of tritium were experienced at FSV primarily because of upsets in the helium circulator auxiliary system, which allowed bearing water to enter and circulate in the primary coolant system. The tritiated moisture was removed by the purification systems and discharged from the plant as liquid waste.

A total of 180 m³ of low-level solid waste has been accumulated at FSV in the past 15 years. This includes waste generated as a result of (1) initial fuel loading; (2) three refuelings, each replacing approximately one-sixth of the reactor core; and (3) numerous plant modifications and maintenance operations, including major work performed on components within the primary coolant system.

During decontamination activities, site health physics personnel were used for radiation monitoring, and environmental monitoring was done by specialists. Contracting the environmental monitoring tasks to specialists led to substantial cost savings (when compared to the costs of training and paying site personnel to perform the tasks).

One of the changes that the FSV personnel would have made with respect to hazard characterization was to collect fewer data points. In reality, only 10,000 to 15,000 characterization points were needed. However, they felt that, based on the hazard characterization, they prioritized their decontamination activities correctly.

Upon completion of the decontamination and dismantlement activities and the successful completion of the final radiological surveys, termination of the 10 CFR 50 license will be requested, confirming the radiological safety of the site with no further technical or regulatory requirements.

A.4.2 FSV Management/Programmatic Issues

Studies relating to three possible alternatives for the future of FSV were initiated in early 1987. The options under consideration were tied either to extending FSV operation as a nuclear plant or shutting down after burnup of the existing fuel. Basically, the alternatives considered for FSV's future included the following:

- decommissioning the plant after the existing fuel was utilized,
- converting the plant to utilize fossil fuels and decommissioning the Nuclear Island, and
- continuing nuclear operation with third party support.

Extensive efforts were initiated to assure FSV's operation as a nuclear plant. The costs of operation, maintenance, securing new fuel, and providing capital improvements for this unique facility could not be borne entirely by the allowable 4.8 cents per kWh return on generation, even with high-capacity factors. Therefore, it was necessary for PSC to secure added revenue to keep FSV operational, and PSC aggressively pursued options that would maintain FSV as a nuclear generation station. An example of these options included a proposal to the DOE to utilize the reactor as a neutron source for the production of plutonium-238. This isotope of plutonium is a nonweapons material utilized as a power source in the U.S. space program satellites. This proposal was subsequently rejected by the DOE in mid-1988. Another option considered utilizing FSV for the development and testing of components for future gas-cooled reactor applications. However, by November 1988, it became obvious that the extensive

financial backing to keep the plant operational could not be secured from outside sources. The financial burden of continuing to operate FSV could not be maintained by PSC, and in early December, the board of directors made the decision to shut down the plant permanently before the end of June 1990.

In the case of FSV, only the DECON and SAFSTOR options were considered practical. The following discussion of the decision process employed to choose between DECON and SAFSTOR is from a paper written by Gregory D. Schmalz.^{A-8}

The ultimate objective of both the SAFSTOR and DECON options is to remove or decontaminate those portions of a facility that are radioactively contaminated in order to make that facility acceptable for unrestricted use. While both options have the same objective, they require different approaches.

In the DECON option, portions of the existing facility, including equipment, structures, and those portions of the facility containing radioactive contaminants, are dismantled and removed or decontaminated to a level that permits the facility to be released for unrestricted use shortly after cessation of power operations. Three major work elements exist with this option: (1) decontamination and dismantlement of the PCRV, (2) decontamination and dismantlement of contaminated or potentially contaminated Balance of Plant (BOP) systems, and (3) site cleanup and the final site radiation survey.

Decontamination and dismantlement of the PCRV include a number of activities necessary to gain access to the internal portions of the PCRV and to remove PCRV internal components prior to removal of activated concrete on inside surfaces of the reactor vessel. A wet dismantlement approach was chosen because it provides optimum shielding and contamination control and will allow the PCRV disassembly to be completed with an optimum balance of schedule, costs, ALARA (as low as reasonably achievable) exposure, and minimum risk.

In the wet dismantlement approach, the PCRV is flooded with water, using techniques that were successfully demonstrated at Three Mile Island. Other proven technologies are used, such as diamond wire cutting, which can be used to segment the top head of the reactor vessel into removable pieces and create an opening in the top of the vessel for access to the remaining components. Once access to the reactor core is obtained, the reactor internal components are removed by "line of sight" removal techniques, that is, by using long-handled tools.

Decontamination and dismantlement of radioactive or potentially radioactive BOP systems refer to those systems, structures, and components external to the reactor vessel. Based on site characterization surveys, those items found to be below releasable limits will either be removed for disposal or sealed and abandoned. Those items found to be radioactive will either be decontaminated in place, removed and decontaminated, or removed and disposed of as radioactive waste.

Site cleanup involves pre- and post-decommissioning radiological characterization surveys of the site, and radiological decontamination as necessary, to meet the regulatory guidelines to allow release for unrestricted use. The final radiation survey demonstrates the effectiveness of the decommissioning process and provides documentation that contaminated materials, structures, areas, and components have been successfully removed or decontaminated to acceptable levels to permit release for unrestricted use. Following completion of the final radiation survey, the request for termination of the 10 CFR 50 license would be initiated.

The SAFSTOR option, while having the same ultimate objective as DECON, isolates the radioactively contaminated portions of the plant for long-term storage and lay up. A portion of the work to place plant systems in a SAFSTOR condition is performed shortly after completion of defueling. The plant is then secured and enters into the SAFSTOR decay period, followed by additional work to complete the decontamination and dismantlement of the reactor systems. Certain on-site staffing levels must be maintained during the SAFSTOR period. Ongoing training of personnel would also be required, resulting in significant cost. In addition, the regulatory environment can change, and the burial costs for radioactive material are subject to significant increases.

The following three stages accomplish the SAFSTOR option: (1) component removal and preparation, (2) decay period, and (3) dismantlement. During component removal and preparation, certain actions are necessary to prepare plant systems and buildings safely to contain radioactive components at the site and to prepare the plant for the long SAFSTOR decay period. These actions result in a sealed reactor vessel capable of isolation for a long period of time.

During the SAFSTOR decay period, the PCRV and other contaminated systems are maintained in an isolated condition during which radioactive decay will occur. The duration of this period, as allowed by present regulations, is 60 years. The objective of the SAFSTOR period is to allow radioactive decay of highly activated components inside the PCRV. Allowing these activated components to decay for 60 years reduces the amount of activated material that remains above limits for unrestricted use. The 10 CFR 50 license remains in effect throughout the SAFSTOR process, and license conditions such as monitoring and surveillance activities are required during the decay period.

During the decay period and prior to initiation of SAFSTOR dismantlement, the SAFSTOR Decommissioning Plan will require revision and NRC approval to reflect a plan that is appropriate for the current regulatory environment and that utilizes current technologies. During dismantlement, the site is prepared for release for unrestricted use by decontamination efforts or removal of all residual radioactive materials to predetermined levels using technologies available at the time. Following completion of these activities, surveys are performed using the regulatory release limits in place at that time to determine whether the site is acceptable for unrestricted use. Based on the current NRC regulations, the required SAFSTOR Decommissioning Plan revisions and SAFSTOR dismantlement/decontamination efforts are basically identical to the effort associated with the DECON option.

While both options were appropriate for the decommissioning of FSV, PSC's objective was to complete the project as safely and rapidly as reasonably possible, with minimum regulatory and technical risks and within the financial capabilities of the company. The DECON option is estimated to be completed in 1995, and the SAFSTOR option was estimated to be completed in the 2050 time frame. Even though the radioactivity levels within the PCRV will be reduced and volumes of radioactive waste to be disposed of may be slightly lower using the SAFSTOR option, uncertainties regarding the future burial costs of this waste pose a significant risk to the project. Other considerations for the SAFSTOR option include uncertainties of low level waste (LLW) disposal availability and rates, regulatory uncertainties, and the fact that technology is available today to decommission FSV.

For either option, upon completion of the decontamination and dismantlement activities and the successful completion of the final radiological surveys, termination of the 10 CFR 50 license will be requested, confirming the radiological safety of the site with no further technical or regulatory requirements.

All activities during the performance of either option must be performed in a manner that protects the health and safety of the public and those personnel performing activities at the facility. With this in mind, increased durations (60-plus years for the SAFSTOR option versus about three years for DECON) translated into increased efforts required to maintain safety levels and increased exposure to regulatory changes.

During the DECON option, the duration of site activities is estimated to be about three years, and plant safety systems, such as fire protection, radiation monitoring and building support systems, are required to be operational. In addition, technical specifications require the surveillance of necessary components and the performance of specific administrative functions, including security, access control, fire protection planning, and emergency response planning, to maintain prescribed levels of safety. The impact of staffing and training for the SAFSTOR option is magnified because PSC had only one nuclear unit.

The performance of SAFSTOR requires three time periods: the component removal time period, the SAFSTOR period and the dismantlement period. The dismantlement period takes approximately the same time as the DECON or early dismantlement period. The cumulative total of these three periods is more than 60 years, during which personnel turnovers will occur and technical expertise will be lost. It will be necessary to maintain plant systems such as fire protection, radiation monitoring, and various facility support systems so that they remain functional. Performance of operational surveillance will be required, and technical specifications will require compliance with specific organizational and administrative requirements. During this entire time frame, radioactive contaminants will be present at the site, resulting in ongoing employee exposure and requirements to maintain the plant in a safe radiological condition.

The NRC 10 CFR 50 license for FSV will remain in force throughout the SAFSTOR period, requiring maintenance of the license documents. These license maintenance activities will

include updates using the 10 CFR 50.59 process, annual updates to the Decommissioning Plan, and possible updates to supporting documents. The quantity of license documents and the long duration of SAFSTOR translates into a greater level of effort, greater staffing requirements and greater direct costs. During the SAFSTOR period, the Price Anderson Act would continue to apply, requiring as much as a \$79 million payment by PSC in the event of a catastrophic accident at *another* nuclear power station. With the DECON option, PSC's financial risks associated with the Price Anderson surcharge are minimized.

The regulatory exposure for SAFSTOR occurs over a long period of time and, in fact, by itself tends to increase risk. The regulatory risks associated with the DECON option are significantly less than those for the SAFSTOR option. The decay of the radioactive components and the concrete will reduce the exposure rate inside the PCRV. At five years after shutdown, the exposure rate at the center of the PCRV cavity is estimated to be 230 R/hr. After a 55-year SAFSTOR period, this dose exposure drops to about 0.2 Rem/h. Even after a SAFSTOR period, access to the PCRV in this configuration would still be limited, requiring significant contamination controls and shielding for access.

The projected waste volume for both the DECON and SAFSTOR options is primarily from the PCRV internals and concrete. The balance of plant waste volume is a small percentage of the total waste volume. The components within the reactor vessel and the concrete would radiologically decay during a 55-year SAFSTOR period. However, most of the components and portions of the concrete would still require removal as radioactive waste.

The dismantlement techniques would still require the removal of the PCRV top head and Core Support Floor. The waste volume for the reactor vessel internals remains unchanged for either the DECON or SAFSTOR option. The decrease in PCRV sidewall concrete depth from the 21–24 inches of concrete to 7–11 inches would result in a decrease in the total waste volume by about 10%. Therefore, the effect of decay in the SAFSTOR period would not significantly decrease the overall waste volume.

The total radioactivity (curie) level in the PCRV is expected to decrease from approximately 2.2×10^6 curies at five years after shutdown to 3.2×10^3 curies after the SAFSTOR period. Waste disposal costs are based on curie content as well as volume. For radioactive waste that has a higher radioactivity level (Class B and Class C waste) but is still considered LLW, the radiation level and curie content are expected to be major contributors to disposal costs. However, most (85%) of the waste volume for either the SAFSTOR or the DECON option is expected to be Class A waste (having the lowest level of activity). The primary contributor to the cost of disposing of the Class A waste is expected to be the waste volume. Therefore, the decreased radioactivity level of the waste after the SAFSTOR period would not contribute significantly to a decrease in disposal costs, especially when volumetric charges are expected to increase at a dramatic rate.

In the U.S., radioactive waste disposal costs will continue to increase in the future as they have in the past. At the Beatty, Utah, facility through December 1992, the base disposal price was

approximately \$35/ft³ with the average Beatty price being approximately \$70/ft³. (The "base price" for radioactive waste disposal includes all usual fees, taxes, and site surcharges. The "average price" not only includes the base price, but all surcharges for excess radiation exposure, package activity, excess weight, and cask handling fees averaged over the total volume of waste during decommissioning.)

During the period between 1992 and 1995, the DECON option time frame, Richland, WA, is the only site assured to be in operation. After January 1, 1993, radioactive waste disposal prices were expected to significantly increase as a result of implementation of the final milestone of the Low Level Radioactive Waste Policy Act Amendments of 1985. Beginning on that date, compacts are allowed to deny waste generated from outside compact member states.

At the Richland site, the average base price for disposal services is estimated to be approximately \$40 to \$50/ft³. Between 1993 and 1995, rising disposal prices at Richland are anticipated to be the result of increased taxes and surcharges, and distributing facility operation costs over a generally decreasing volume of radioactive waste offered for disposal before the end of 1995. The base price was initially estimated to be \$140/ft³. Recent court rulings in Washington have resulted in a lower, more stable price through 1995 than in the original estimate.

In the event that the SAFSTOR option was selected for FSV, the cost for radioactive waste disposal in the year 2045, in PSC's opinion, was extremely difficult to predict. History shows that disposal price increases are primarily the result of government taxes and surcharges added to the base price. In only a few cases have disposal site operators increased the base disposal rate to recover their cost of operation or maintain an adequate profit margin.

Escalation of disposal costs has increased 11.9% per year historically over the past 10 years. It was estimated that disposal costs in the future will continue to increase at an average of 10% per year for the next 10 years and at a subsequent rate of increase of approximately 5% per year (i.e., CPI) for the remainder of the SAFSTOR period to the year 2045.

Upon conclusion of the evaluation of the DECON and SAFSTOR options, engineering management recommended pursuing the DECON option to executive management and the board of directors.

FSV established an internal working group for deactivation that was assigned to spend 80% of its time on D&D planning. The internal working group consisted of various senior members of the FSV plant staff, each of which brought unique perspectives to the planning process as well as an openness to considering a variety of options. Special consideration was given to LLW, occupational exposures, the decommissioning strategy plan, costs, staffing needs, and decay levels (with the intent to minimize the time that personnel are exposed to radioactivity). The decision process described in the previous paragraphs was done by this group. Many issues were included in the decision process, such as maintenance of facility roofs (both repairs and re-roofing). Structures and systems at the site were evaluated by engineers, using senior

engineers as consultants. Hundreds of pages of documentation, which took a year to complete, exists. The group explored different scenarios, including operation and maintenance costs in the SAFSTOR mode. Insurance costs were a major factor in the scenarios. To assure that the potential SAFSTOR and DECON activities were realistic, the internal working group met with plant management (who were not a part of the team) to discuss the various options. The main question asked to management was, "If you must do this, what would you need to get it done?"

One of the more important lessons learned by the FSV plant staff was to do *early planning*. This early planning was accomplished primarily through the development of the FSV proposed decommissioning plan (PDP). The PDP details the major technical actions to be carried out during decommissioning. The major elements of the PDP are as follows:

- Methodology for removal of the activated portions of the PCRV and internal reactor radioactive components.
- Methodology for the decontamination and/or dismantlement of those portions of the PCRV structure and radioactive BOP systems that exceed limits for unrestricted release of residual radioactive materials.
- Estimates of volumes, and definition of techniques and shipment processes of all radioactive waste for off-site disposal.
- Discussion of the site remediation techniques, if required.
- Details of the facility radiological status, radiation protection program, cost estimate, fire protection plan, technical specifications, emergency response plan, security plan and radioactive waste management.
- The proposed final radiation survey plan that confirms release of the site for unrestricted use. Once performed and the results found to meet the site release criteria for unrestricted use, the final site survey serves as the basis for requesting termination of the FSV 10 CFR 50 license.

The NRC issued a set of review comments for the PDP. One of the comments was, "Describe the specific methods that will be used for cutting the piping of the Balance of Plant Systems (saws, touches, thermal cutting, shears)." In responding to these comments, there was concern that if the response were too specific and too detailed, it would become part of the licensing basis and would be difficult to deviate from or change without considerable effort. Therefore, in the responses, an attempt was made to include possible alternative methods and provide some additional detail, but not to tie things down so tightly that there would be no latitude later, during decommissioning.

The FSV PDP was written such that the licensee can make changes in a manner almost identical to how operating reactors make changes in accordance with 10 CFR 50.59. However, the NRC, in issuing the Decommissioning Order for the Shoreham Nuclear Power Station on June 11, 1992, had significantly modified that process. For Shoreham, the NRC stated that the licensee could make changes provided that

- Such changes are approved in writing by the licensee's on-site review committee;

- The Director, Office of Nuclear Material Safety and Safeguards, is notified of such changes in writing and is provided with a copy of the written approval by the on-site review committee not less than 30 days before such changes are implemented; and
- Such changes do not result in an unreviewed safety question or result in environmental impacts different from and exceeding those set forth in the licensee's Supplement to Environmental Report December 1990.

Changes not meeting the above three criteria must be submitted by the licensee to the Director, Office of Nuclear Material Safety and Safeguards, for prior approval before they may be implemented.

This is considerably different from the normal 10 CFR 50.59 process, wherein, if the change does not result in an unreviewed safety issue, the licensee may implement the change after on-site review committee approval, and the NRC is only advised of such changes in an annual report.

Discussions with the NRC indicated that the NRC intended to invoke the standard 10 CFR 50.59 process for FSV, basically only changing the wording to replace the final safety analysis report (FSAR) as the licensing document with the Decommissioning Plan. This should provide reasonable capability to make changes to the Decommissioning Plan.

The NRC was also aware of the potential delay of the start of decommissioning on August 1, 1992, and advised the utility that it would be appropriate and acceptable for the preliminary decommissioning activities to begin under the present POL and the existing technical specifications. On that basis, safety evaluations in accordance with 10 CFR 50.59 were prepared and approved as appropriate, and the removal of asbestos from the plant piping, cutting and removal of prestressing tendons, removal of graphite blocks with the fuel handling machine, and removal of the steam generator secondaries was initiated in mid-July 1992. During the decommissioning process, rust and corrosion were guarded against. Systems were evaluated and, if they were not needed, were eliminated, through salvage, moving to other sites, etc. If a system was necessary for deactivation, a maintenance plan covering its usage period was developed.

Deactivation activities used normal staff personnel and operable systems. PSC attempted to keep all FSV staff and was quite successful because only one person left when knowledge of the plant shutdown became known. The staff at the plant is much smaller now than when it was operating, but outplacement to other locations within the company avoided layoffs.

A.4.3 FSV Requirements and Regulatory Issues

During Decommissioning Planning, significant attention was directed toward the development of the site release criteria and methodology for both release of the site for unrestricted use and materials off-site. The U.S. does not have a lower "limit" for radioactivity. It was important to develop an acceptable methodology that would receive regulatory acceptance since the

dismantlement/decontamination approach selected will not result in a "bare walls" plant after completion of physical decommissioning. FSV decided to define the radiological and hazardous material exposure limits for SAFSTOR and DECON as the same, which resulted in putting the SAFSTOR and DECON options on the same footing. There were uncertainties because of the potential for regulatory changes; however, FSV chose to ignore this. An educated guess was made on what reasonable exposure limits were, and then the appropriate regulatory agency was contacted to verify it.

To determine the regulations and requirements applicable to the FSV site, letters were written to regulators discussing the decontamination process and requesting guidance. This seemed to work well. In addition, FSV worked with the EPA and the state on water quality issues. Letter agreements with the state on tritium releases (based on the water flow) ensured that there was no misinterpretation. FSV has pages of regulations applicable to SAFSTOR and D&D (see Appendix B). If FSV were required to meet 10 CFR 50 Part 20 (Radiation Protection Guides), costs would be increased by 5%. A cost/benefit analysis was done for the allotted time periods and the results presented to the regulators. The impact the regulations would have on the costs, etc., was clearly shown, and a compromise was made.

When FSV looked at translating operational technical specifications to SAFSTOR operation and maintenance requirements, the systems involved were evaluated with respect to their technical specifications. The question asked for each system was, "Does it make sense to keep this system tech speced?" Engineering judgment was used to classify the systems as ones that should or should not be tech speced (i.e., put under technical specifications).

In November 1990, PSC submitted to the NRC the FSV PDP, based on the DECON option, as required by 10 CFR 50.82. Since decommissioning represents a major licensing change, it requires a major licensing review activity by the NRC. The PDP replaces the FSAR, and, as such, becomes the governing licensing document for FSV activities. In this review, the NRC was charged with assessing the following:

- the technical adequacy of the dismantlement and decontamination techniques to be employed,
- the radioactive waste management program including handling and subsequent off-site shipment to burial in the licensed LLW facility to be utilized,
- the radiation protection program to be utilized,
- the final radiation survey methodology and associated site release criteria,
- programs to be utilized during decommissioning for protection of occupational and public health and safety, such as emergency response and fire protection, and
- a determination that the cost estimate and funding plan are adequate to ensure completion of the decommissioning project.

PSC was required, in accordance with 10 CFR 50.82, to apply within two years following the permanent shutdown of operations for the authority to decommission the plant as detailed in the PDP.

From February through October 1991, various supplemental documentation such as the cost estimate, environmental report update, funding plan, QA plan, security plan, emergency response plan, and fire protection plan were filed with the NRC. In addition, PSC responded to two rounds of comments from the NRC on the PDP.

After reviewing and approving the PDP, on November 23, 1992, the NRC issued the FSV Decommissioning Order, which established the formal requirements for carrying out all decommissioning activities until the site is released for unrestricted use and the 10 CFR 50 license is terminated.

A.4.4 FSV Transitioning Facility Risk Issues

FSV performed a PRA for nuclear and non-nuclear hazards. The main hazards identified included fires, tornadoes, and industrial-type accidents. Of FSV's accident scenarios, fire was the most threatening with respect to radiological releases to workers and the public. It was also more likely to occur. If a scenario had a likelihood of occurrence of less than $1E-4$, it was ignored. However, if its likelihood was greater than $1E-3$, design, surveillance, etc., were used to ensure that it would not occur. There were no significant radiological risks to surveillance and maintenance personnel; primarily industrial-type risks are present. However, plant personnel are expected to follow occupational safety and health act (OSHA) standards and to do their jobs safely.

FSV attempted to lower significant risk as much as possible during decontamination. Fire doors have been left in place, radiation monitoring and fire protection systems are operable, an intelligent maintenance program is still in effect, and component reliability is still being tracked. In addition, FSV looked at the potential hazards of removing a system from service before it was deactivated. FSV has some mixed waste (contaminated lead) at the site; however, it will be reprocessed. It is currently being stored in a barrel at the site, and there is no time constraint on dealing with this waste until the barrel is full.

An additional comment from the NRC requiring response by FSV on the initial PDP submittal requested additional detailed information on the ALARA principles and controls as well as the procedures and equipment that will be used to protect employees and the public's health and safety. This was answered by providing more detail on the ALARA plans and programs and restructuring that section in the PDP to address every aspect of NRC Regulatory Guide 8.8, Information Relevant to Ensuring that Occupational Radiation Exposures at Nuclear Power Stations Will Be As Low As Is Reasonably Achievable, and NRC Regulatory Guide 8.10, Operating Philosophy for Maintaining Occupational Radiation Exposures As Low As Is Reasonably Achievable.

One of the FSV decommissioning activities involved flooding the reactor vessel with water to provide shielding for component removal operations. The graphite blocks in the reactor contain tritium that would be released into the water, and the tritiated water would eventually have to be removed from the vessel. It was estimated that about 500 curies of tritium would be released

into the 325,000 gallons of water in the reactor vessel. The planned method of disposal was to bleed tritiated water from the vessel and mix it with cooling tower blowdown water, which is then discharged to the river, the normal discharge path for liquid radioactive effluents from FSV. The NRC had a series of concerns with this operation.

One concern was whether the estimate of the release of 500 curies of tritium into the water was accurate. The estimate was based on calculations that showed that the maximum amount of tritium that could have been generated in the FSV reactor during its entire power history was 100,000 curies. There were technical reports of British experiments with graphite in which tritium was leached out of small samples, and that data, along with some conservatism, resulted in the estimate of 500 curies leaching into the water. The NRC was hesitant to accept the 500 curie estimate, based on the limited testing. The NRC utilized its most knowledgeable individual, who thoroughly researched the problem and available information. That individual also concluded that the availability of applicable test information was extremely limited, but that the British data were thorough and the most applicable, and that the application of the data to the FSV was conservative and reasonable.

The NRC remained concerned with the potential for higher levels of tritium and requested information on alternative methods and on the amount of tritium that would cause alternative methods for discharge to be considered. Three alternative methods for disposal had been considered previously: evaporation from solar ponds, mechanical evaporators, and solidifying the tritiated water into drums. For the discharge of tritium into the river, the rate of discharge is governed by 10 CFR 20 limits at the release point at which, after mixing with plant cooling tower blowdown flow, it is limited to 3 million picocuries per liter. In addition, Appendix I of 10 CFR 50 places limits on doses to the public of 3 mR/year. In analyzing the decommissioning operational schedule, the scheduled time from the initial filling of the reactor vessel until all the water had to be discharged was 23 months. Over that time, approximately 8000 curies could be discharged. Calculations, in accordance with 10 CFR 50 Appendix I, indicated that a discharge of 8000 curies in two calendar years was also acceptable. If more than 8000 curies were required to be discharged, additional time would be required, causing significant schedule delays at very high costs. Therefore, the NRC was advised that up to 8000 curies of tritium in the water would not cause a problem. The solidification of the water into drums for disposal was estimated to add about \$10 million to the cost of the project. The NRC appeared to be satisfied that the number of curies that could be handled without perturbing the planned operation (8000 curies) was 50 times more than expected, and even at that, the cost of alternate disposal was not outlandish.

The NRC then indicated that there had been a problem at SRP with the discharge of tritium where the discharges exceeded environmental protection agency (EPA) safe drinking water standards. Although FSV was in compliance with NRC regulations and the river discharged into was not used for drinking water, the NRC was concerned with public perception and attitude, and with tritium discharge becoming an emotional issue. The NRC asked if the EPA drinking water standard of 20 thousand picocuries per liter in the river could be complied with. PSC, in accordance with its Offsite Dose Calculation Manual and the procedures and methods

therein, reported that when the discharge was within the NRC limits, and mixed with the river flow, it would be in compliance. Meeting the EPA drinking water standard became a commitment.

A.4.5 FSV Cost Increases and Uncertainty

The utility initially considered proposals for an IPP to decommission the plant and repower it with natural gas. Several factors influenced the decision on what the final status of the plant would be. One factor was the assumption by PSC of the assets of Colorado Ute, a utility that went bankrupt. The utility, in acquiring the assets of Colorado Ute, acquired additional generation capacity and was no longer able to justify repowering the plant in 1995 as was initially projected. The power needs would only justify repowering in 1998 or later. In addition, the utility reviewed the accounting methodology used in 1986 in writing down the FSV plant assets. That review convinced them that they had a legal basis for recovering additional revenue to cover decommissioning. The utility had a continuing discussion with CPUC and reached an agreement with all parties to recover \$13.9 million per year for 12 years from the rate base. In reality, customers were not charged. A utility has the option to charge customers for some of the services they use; PSC chose not to charge their customers for these services to avoid passing on decommissioning costs. As part of the agreement with CPUC, the utility agreed to institute more aggressive conservation programs and to fund additional programs for those customers that were less able to meet their utility bills. PSC was still required to get a decreasing letter of credit. A New York bank will let the utility borrow \$150 million to finance the D&D work; PSC pays a monthly premium to the bank to have the right to borrow this money.

The decommissioning costs for FSV are estimated to be \$157 million. The LLW disposal costs and the availability of disposal sites provided the greatest uncertainty to the decommissioning process. In addition, the variability of the regulatory climate generates a large uncertainty to the process. To deal with this uncertainty, FSV first established a baseline for all decommissioning costs. Assumptions, uncertainties, and reasons why the uncertainties exist were documented. Uncertainties were quantified using engineering judgment to choose an intelligently determined number; for example, for LLW a 3%, 5%, 8%, and 11.9% variability was used with the baseline. No sensitivity or free release studies were performed (free release does impact the disposal costs). 2 mR/h over background was used and costs calculated. To reduce D&D costs, all components that were easy to dismantle and ship out were removed as soon as possible (helium circulators were removed and shipped out first). Components with large waste volumes were also targeted for quick elimination. There was a large cost savings for getting rid of all possible components as quickly as possible.

Operations and maintenance costs for on-site storage of the spent fuel is \$300K/yr. This includes insurance, fees, basic maintenance, and personnel costs.

An interesting finding by FSV staff was discovered when, in order to determine the benefits from time-related reduction in radioactivity levels, an activation analysis was done out to 55 years. There was only a 10% decrease in the radioactivity at the site; therefore, no real advantage existed for delaying decommissioning 55 years (i.e., for placing the site into SAFSTOR).

A.4.6 FSV Stakeholder Concerns

The removal of the spent fuel from the FSV reactor was the responsibility of PSC. However, the fuel is owned by the DOE, and it is committed to taking possession of and storing it. PSC intended to begin defueling and shipping the fuel to INEL in early 1991. However, Governor Andrus, of Idaho, strenuously objected, and a series of legal maneuvers ensued. This complication delayed the decommissioning schedule. However, PSC had foreseen this possibility and had moved ahead with construction of an ISFSI in February 1991 and received the license to operate the ISFSI in November 1991. Therefore, in December 1991, PSC elected to defuel the reactor and transfer the fuel to the ISFSI. The defueling of the reactor and movement of all fuel to the ISFSI was completed on June 15, 1992.

The NRC requested that PSC and its contractors "submit the final dismantlement methods and a supporting safety analysis for NRC review. Alternatively, provide descriptions and safety analysis for potential options that may be used. Include evaluations of and methods to minimize personnel exposure in your safety analysis." The request for and use of the term *safety analysis* was confusing because it is commonly used only for analysis of off-site doses. After considerable internal discussion, it was concluded that what the NRC was probably looking for was the occupational radiation exposure estimates. Telephone conversations with the NRC were not successful in determining exactly what was required. The concern also existed that too much detail might be written into the licensing basis and it would be difficult to deviate from it or change it.

Based on the concern that the right question might not be answered and the inability to resolve the issue, PSC upper management met with NRC management, and as a result of the meeting, a longer meeting was arranged. PSC and its contractors prepared a day-long presentation that was designed to "sell" what was believed to be a reasonable level of detail for the NRC. The meeting was very successful. It convinced the NRC that only a small number of decommissioning activities were of significant concern and required any additional detailed explanation. The meeting was more of a success, however, because it brought PSC and its contractors and key NRC personnel together in a detailed day-long discussion. PSC believes that it convinced the NRC that the involved personnel were extremely knowledgeable and competent and that the details they were interested in were being addressed. It seemed that a much better working relationship existed after the meeting. In addition, as a result of the meeting, the NRC committed to a weekly telephone conference call to answer any questions and discuss status. The NRC had a significant number of management personnel involved in each telephone conference. This telephone conference call was extremely successful in

expeditiously answering questions, explaining details, and, in many instances, eliminating the time-consuming written response.

The NRC asked whether the State of Colorado was fully aware of plans to discharge tritium into the river. The State of Colorado, Radiation Control Division, had been supplied with all of the decommissioning documents, including the Supplement to the Environmental Report, which discussed the tritium discharge in detail and the resultant doses. The Radiation Control Division had been involved in numerous meetings and in some cases had made comments to the documents, but it had not made any comment or response on the Supplement to the Environmental Report. The NRC requested that the State of Colorado confirm possession of the Supplement to the Environmental Report and agree that it had no problem with the tritium discharge.

The Radiation Control Division decided that the Water Quality Control Division had to be involved. The Water Quality Control Division was not aware of the plan to discharge tritium and, in fact, claimed lack of knowledge that the plant ever discharged any tritium, even though a commitment of the FSV discharge permit was to report the tritium discharges annually and that had been done. There was also a question as to whether the State of Colorado had a legal basis for regulating this discharge. The Water Quality Control Division first asked why liquid discharge was being done and why the liquid was not being evaporated. After reviewing the process in detail, the Water Quality Control Division indicated that the river flow rates used by PSC to determine the amount of dilution were inaccurate and that significantly lower flow rates should be used. The utility had historically used flow rates of 653 cubic feet per second, and the Water Quality Control Division said that the flow in some months was closer to 60 cubic feet per second. PSC hired an experienced hydrologist, who reviewed the flow data from the last 10 years and recalculated the "Monthly 30-Day Low Flows." These ranged from 118 to 394 cubic feet per second. Utilizing these lower river flow rates, a discharge of approximately 7000 curies of tritium over the 23-month period could occur, instead of the 8000 curies previously calculated. Since there was confidence that 500 curies was a realistic estimate, utilization of these revised flow rates was acceptable. The State of Colorado then advised the NRC that "their concerns had been adequately addressed."

PSC emphasized the importance of having good communications with regulators and individuals living within the state. Groups were invited to visit the site, including children. Senior FSV personnel went to meetings to answer questions. News flyers were sent out quarterly to the local community sharing plant information, and discussions included what FSV was currently doing and what had been done. Communications with the nuclear community—local, society, industrial, and environmental groups—also occurred. Routes used to transport waste were not disclosed; however, studies done to determine "acceptable societal risk" with respect to these routes were discussed.

A.4.7 FSV Waste Minimization and Avoidance of Mixed-Waste Generation

Waste minimization procedures used included compaction, smelting, re-use, and free-release (if it was cost effective). To minimize packaging, FSV looked at Low Specific Activity (LSA) boxes, liners, and packing as tight as possible. Loading and unloading were preplanned. Self-shielding was used for packaging.

A.4.8 FSV Industry Involvement

PSC selected a consortium led by Westinghouse Electric Corporation to decommission FSV under a fixed price contract. Other members of the Westinghouse consortium included MK Ferguson and Scientific Ecology Group. The selection of the contractor for decommissioning FSV was a year-long process. A bidding process was used with some contractors as part of several consortiums. Before a contractor was chosen, credentials were evaluated. This evaluation included looking at the companies' experience on the job, talking to the companies' previous customers (including subcontractors' customers). The PSC team that worked on FSV's D&D Plan worked on the bid specifications. A proposed statement of work was laid out, but companies were responsible for making specific proposals for performing the work.

The first major question asked by the NRC involved the estimated cost for decommissioning. The PDP, as originally submitted, took the approach that the estimated cost for the decommissioning was the fixed price of the Westinghouse Team Contract, plus the utility costs during the decommissioning, and some contingency for changes. A meeting was held with the NRC to discuss the cost estimate issue in more detail. The NRC stated that the fixed price contract was fixed for a given scope of work but performance of that work did not guarantee that the site would be releasable. Additional details were required to determine whether the work and funds provided would permit completion of decommissioning and termination of the license. The NRC verbally stated that its responsibility was to assure that the estimate was complete and accurate so that the contractor would not partially complete the contract, run out of money, and then default, leaving the utility with insufficient funds to complete decommissioning and with responsibility possibly reverting to the NRC. The NRC required that for each individual task to be performed, detail be provided on the method of accomplishment, the estimated duration of the task, crew size required, equipment required, supplies required, volume of waste, radiation levels, and radiation exposure. They also requested transportation and burial costs. The NRC also required that if any alternate methodology were considered, the alternate method must also be estimated and the differential costs included. This resulted in the preparation and submittal of a detailed cost estimate consisting of approximately 500 pages of information.

A.4.9 FSV Recycle and Reuse Opportunities

PSC is planning to repower the plant using natural gas. The turbine is only three years old and is worth \$50 million. Since the plant will be repowered, efforts are being made to maintain the

site. Equipment and components not necessary for the repower efforts are being sold to other plants. PSC is re-using as much as possible.

A.4.10 FSV Technology Development or Enhancement Needs

Technologies that PSC would have found useful during the D&D process included a means to sample core internals remotely to more effectively and quickly characterize the site.

A.4.11 FSV Lessons Learned

In the case of the FSV Nuclear Generating Station, only the DECON and SAFSTOR options were considered to be practical. The ultimate objective of both the SAFSTOR and DECON options is to remove or decontaminate those portions of a facility that are radioactively contaminated in order to make that facility acceptable for unrestricted use. While both options have the same objective, they require different approaches. In the DECON option, portions of the existing facility, including equipment, structures, and those portions of the facility containing radioactive contaminants, are dismantled and removed or decontaminated to a level that permits the facility to be released for unrestricted use shortly after cessation of power operations.

The SAFSTOR option isolates the radioactively contaminated portions of the plant for long-term storage and lay up. A portion of the work to place plant systems in a SAFSTOR condition is performed shortly after completion of defueling. The plant is then secured and enters into the SAFSTOR decay period, followed by additional work to complete the decontamination and dismantlement of the reactor systems. Certain on-site staffing levels must be maintained during the SAFSTOR period. Ongoing training of personnel would also be required, resulting in significant cost. During the SAFSTOR decay period, contaminated systems are maintained in an isolated condition in which radioactive decay will occur. The duration of this period, as allowed by present regulations, is 60 years. The decay period reduces the amount of activated material that remains above limits for unrestricted use. The 10 CFR 50 license remains in effect throughout the SAFSTOR process, and license conditions such as monitoring and surveillance are required.

During the decay period and prior to initiation of SAFSTOR dismantlement, the SAFSTOR Decommissioning Plan will require revision and NRC approval, to produce a plan that is appropriate for the current regulatory environment and that utilizes current technologies. During dismantlement, the site is prepared for release for unrestricted use by decontamination efforts or removal of all residual radioactive materials to predetermined levels using technologies available at the time. Following completion of these activities, surveys will be performed using the regulatory release limits in place to determine whether the site is acceptable for unrestricted use.

While both the DECON and SAFSTOR options were appropriate for decommissioning FSV, PSC's objective was to complete the project as safely and rapidly as was reasonably possible,

with minimum regulatory and technical risk and within the financial capabilities of the company. The DECON option was estimated to be completed in 1995, while the SAFSTOR option was estimated to be in the 2050 time frame. Even though radioactivity levels would be reduced and disposal volumes of radioactive waste might be slightly lower using the SAFSTOR option, uncertainties regarding the future burial costs of this waste posed a significant risk to the project. Other considerations with respect to the SAFSTOR option included uncertainties regarding disposal availability and rates for LLW, regulatory uncertainties, and the fact that technology is available today to decommission the plant.

All activities, during the performance of either option, must be performed in a manner that protects the health and safety of the public and those personnel performing activities at the facility. With this in mind, increased durations, 60-plus years for the SAFSTOR option versus about 3 years for DECON, translated into increased efforts required to maintain safety levels and increased exposure to regulatory changes.

During the performance of the DECON option, the duration of site activities is estimated to be about 3 years. During this time, plant safety systems, such as fire protection, radiation monitoring, and building support systems, are required to be operational. In addition, technical specifications require the surveillance of necessary components and the performance of specific administrative functions, including security, access control, fire protection planning, and emergency response planning, to maintain prescribed levels of safety. The impact of staffing and training for the SAFSTOR option is magnified because PSC has only one nuclear unit.

SAFSTOR requires three time periods: the component removal time period; the SAFSTOR period; and the dismantlement period. The dismantlement period takes approximately the same amount of time as the DECON or early dismantlement period. The cumulative total of these three periods is more than 60 years. During this time, personnel turnovers will occur and technical expertise will be lost. It will be necessary to maintain plant systems such as fire protection, radiation monitoring and various facility support systems so that they remain functional. Performance of operational surveillance will be required, and technical specifications will require compliance with specific organizational and administrative requirements. During this entire time frame, radioactive contaminants will be present at the site, resulting in ongoing employee exposure and requirements to maintain the plant in a safe radiological condition.

The NRC 10 CFR 50 license for FSV will remain in force throughout the SAFSTOR period, requiring maintenance of the license documents. These license maintenance activities will include updates using the 10 CFR 50.59 process, annual updates to the Decommissioning Plan, and possible updates to supporting documents. The quantity of license documents and the long duration of SAFSTOR translates into a greater level of effort, greater staffing requirements, and greater direct costs. During the SAFSTOR period, the Price Anderson Act would continue to apply, requiring as much as a \$79 million payment by PSC in the event of a catastrophic accident at *another* nuclear power station. With the DECON option, PSC's financial risks associated with the Price Anderson surcharge are minimized.

The regulatory exposure for SAFSTOR occurs over a long period of time and, in fact, by itself tends to increase risk. The regulatory risks of the DECON option are significantly less than those of the SAFSTOR option. The decay of the radioactive components and the concrete will reduce the exposure rate inside the PCR. The total radioactivity (curie) level in the PCR is expected to decrease from approximately 2.2×10^6 curies at five years after shutdown to 3.2×10^3 curies after the SAFSTOR period. Even after a SAFSTOR period, access to the PCR would still be limited, requiring significant contamination controls and shielding for access. Waste disposal costs are based on curie content as well as volume. For radioactive waste that has a higher radioactivity level (Class B and Class C waste) but is still considered LLW, the radiation level and curie content are expected to be major contributors to disposal costs. However, most (85%) of the waste volume for either the SAFSTOR or the DECON option is expected to be Class A waste (having the lowest level of activity). The primary contributor to the cost of disposing of the Class A waste is expected to be the waste volume. Therefore, the decreased radioactivity level of the waste after the SAFSTOR period would not contribute significantly to a decrease in disposal costs, especially when volumetric charges are expected to increase at a dramatic rate.

In the U.S., radioactive waste disposal costs will continue to increase as they have in the past. At the Beatty, Utah, facility through December 1992, the base disposal price was approximately \$35/ft³ with the average Beatty price being approximately \$70/ft³. (The "base price" for radioactive waste disposal includes all usual fees, taxes, and site surcharges. The "average price" includes not only the base price, but all surcharges for excess radiation exposure, package activity, excess weight, and cask handling fees averaged over the total volume of waste during decommissioning.)

During the period between 1992 and 1995, the DECON option time frame, Richland, WA, is the only site assured to be in operation. After January 1, 1993, radioactive waste disposal prices were expected to significantly increase. This increase was the result of implementing the final milestone of the Low Level Radioactive Waste Policy Act Amendments of 1985. Beginning on this date, compacts will be allowed to deny waste generated from outside compact member states.

At the Richland site, the average base price for disposal services is estimated to be approximately \$40 to \$50/ft³. Between 1993 and 1995, rising disposal prices at Richland are anticipated to be the result of increased taxes and surcharges, and distributing facility operation costs over a generally decreasing volume of radioactive waste offered for disposal. Before the end of 1995, the base price was initially estimated to be \$140/ft³. Recent court rulings in Washington have resulted in a lower, more stable price through 1995 than in the original estimate.

Had the SAFSTOR option been selected for FSV, the cost for radioactive waste disposal in the year 2045, in PSC's opinion, would have been extremely difficult to predict. History shows that disposal price increases are primarily the result of government taxes and surcharges added

to the base price. In only a few cases have disposal site operators increased the base disposal rate to recover their cost of operation or maintain an adequate profit margin.

Disposal costs have increased at 11.9% per year historically over the past 10 years. Disposal costs in the future are estimated to increase at an average of 10% per year for the next 10 years and at a subsequent rate of increase of approximately 5% per year (i.e., CPI) for the remainder of the SAFSTOR period to the year 2045.

Upon conclusion of the evaluation of the DECON and SAFSTOR options, engineering management recommended pursuing the DECON option to executive management and the board of directors.

FSV established an internal working group for deactivation that was assigned to spend 80% of its time on D&D planning. The internal working group consisted of various senior members of the FSV plant staff, each of which brought unique perspectives to the planning process as well as an openness to considering a variety of options. Special consideration was given to LLW, occupational exposures, the decommissioning strategy plan, costs, staffing needs, and decay levels (with the intent to minimize the time that personnel are exposed to radioactivity). The decision process described in the previous paragraphs was done by this group. Many issues were included in the decision process, such as maintenance of facility roofs (both repairs and re-roofing). Structures and systems at the site were evaluated by engineers, using senior engineers as consultants. Hundreds of pages of documentation, which took a year to complete, exists. The group explored different scenarios, including operation and maintenance costs in the SAFSTOR mode. Insurance costs were a major factor in the scenarios. To assure that the potential SAFSTOR and DECON activities were realistic, the internal working group met with plant management (who were not a part of the team) to discuss the various options. The main question asked to management was, "If you must do this, what would you need to get it done?"

One of the more important lessons learned by the FSV plant staff was to do *early planning*. This early planning was accomplished primarily through the development of the FSV PDP. The PDP details the major technical actions to be carried out during decommissioning. The major elements of the PDP are as follows:

- Methodology for removal of the activated portions of the PCRV and internal reactor radioactive components.
- Methodology for the decontamination and/or dismantlement of those portions of the PCRV structure and radioactive BOP systems that exceed limits for unrestricted release of residual radioactive materials.
- Estimates of volumes, and definition of techniques and shipment processes of all radioactive waste for off-site disposal.
- Discussion of the site remediation techniques, if required.
- Details of the facility radiological status, radiation protection program, cost estimate, fire protection plan, technical specifications, emergency response plan, security plan and radioactive waste management.

- The proposed final radiation survey plan that confirms release of the site for unrestricted use. Once performed and the results found to meet the site release criteria for unrestricted use, the final site survey serves as the basis for requesting termination of the FSV 10 CFR 50 license.

The NRC issued a set of review comments for the PDP. One of the comments was, "Describe the specific methods that will be used for cutting the piping of the Balance of Plant Systems (saws, touches, thermal cutting, shears)." In responding to these comments, there was concern that if the response were too specific and too detailed, it would become part of the licensing basis and would be difficult to deviate from or change without considerable effort. Therefore, in the responses, an attempt was made to include possible alternative methods and provide some additional detail, but not to tie things down so tightly that there would be no latitude later, during decommissioning.

The FSV PDP was written such that the licensee can make changes in a manner almost identical to how operating reactors make changes in accordance with 10 CFR 50.59.

The NRC was also aware of the potential delay of the start of decommissioning on August 1, 1992, and advised the utility that it would be appropriate and acceptable for the preliminary decommissioning activities to begin under the present POL and the existing technical specifications. On that basis, safety evaluations in accordance with 10 CFR 50.59 were prepared and approved as appropriate, and the removal of asbestos from the plant piping, cutting and removal of prestressing tendons, removal of graphite blocks with the fuel handling machine, and removal of the steam generator secondaries was initiated in mid-July 1992. During the decommissioning process, rust and corrosion were guarded against. Systems were evaluated and, if they were not needed, were eliminated, through salvage, moving to other sites, etc. If a system was necessary for deactivation, a maintenance plan covering its usage period was developed.

Deactivation activities used normal staff personnel and operable systems. PSC attempted to keep all FSV staff and was quite successful because only one person left when knowledge of the plant shutdown became known. The staff at the plant is much smaller now than when it was operating, but outplacement to other locations within the company avoided layoffs.

Another important lesson learned by the FSV plant staff was that before appropriate decontamination activities can be chosen, site characterization must be done. To characterize the hazards at the plant, 35,000 radiological data points were taken. A bar code system was used to track the radiological information, which made information retrieval relatively easy. Environmental characterization (such as EPA-type hazards and mixed waste) was also done. A 14-volume set of characterization information is available. According to NUREG 5849 and 2082, radiological surveys are required, including pathway analysis. After decontamination activities, an area was resurveyed to ensure successful decontamination.

During decontamination activities, site health physics personnel were used for radiation monitoring, and environmental monitoring was done by specialists. Contracting the environmental monitoring tasks to specialists led to substantial cost savings (when compared to the costs of training and paying site personnel to perform the tasks).

One of the changes that the FSV personnel would have made with respect to hazard characterization was to collect fewer data points. In reality, only 10,000 to 15,000 characterization points were needed. However, FSV felt that, based on the hazard characterization, the decontamination activities were correctly prioritized.

During Decommissioning Planning, significant attention was directed toward the development of the site release criteria and methodology for both release of the site for unrestricted use and materials off-site. The U.S. does not have a lower "limit" for radioactivity. It was important to develop an acceptable methodology that would receive regulatory acceptance, since the dismantlement/decontamination approach selected will not result in a "bare walls" plant after completion of physical decommissioning.

To determine the regulations and requirements applicable to the FSV site, letters were written to regulators discussing the decontamination process and requesting guidance. This seemed to work well. In addition, FSV worked with the EPA and the state on water quality issues. Letter agreements with the state on tritium releases (based on the water flow) ensured that there was no misinterpretation. FSV has pages of regulations applicable to SAFSTOR and D&D (see Appendix B). If FSV were required to meet 10 CFR 50 Part 20 (Radiation Protection Guides) costs would be increased by 5%. A cost/benefit analysis was done for the allotted time periods and the results presented to the regulators. The impact the regulations would have on the costs, etc., was clearly shown and a compromise was made.

When FSV looked at translating operational technical specifications to SAFSTOR operation and maintenance requirements, the systems involved were evaluated with respect to their technical specifications. The question asked for each system was, "Does it makes sense to keep this system tech speced?" Engineering judgment was used to classify the systems as to whether they should or should not be tech speced.

In November 1990, PSC submitted to the NRC the FSV PDP, based on the DECON option, as required by 10 CFR 50.82. Since decommissioning represents a major licensing change, it requires a major licensing review activity by the NRC. The PDP replaces the FSAR, and, as such, becomes the governing licensing document for FSV activities. In this review, the NRC was charged with assessing the following:

- the technical adequacy of the dismantlement and decontamination techniques to be employed,
- the radioactive waste management program including handling and subsequent off-site shipment to burial in the licensed LLW facility to be utilized,
- the radiation protection program to be utilized,

- the final radiation survey methodology and associated site release criteria,
- programs to be utilized during decommissioning for protection of occupational and public health and safety, such as emergency response and fire protection, and
- a determination that the cost estimate and funding plan are adequate to ensure completion of the decommissioning project.

PSC was required, in accordance with 10 CFR 50.82, to apply within two years following the permanent shutdown of operations for the authority to decommission the plant as detailed in the PDP.

From February through October 1991, various supplemental documentation such as the cost estimate, environmental report update, funding plan, QA plan, security plan, emergency response plan, and fire protection plan were filed with the NRC. In addition, PSC responded to two rounds of comments from the NRC.

FSV performed a PRA for nuclear and nonnuclear hazards. The main hazards identified included fires, tornadoes, and industrial-type accidents. Of FSV's accident scenarios, fire was the most threatening with respect to radiological releases to workers and the public. It was also more likely to occur. If a scenario had a likelihood of occurrence of less than $1E-4$, it was ignored. However, if its likelihood was greater than $1E-3$, design, surveillance, etc., were used to ensure that it would not occur. There were no significant radiological risks to surveillance and maintenance personnel; primarily industrial-type risks are present. However, plant personnel are expected to follow OSHA standards and to do their jobs safely.

FSV attempted to lower significant risk as much as possible during decontamination. Fire doors have been left in place, radiation monitoring and fire protection systems are operable, an intelligent maintenance program is still in effect, and component reliability is still being tracked. In addition, FSV looked at the potential hazards of removing a system from service before it was deactivated.

One of the FSV decommissioning activities involved flooding the reactor vessel with water to provide shielding for component removal operations. The graphite blocks in the reactor contain tritium that would be released into the water, and the tritiated water would eventually have to be removed from the vessel. It was estimated that about 500 curies of tritium would be released into the 325,000 gallons of water in the reactor vessel. The planned method of disposal was to bleed the tritiated water from the vessel and mix it with cooling tower blowdown water, which is then discharged to the river, the normal discharge path for liquid radioactive effluents from FSV.

The NRC then indicated that there had been a problem at SRP with the discharge of tritium where the discharges exceeded EPA safe drinking water standards. Although FSV was in compliance with NRC regulations and the river discharged into was not used for drinking water, the NRC was concerned with public perception and attitude, and with tritium discharge becoming an emotional issue. The NRC asked if the EPA drinking water standard of 20

thousand picocuries per liter in the river could be complied with. PSC, in accordance with its Offsite Dose Calculation Manual and the procedures and methods therein, reported that when the discharge was within the NRC limits, and mixed with the river flow, it would be in compliance. Meeting the EPA drinking water standard became a commitment.

The decommissioning costs for FSV are estimated to be \$157 million. The LLW disposal costs and the availability of disposal sites provided the greatest uncertainty to the decommissioning process. In addition, the variability of the regulatory climate generates a large uncertainty to the process. To deal with this uncertainty, FSV first established a baseline for all decommissioning costs. Assumptions, uncertainties, and reasons why the uncertainties exist were documented. Uncertainties were quantified using engineering judgment to choose an intelligently determined number; for example, for LLW a 3%, 5%, 8%, and 11.9% variability was used with the baseline. No sensitivity or free release studies were performed (free release does impact the disposal costs). 2 mR/h over background was used and costs calculated. To reduce D&D costs, all components that were easy to dismantle and ship out were removed as soon as possible (helium circulators were removed and shipped out first). Components with large waste volumes were also targeted for quick elimination. There was a large cost savings for getting rid of all possible components as quickly as possible.

Operations and maintenance costs for on-site storage of the spent fuel is \$300K/yr. This includes insurance, fees, basic maintenance, and personnel costs.

An interesting finding by FSV staff was discovered when, in order to determine the benefits from time-related reduction in radioactivity levels, an activation analysis was done out to 55 years. There was only a 10% decrease in the radioactivity at the site; therefore, no real advantage existed for delaying decommissioning 55 years (i.e., for placing the site into SAFSTOR).

The removal of the spent fuel from the FSV reactor was the responsibility of PSC. However, the fuel is owned by the DOE, and it is committed to taking possession of and storing it. PSC intended to begin defueling and shipping the fuel to INEL in early 1991. However, Governor Andrus, of Idaho, strenuously objected, and a series of legal maneuvers ensued. This complication delayed the decommissioning schedule. However, PSC had foreseen this possibility and had moved ahead with construction of an ISFSI.

The NRC requested that PSC and its contractors "submit the final dismantlement methods and a supporting safety analysis for NRC review. Alternatively, provide descriptions and safety analysis for potential options that may be used. Include evaluations of and methods to minimize personnel exposure in your safety analysis." The request for and use of the term *safety analysis* was confusing because it is commonly used only for analysis of off-site doses. After considerable internal discussion, it was concluded that what the NRC was probably looking for was the occupational radiation exposure estimates. Telephone conversations with the NRC were not successful in determining exactly what was required. The concern also

existed that too much detail might be written into the licensing basis and it would be difficult to deviate from it or change it.

Based on the concern that the right question might not be answered, and the inability to resolve the issue, PSC upper management met with NRC management, and as a result of the meeting, a longer meeting was arranged. PSC and its contractors prepared a day-long presentation that was designed to "sell" what was believed to be a reasonable level of detail for the NRC. The meeting was very successful. It convinced the NRC that only a small number of decommissioning activities were of significant concern and required any additional detailed explanation. The meeting was more of a success, however, because it brought PSC and its contractors and key NRC personnel together in a detailed day-long discussion. PSC believes that it convinced the NRC that the involved personnel were extremely knowledgeable and competent and that the details they were interested in were being addressed. It seemed that a much better working relationship existed after the meeting. In addition, as a result of the meeting, the NRC committed to a weekly telephone conference call to answer any questions and discuss status. The NRC had a significant number of management personnel involved in each telephone conference. This telephone conference call was extremely successful in expeditiously answering questions, explaining details, and, in many instances, eliminating the time-consuming written response.

PSC emphasized the importance of having good communications with regulators and individuals living within the state. Groups were invited to visit the site, including children. Senior FSV personnel went to meetings to answer questions. News flyers were sent out quarterly to the local community sharing plant information, and discussions included what FSV was currently doing and what had been done. Communications with the nuclear community—local, society, industrial, and environmental groups—also occurred. Routes used to transport waste were not disclosed; however, studies done to determine "acceptable societal risk" with respect to these routes were discussed.

Waste minimization procedures used included compaction, smelting, re-use, and free-release (if it was cost effective). To minimize packaging, FSV looked at LSA boxes, liners, and packing as tight as possible. Loading and unloading were preplanned. Self-shielding was used for packaging.

The selection of the contractor for decommissioning FSV was a year-long process. A bidding process was used with some contractors as part of several consortiums. Before a contractor was chosen, credentials were evaluated. This evaluation included looking at the companies' experience on the job, talking to the companies' previous customers (including subcontractors' customers). The PSC team that worked on FSV's D&D Plan worked on the bid specifications. A proposed statement of work was laid out, but companies were responsible for making specific proposals for performing the work.

The first major question asked to PSC by the NRC involved the estimated cost for decommissioning. The PDP, as originally submitted, took the approach that the estimated cost

for the decommissioning was the fixed price of the Westinghouse Team Contract, plus the utility costs during the decommissioning, and some contingency for changes. A meeting was held with the NRC to discuss the cost estimate issue in more detail. The NRC stated that the fixed price contract was fixed for a given scope of work, but performance of that work did not guarantee that the site would be releasable. Additional details were required to determine whether the work and funds provided would permit completion of decommissioning and termination of the license. The NRC verbally stated that its responsibility was to assure that the estimate was complete and accurate so that the contractor would not partially complete the contract, run out of money, and then default, leaving the utility with insufficient funds to complete decommissioning and with responsibility possibly reverting to the NRC. The NRC required detailed information for each individual task, which included the method of accomplishment, estimated duration of the task, crew size required, equipment required, supplies required, volume of waste, radiation levels, and potential radiation exposure. Transportation and burial costs were also requested. The NRC required that if any alternate methodologies were considered, the alternate methods must also be estimated and the differential costs included. This resulted in the preparation and submittal of a detailed cost estimate consisting of approximately 500 pages of information.

PSC is planning to repower the plant using natural gas, since the turbine is only three years old and is worth \$50 million. Because the plant will be repowered, efforts were made to maintain the site. Equipment and components not necessary for the repower efforts were sold to other plants. PSC reused as much equipment as possible.

Technologies that PSC would have found useful during the D&D process included a means to sample core internals remotely to more effectively and quickly characterize the site.

A.5 Humboldt Bay 3

The Humboldt Bay Power Plant (HBPP) Unit 3 is a General Electric natural circulation, single cycle boiling water reactor (BWR) rated at 65 MWe. The plant is located four miles southwest of Eureka, CA, and is operated by Pacific Gas and Electric Company (PG&E). The plant site also includes two fossil-fueled units and two gas-turbine-powered mobile emergency power plants.^{A-11,12}

HBPP Unit 3 was granted a construction permit by the AEC on October 17, 1960. The reactor achieved initial criticality on February 16, 1963, and began commercial operation in August of the same year. During the period from August 1963 to July 1976, HBPP Unit 3 generated more than 4.7 billion kWh of electricity and had a cumulative availability factor of 85.9%.^{A-11}

On July 2, 1976, the HBPP Unit 3 reactor was shut down for annual refueling and to conduct seismic modifications. In December 1980, it became apparent that the cost of completing required backfits might make it uneconomical to restart the unit, and work was suspended at

that time. An updated economic analysis in 1983 indicated that restarting would probably never be economical, and in June 1983, the utility announced its intention to decommission the unit.^{A-11}

The alternatives that the NRC defined for decommissioning included shipment of spent fuel off-site, prior to an amendment of a POL. Because no U.S. facilities receive spent fuel and because no spent-fuel reprocessing facilities, away-from-reactor storage facilities, or geological repositories are operating or accepting uncontracted for spent fuel, the utility included spent-fuel storage at HBPP within its definition of custodial SAFSTOR. The utility has plans to place HBPP into custodial SAFSTOR for a dormancy period of as long as 30 years. The spent-fuel assemblies will be stored on site until a federal repository is operating and able to receive the spent fuel.^{A-11}

The fuel was removed from the reactor in early 1984. The spent-fuel pool contains 390 spent-fuel assemblies and 54 in-core fission chambers.^{A-12} The reactor primary containment is located entirely below grade and consists of the drywell vessel, which houses the reactor, and a suppression chamber located concentrically around the drywell.^{A-11}

A.5.1 HBPP Hazard Characterization

PG&E has committed to maintaining its ALARA exposures. The plant has created an ALARA committee; the members include the Plant Manager (who is the chairman of the committee), Plant Engineer, Senior Chemical and Radiation Protection Engineer, Supervisor of Operations, Quality Control Supervisor, and Radiation and Process Monitor (RPM) Foreman.

The ALARA committee meets monthly or as called for by the chairman or the RPM and has the following functions and responsibilities:

- Review of radiation exposures associated with routine operations and maintenance and recommend future exposure reduction goals,
- Review of planned jobs where potential exposures might exceed 500 mRem total for the job or 100 mRem for any individual and establish exposure limits and person-Rem goals for that job,
- Review of completed jobs for achievement of goals and future improvements,
- Review of plant radiation and contamination levels annually and recommend future exposure reduction goals, and
- Review of plant design changes and plant procedures for ALARA considerations.

Before the ALARA committee review of a proposed job, the individuals planning the job estimate the expected radiation exposures based on radiation surveys conducted in the area where the job will be performed and the time required to perform the job, as indicated by prior experience. These estimates are reviewed by the Radiation Protection Department. If the established review thresholds of 500 mRem for the total job or 100 mRem for any individual are expected to be exceeded, an ALARA review checklist is completed and reviewed by the

ALARA committee to document the consideration of specific actions that may be taken to reduce radiation exposures.

All radiation workers at HBPP receive, as part of their radiation protection training, an indoctrination in the principles of ALARA radiation exposure control. In this training, the responsibility of the individual worker to follow procedures and safety rules and to maintain his own exposure ALARA is emphasized. The principles of minimizing the duration of exposure, maintaining distance from the source, and reducing source terms are included in the training.

In addition, the ALARA program looks at reducing exposures in a variety of other areas:

- *Design* - through planning; reviews; system, subsystem, and component selection and location; operator usage considerations; and maintainability,
- *Construction* - procedures; planning; methods; testing; and scheduling,
- *Operation* - procedures; license compliance; techniques; equipment usage; maintenance; and operating experience feedback from company and industry experience,
- *Personnel* - training; management support, motivation, and supervision,
- *Administration* - policy; guidance; controls; licensing position; and documentation, and
- *Management* - involvement; commitment; supervision; and oversight.

A.5.2 HBPP Management/Programmatic Issues

Systems and equipment not required by the HBPP Unit 3 operating license for the cold shutdown mode and not required to support deactivation activities were secured in preparation for SAFSTOR. Preparations included unloading the reactor core; draining, flushing, and securing systems; de-energizing instruments and controls no longer required; and isolating nonoperational from operational systems.

During deactivation to SAFSTOR, systems no longer required by the revised technical specifications are secured and isolated. Systems required to support deactivation activities but not required during SAFSTOR are secured upon the completion of those activities. The objectives of the system lay-up are as follows, to:

- drain systems containing fluids to the maximum extent practical,
- remove or shield significant sources of radiation in areas routinely accessible during SAFSTOR,
- seal connections between secured and operating systems by either using blank flanges or by cutting and capping the lines to prevent operating system leakage from refilling a system that has been drained, and
- de-energize motors, valves, instrumentation and other electrical components associated with secured systems.

The DECON alternative requires that equipment, structures, and those portions of the facility containing radioactive contaminants be removed or decontaminated to a level that permits the property to be released for unrestricted use shortly after operations cease. This alternative was not feasible for the HBPP because spent-fuel assemblies must be stored at the site until a permanent federal repository is available to receive them, and a repository is not likely to be ready before 2003. After a 30-year SAFSTOR, HBPP will be dismantled, and the site will be decontaminated and released for unrestricted use (delayed DECON).

The SAFSTOR alternative involves placing a nuclear facility in a safe condition and maintaining it in that state until it is dismantled and all remaining radioactive materials, which would restrict use, are removed. The facility may be left intact except for the fuel assemblies, which must be removed from the reactor, and radioactive fluids and wastes, which must be removed from the site. PG&E selected the SAFSTOR alternative because (1) it is the most cost-effective alternative because there is no federal repository for spent fuel and (2) it allows for radionuclide decay so that when fuel dismantling takes place, occupational radiation exposures will be reduced. The use of SAFSTOR includes the storage of the spent-fuel assemblies in the spent-fuel storage pool.

The only other viable alternative for the spent fuel is to construct an ISFSI at another site. The only difference between this alternative and storage of the spent fuel at the HBPP site is that an ISFSI away from the reactor site would require off-site shipment of spent fuel and construction of a fuel-handling facility. Thus, this alternative would be more costly and would have additional environmental impacts associated with off-site transportation of spent fuel. Also, moving the spent fuel would require handling and shipping the fuel twice, resulting in more exposure to workers and an increased potential for accidental releases.

During the SAFSTOR period and until initiation of the final decommissioning program, necessary plant systems will be operated and maintenance performed on structures, systems, and components, as required, to ensure continued safe conditions within the plant. The maintenance program established for the safe storage period is a modified version of the plant maintenance program and includes both preventive and corrective maintenance.

The preventive maintenance program provides for a regularly scheduled series of inspections, tests, and services for structures, systems, and components. The frequency of preventive maintenance is established on the basis of prior experience, ongoing operational use, plant conditions, and, where applicable, technical specification requirements. The objective of the preventive maintenance program is to ensure continued, reliable performance of necessary structures, systems, and components (equivalent to or better than the reliability existing at the beginning of the SAFSTOR period).

The corrective maintenance program provides for analysis and appropriate action to be taken when performance of structures, systems, and components is determined to be degraded. Adequate stores of spare parts and servicing equipment are maintained to ensure that corrective action can be taken within the time frame required by the technical specifications.

A.5.3 HBPP Requirements and Regulatory Issues

The radiological conditions at Unit 3 at the start of the safe storage period are in compliance with the Standards for Protection Against Radiation, 20 CFR 20. These standards accomplish the following:

- Discuss the control of releases of radioactive materials to the environment and limiting radiation doses to workers and members of the public,
- Provide limits on air and water effluent concentrations of approximately 250 radionuclides,
- Set limits of radiation exposure for individuals in both restricted (worker) and unrestricted (general public) areas,
- Describe ALARA (ICRP 26), and
- Apply to HBPP Unit 3 until the license is terminated.

The HBPP Unit 3 operating license addresses the Radiation Protection Plan, which states: "Radiation control procedures shall be maintained and made available to all plant personnel. These procedures shall show permissible radiation exposure and shall be consistent with the requirements of 10 CFR 20."

The waste management requirements applicable to the HBPP are as follows:

- 10 CFR 61, which sets forth the acceptance criteria of radioactive waste for land disposal. The NRC's technical position papers on radioactive waste classification and waste form give guidance for determining compliance with Part 61. This regulation is applicable to all shipments of radwaste from Unit No. 3 to LLW disposal sites.
- 10 CFR 71, which establishes the standards of Type B, Fissile Class I, II, and III packages for packaging of radioactive material for transport and transportation of radioactive material.
- 40 CFR 260, Hazardous Waste Management System General; 40 CFR 261, Identification and Listing of Hazardous Wastes; 40 CFR 262, Standards Applicable to Transporters of Hazardous Waste.

The HBPP Unit 3 operating license addresses waste disposal and sets the following limits and requirements:

- Radioactive waste discharge will not exceed the limits given in 10 CFR 20.
- The radiological inventory of wastes within the Liquid Radioactive Waste System will not exceed 10,000 Ci.
- Water from the reactor caisson sump is sampled and analyzed monthly for total alpha, beta, and gamma activity. Average and maximum values will be reported annually along with the results of the groundwater monitoring program.

- The radiological inventory of wastes within the Solid Radioactive Waste System shall not exceed 50,000 Ci.

Under the DOT Act of 1966, the DOT has regulatory responsibility for safety in the transportation of hazardous and radioactive material. 49 CFR addresses packaging requirements, shipping papers, radiation level limitations, contamination control, labeling, placarding, storage, and transportation. Certain states have established agreements with the NRC and adopted 49 CFR regulations for intrastate shipments. Under certain conditions, the containers for radioactive waste must have a state's approval before transport within or across that state's boundaries.

Other applicable regulations include the following:

- 40 CFR 61 - National Emissions Standards for Hazardous Air Pollutants
- 40 CFR 122 - National Pollutant Discharge Elimination System
- 40 CFR 129 - Toxic Pollutant Effluent Standard
- 40 CFR 141 - National Interim Primary Drinking Water Regulations
- 40 CFR 190 - Radiation Protection Standards for Nuclear Power Operations
- 40 CFR 260 - Resource Conservation and Recovery Act (RCRA) of 1976

The California Waste Discharge Permit for HBPP also specifies release limits for liquid effluents.

OSHA has set standards limiting worker exposures to toxic substances. These standards do not extend to the public. In addition to specifying permissible exposure limits for substances previously encountered in the Unit, such as metals, chromates, sodium hydroxide, sulfuric acid, solvents, and asbestos, additional regulations specify requirements for medical examinations, monitoring, methods to minimize airborne contamination, personal protective equipment, personal hygiene, signs and labels, access control, training, and waste disposal. 29 CFR 1910 also regulates radiological exposure and directly references 10 CFR 20. California OSHA regulations are consistent with 29 CFR 1910.

A.5.4 HBPP Transitioning Facility Risk Issues

Accidents during the SAFSTOR period have a low probability, are few in number, and are of minor consequence in comparison to accidents associated with reactor operations. The more severe accidents that could be credible during SAFSTOR operations were analyzed and are the following:

- Spent-fuel handling accident,
- Any event rupturing the spent-fuel storage pool,
- Heavy load drop into the spent-fuel storage pool,
- Uncontrolled release of radioactive liquid radwaste tankage to the environment, and

- Explosions, delayed ignition of flammable vapor clouds, release of toxic chemicals, or fire.

A.5.5 HBPP Cost Increases and Uncertainty

The cost of transitioning HBPP into the custodial SAFSTOR mode is estimated to be approximately \$14 million, including costs for the following activities:

- Surveys and analyses to perform radiological characterization,
- Preparation of the SAFSTOR Decommissioning Plan, Environmental Assessment Report, and Draft Dismantlement Plan,
- Labor and materials for unloading fuel from the reactor vessel and the securing of plant systems no longer required by the operating license, and
- Processing, packaging, shipment, and disposal of radioactive wastes from the site.

Cost estimates were prepared based on the detailed work breakdown schedule developed at the outset of the project and on experience in performing similar activities at HBPP and known plant labor and material costs. Costs to perform the SAFSTOR decommissioning of HBPP have been included in PG&E's Nuclear Plant Operations budget and the project.

During the SAFSTOR period, funds will be required to maintain the unit in accordance with the POL and associated technical specifications. Maintenance and surveillance activities during the SAFSTOR period will be similar to activities conducted during operation, but reduced in scope. Funds for SAFSTOR costs will be allocated in the HBPP Power Plant annual operations and maintenance budget. The California Public Utilities Commission has authorized that the operation and maintenance expenses, including certain expenditures of SAFSTOR activities, be recovered in rates.

A.5.6 HBPP Stakeholder Concerns

No information was obtained that specifically addressed stakeholder issues.

A.5.7 HBPP Waste Minimization and Avoidance of Mixed-Waste Generation

No information was obtained that specifically addressed these issues.

A.5.8 HBPP Industry Involvement

No information was obtained that specifically addressed industry involvement at HBPP.

A.5.9 HBPP Recycle and Reuse Opportunities

No specific information was obtained that addressed recycle and reuse opportunities.

A.5.10 HBPP Technology Development or Enhancement Needs

No technology development or enhancement needs were discovered in the documentation reviewed.

A.5.11 HBPP Lessons Learned

The HBPP has committed to minimizing both worker and public exposures to contaminated materials. An ALARA committee has been created that meets monthly or as called for by the chairman or the RPM and has the following functions and responsibilities:

- Review radiation exposures associated with routine operations and maintenance and recommend future exposure reduction goals,
- Review planned jobs where potential exposures might exceed 500 mRem total for the job or 100 mRem for any individual and establish exposure limits and person-rem goals for that job,
- Review completed jobs for achievement of goals and future improvements,
- Review plant radiation and contamination levels annually and recommend future exposure reduction goals, and
- Review plant design changes and plant procedures for ALARA considerations.

Before the ALARA committee review of a proposed job, the individuals planning the job estimate the expected radiation exposures based on radiation surveys conducted in the area where the job will be performed and the time required to perform the job, as indicated by prior experience. These estimates are reviewed by the Radiation Protection Department. If the established review thresholds of 500 mRem for the total job or 100 mRem for any individual are expected to be exceeded, an ALARA review checklist is completed and reviewed by the ALARA committee to document the consideration of specific actions that may be taken to reduce radiation exposures.

All radiation workers at HBPP receive, as part of their radiation protection training, an indoctrination in the principles of ALARA radiation exposure control. In this training, the responsibility of the individual worker to follow procedures and safety rules and to maintain his own exposure ALARA is emphasized. The principles of minimizing the duration of exposure, maintaining distance from the source, and reducing source terms are included in the training.

In addition, the ALARA program looks at reducing exposures in a variety of other areas:

- *Design* - through planning; reviews; system, subsystem, and component selection and location; operator usage considerations; and maintainability,
- *Construction* - procedures; planning; methods; testing; and scheduling,

- *Operation* - procedures; license compliance; techniques; equipment usage; maintenance; and operating experience feedback from company and industry experience,
- *Personnel* - training; management support, motivation, and supervision,
- *Administration* - policy; guidance; controls; licensing position; and documentation, and
- *Management* - involvement; commitment; supervision; and oversight.

Systems and equipment not required by the HBPP Unit 3 operating license for the cold shutdown mode and not required to support deactivation activities were secured in preparation for SAFSTOR. Preparations included unloading the reactor core; draining, flushing, and securing systems; de-energizing instruments and controls that are no longer required; and isolating nonoperational from operational systems.

During deactivation to SAFSTOR, systems no longer required by the revised technical specifications are secured and isolated. Systems required to support deactivation activities but not required during SAFSTOR are secured upon the completion of those activities. The objectives of the system lay-up are as follows, to:

- drain systems containing fluids to the maximum extent practical,
- remove or shield significant sources of radiation in areas routinely accessible during SAFSTOR,
- seal connections between secured and operating systems by either using blank flanges or by cutting and capping the lines to prevent operating system leakage from refilling a system that has been drained, and
- de-energize motors, valves, instrumentation and other electrical components associated with secured systems.

The SAFSTOR alternative involves placing a nuclear facility in a safe condition and maintaining it in that state until it is dismantled and all remaining radioactive materials, which would restrict use, are removed. The facility may be left intact except for the fuel assemblies, which must be removed from the reactor, and radioactive fluids and wastes, which must be removed from the site. PG&E selected the SAFSTOR alternative because (1) it is the most cost-effective alternative because there is no federal repository for spent fuel and (2) it allows for radionuclide decay so that when fuel dismantling takes place, occupational radiation exposures will be reduced. The use of SAFSTOR includes the storage of the spent-fuel assemblies in the spent-fuel storage pool.

The only other viable alternative for the spent fuel is to construct an ISFSI at another site. The only difference between this alternative and storage of the spent fuel at the HBPP site is that an ISFSI away from the reactor site would require off-site shipment of spent fuel and construction of a fuel-handling facility. Thus, this alternative would be more costly and would have additional environmental impacts associated with off-site transportation of spent fuel.

Also, moving the spent fuel would require handling and shipping the fuel twice, resulting in more exposure to workers and an increased potential for accidental releases.

During the SAFSTOR period and until initiation of the final decommissioning program, necessary plant systems will be operated and maintenance performed on structures, systems, and components, as required, to ensure continued safe conditions within the plant. The maintenance program established for the safe storage period is a modified version of the plant maintenance program and includes both preventive and corrective maintenance.

The preventive maintenance program provides for a regularly scheduled series of inspections, tests, and services for structures, systems, and components. The frequency of preventive maintenance is established on the basis of prior experience, ongoing operational use, plant conditions, and, where applicable, technical specification requirements. The objective of the preventive maintenance program is to ensure continued, reliable performance of necessary structures, systems, and components (equivalent to or better than the reliability existing at the beginning of the SAFSTOR period).

The corrective maintenance program provides for analysis and appropriate action to be taken when performance of structures, systems, and components is determined to be degraded. Adequate stores of spare parts and servicing equipment are maintained to ensure that corrective action can be taken within the time frame required by the technical specifications.

The radiological conditions at Unit 3 at the start of the safe storage period are in compliance with the Standards for Protection Against Radiation, 20 CFR 20. These standards accomplish the following:

- Discuss the control of releases of radioactive materials to the environment and limiting radiation doses to workers and members of the public,
- Provide limits on air and water effluent concentrations of approximately 250 radionuclides,
- Set limits of radiation exposure for individuals in both restricted (worker) and unrestricted (general public) areas,
- Describe ALARA (ICRP 26), and
- Apply to HBPP Unit 3 until the license is terminated.

The waste management requirements applicable to the HBPP are as follows:

- 10 CFR 61, which sets forth the acceptance criteria of radioactive waste for land disposal. The NRC's technical position papers on radioactive waste classification and waste form give guidance for determining compliance with Part 61. This regulation is applicable to all shipments of radwaste from Unit No. 3 to LLW disposal sites.

- 10 CFR 71, which establishes the standards of Type B, Fissile Class I, II, and III packages for packaging of radioactive material for transport and transportation of radioactive material.
- 40 CFR 260, Hazardous Waste Management System General; 40 CFR 261, Identification and Listing of Hazardous Wastes; 40 CFR 262, Standards Applicable to Transporters of Hazardous Waste.

The HBPP Unit 3 operating license addresses waste disposal and sets the following limits and requirements:

- Radioactive waste discharge will not exceed the limits given in 10 CFR 20.
- The radiological inventory of wastes within the Liquid Radioactive Waste System will not exceed 10,000 Ci.
- Water from the reactor caisson sump is sampled and analyzed monthly for total alpha, beta, and gamma activity. Average and maximum values will be reported annually along with the results of the groundwater monitoring program.
- The radiological inventory of wastes within the Solid Radioactive Waste System shall not exceed 50,000 Ci.

Under the DOT Act of 1966, the DOT has regulatory responsibility for safety in the transportation of hazardous and radioactive material. 49 CFR addresses packaging requirements, shipping papers, radiation level limitations, contamination control, labeling, placarding, storage, and transportation. Certain states have established agreements with the NRC and adopted 49 CFR regulations for intrastate shipments. Under certain conditions, the containers for radioactive waste must have a state's approval before transport within or across that state's boundaries.

Other applicable regulations include the following:

- 40 CFR 61 - National Emissions Standards for Hazardous Air Pollutants
- 40 CFR 122 - National Pollutant Discharge Elimination System
- 40 CFR 129 - Toxic Pollutant Effluent Standard
- 40 CFR 141 - National Interim Primary Drinking Water Regulations
- 40 CFR 190 - Radiation Protection Standards for Nuclear Power Operations
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personal hygiene, signs and labels, access control, training, and waste disposal. 29 CFR 1910 also regulates radiological exposure and directly references 10 CFR 20. California OSHA regulations are consistent with 29 CFR 1910.

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- Heavy load drop into the spent-fuel storage pool,
- Uncontrolled release of radioactive liquid radwaste tankage to the environment, and
- Explosions, delayed ignition of flammable vapor clouds, release of toxic chemicals, or fire.

The cost of transitioning HBPP into the custodial SAFSTOR mode is estimated to be approximately \$14 million, including costs for the following activities:

- Surveys and analyses to perform radiological characterization,
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A.6 Pathfinder

The following information on the Pathfinder Atomic Power Plant is from the "Case Study: Pathfinder Decommissioning" paper written by John Closs^{A-15} and from interviews the authors of this document had with Northern States Power employees at the Pathfinder Plant. The

lessons learned section highlights information that, in the opinion of the authors of this document, will provide valuable lessons to individuals and teams planning decontamination and decommissioning projects.

The Pathfinder Atomic Power Plant, built and operated by Northern States Power Company (NSP), is located six miles northeast of Sioux Falls, SD. The plant was part of the Atoms for Peace program. The AEC was looking for "unique" reactor designs and provided NSP the research and development necessary to build the plant as well as the fuel. NSP retained ownership of the plant and its subsequent decommissioning costs. The Pathfinder Plant was a demonstration BWR with a nuclear superheater. The plant's 66-MWe nuclear reactor first went critical in 1964. After several years of subcritical and low-power operations (equivalent to only 88 days of full power operation), the reactor underwent its final shutdown on September 16, 1967.

After establishing that the plant required structural and design upgrades because of the mechanical failure of the steam generators, NSP made an economic decision to keep the nuclear reactor permanently shut down. NSP began to repower the Pathfinder Plant with gas-fired boilers in 1968. The reactor was defueled and then placed in SAFSTOR during 1969 and 1970. Its operating license was surrendered for a by-product material possession license under the provisions of 10 CFR 30. Following conversion, Pathfinder was placed back into commercial operation as a fossil-fueled peaking plant and continues to operate.

Pathfinder's decommissioning phase began in the late 1980s when NSP examined the feasibility of completing its decommissioning work while low level waste (LLW) disposal sites were available and disposal costs were relatively low. Following NSP's decision to demolish the unused nuclear portions of the site, several conferences with the NRC were conducted to discuss the proposed project. In January 1990, the NSP decommissioning team arrived at the site, and in July 1990, they began to dismantle the nuclear portions of the plant.

The scope of the decommissioning phase included (1) the reactor building and its contents, including the reactor vessel, (2) the fuel handling building and its contents, and (3) the fuel transfer vault between the reactor building and the fuel handling building. Radioactive material and residual contamination contained in the fossil-fired plant was not included in the scope.

The Pathfinder reactor vessel was lifted out of the reactor building on May 14, 1991. NSP was granted a Certificate of Compliance by the NRC for shipping the reactor vessel as a Type A package. On August 7, 1991, the vessel was shipped in one piece to a commercial disposal facility near Richland, WA.

A.6.1 Pathfinder Hazard Characterization

The reactor fuel, which was 97% U-235, was removed and returned to the AEC. In preparation for the SAFSTOR period, the piping was drained and dried. Drying was done using a condenser vacuum, which meant that the plant had to be running. The pipes were then sealed

and utilities turned off, including power. A sump, which was accessible in the turbine building, was located at the bottom of the fuel handling pool. At the recommendation of the Atomic Energy Commission (AEC), the reactor vessel was filled with 6 mm (1/4 inch) diameter pea gravel. The control rods were left in the vessel so that they would not be damaged, resulting in the reactor becoming permanently unusable. The control rod drives were cut in half and placed into the fuel storage pool, all inactive gear was placed into SAFSTOR. To prevent circulation, plastic was used to cover holes, such as stairways. The original radiological survey took 6 months and consisted of several hundred measured points. It was an extensive effort, requiring a number of plant personnel to take smears in the containment building. SAFSTOR was officially begun in 1971 when the nuclear areas were sealed off.

In 1980, Pacific Northwest National Laboratory (PNL) contracted with the NRC to perform radiological sampling at the plant. Holes were drilled at various locations within the SAFSTOR portions of the plant and radiation levels determined. The only area not checked was the bioshield. The radiological sampling by PNL provided valuable information to plant personnel when final decommissioning activities were planned and executed. PNL had essentially done almost all of the necessary site characterization. A calculation was used to determine the radiological levels of the bioshield.

NSP committed to a less than 5 mR/h background radiation level. Because the plant was clean, NSP felt that this would be attainable. However, proof of meeting this level could be very expensive because nature is working against it. Background levels at the county courthouse, which was built at the same time and is similar in construction to the Pathfinder Plant, were measured at 8 mR/h. In fact, the cleanest air in the area around the plant was at the air filters in the plant, not outside the plant, since radon was present.

The Pathfinder package contained both activated and contaminated materials with a total measured radioactivity of 2.08×10^{13} Bq (562 curies). The activated inventory constituted most of the radioactivity of the package. The total activation inventory consisted primarily of cobalt-60, iron-55, nickel-59 and nickel-63. In addition, approximately 3.52×10^9 Bq (95 millicuries) of the same radionuclides were present in the form of surface contamination on the interior surfaces of the package (i.e., reactor vessel) internals. The principal radionuclide of the interior surface contamination was cobalt-60, based on data taken by scraping samples from the feedwater system piping attached to the vessel. This sample point was judged to be a conservative representation of the vessel source of surface contamination. The individual quantities of surface contamination were small relative to the activation inventory.

Since the reactor vessel and its internals contained only 2.08×10^{13} Bq (562 curies) of radioactivity, it did not warrant an effort to segment and package the vessel and internals. Based on a vessel activation and shielding analysis, the vessel and internals qualified as low specific activity (LSA) material and the Pathfinder package qualified as a Type A container.

The pea gravel poured into the reactor vessel apparently filled all cavities uniformly with the exception of one area at the side of the vessel. At this location, there was a "hot spot" with a

radiation reading of about 6 mSv (600 mR/h), whereas all other areas at the same elevation were about 1.5 mSv (150 mR/h). To stabilize the gravel and fill the void spot, the vessel was pumped full with a grout. Other than the filling of the void, no direct credit was taken for the shielding effectiveness of the grout in the shielding analysis.

A number of surprises were found during decommissioning: (1) there was residual water remaining in the reactor vessel from the grouting process, (2) the fuel transfer vault drain line was broken, (3) there was a false floor below the spent-fuel pool, (4) the equipment hatch was a spill area, (5) there was concrete/rebar activation around the neutron detector ports, and (6) there was concrete/rebar activation in the reactor vessel cavity.

When starting the decommissioning effort, only 30 mCi were left out of 16,000 mCi measured at the beginning of the SAFSTOR period. The POL allowed for 37,000 mCi. The radiation/radwaste statistics were as follows:

- Average Radiation
 - Direct was <1mR/h,
 - Smearable was <100 dpm/100cm², and
 - Airborne was <1mpc;
- Dose Received
 - Total was 3.95 Rem,
 - Highest Person was 0.30 Rem;
- Volume Radwaste Shipped was 975 m³;
- Curies Radwaste Shipped was 561.8 Ci; and
- Weight Radwaste Shipped was 1224 tons.

A.6.2 Pathfinder Management/Programmatic Issues

NSP had three levels of management at the site, which meant that one *always knew whom to call* when a problem developed. NSP Headquarters management stayed in the background, providing funding and then trusting personnel at the site to get the job done. Site personnel resolved the details (i.e., they were empowered). The on-site crew remained lean throughout the decommissioning project. Many plant personnel were transferred to NSP's Monticello Plant. When assets were not available, NSP hired outside labor for the duration of the need. The decommissioning project had a lot of team spirit that made a huge difference in the success of the project. There was a "lifeboat" mentality: the on-site crew were in this together; if a problem developed, they worked as a team to solve it.

General procedures were in place during the project; however, decommissioning the plant was looked at differently than operating the plant. The quality assurance (QA) personnel at the site saw the situation the same way, and QA requirements were adjusted to reflect the new situation. There was no formal training during the project, since the crew met daily, except for general group training, which was done for personnel at the start of their employment. When work was to begin in specific areas, the procedure was to issue a work permit.

During the SAFSTOR phase, the nuclear steam supply system (NSSS) was dismantled to the extent necessary to render it inoperable and incapable of being restored to service. All nuclear fuel was removed from the reactor and shipped off-site. The reactor vessel was drained and connected to a vacuum pump to remove all residual water from nondrainable cavities. The control rods and blades were left in the reactor vessel, and the vessel was filled with gravel. Power and ventilation were cut off, and pipes were cut.

To start the decommissioning phase, it was necessary to restore power and ventilation in those portions of the plant that were in SAFSTOR by running new lines, which were painted orange to mean *do not touch*. The only item that was not brought in was the crane, which was refurbished because it had been disabled (actually welded in place to ensure no movement during an earthquake) in the SAFSTOR phase.

Decommissioning was viewed as a high volume of low technology work in a relatively clean environment. The sequence used during the decommissioning phase was to remove (1) asbestos, (2) hazardous material, (3) cables, (4) piping, (5) equipment, (6) concrete and rebar, and (7) structures. Milestones for the project were as follows:

- June 1990 - Approval to start phase II decommissioning.
- October 1990 - Reactor vessel package certification received.
- May 1991 - Reactor vessel lifted.
- August 1991 - Reactor vessel shipped.
- August 1991 - Reactor vessel buried.
- April 1992 - Final survey completed.

A.6.3 Pathfinder Requirements and Regulatory Issues

The decision to switch from a nuclear facility to a fossil-fueled plant was primarily economic. The costs for modifications to bring the plant up to code with respect to new safety requirements were prohibitive. In addition, in 1964, NRC specifications were constantly changing, and NSP saw that *many* regulations would be added to the nuclear industry in the future, which would lead to cost increases.

Passage of the 1980 Low Level Waste Act and its 1985 Amendment allowed burial surcharges. Plant owners were looking at losing access to LLW burial and the coming of time limits. The longer NSP waited to bury its LLW, the higher the cost. If disposal of the reactor vessel was postponed for a year, the cost increase was anticipated to be \$1 million. In addition, NSP would be required use a Type B container, which would significantly increase costs. The total radioactivity present was 2.08×10^{13} Bq (562 curies). However, most of the reactor vessel container source term consisted of activated base metal that was not readily dispersible. The remaining source term was estimated to be 3.52×10^9 Bq (95 millicuries), consisting of a thin corrosion film that was bound to the surfaces of the Pathfinder vessel and internals and was further bound by the grout poured into the vessel. The maximum specific activity of the package was approximately 9.18×10^6 Bq (0.248 millicuries) per gram. Since this value is less

than 1.11×10^7 Bq (0.3 millicuries) per gram, the package qualified as an LSA package. The package was exempt from the additional requirements for Type B packages, and qualified as a Type A package. If analysis had shown the package to be Type B, NSP would probably have considered alternate methods for disposing of the vessel.

Based on the shielding analysis of the vessel package with a 40 percent void fraction in the gravel (no credit has been given for the addition of the grout), 50 mm (2 in.) of steel shielding was added to the vessel package to meet the NRC and DOT transport regulations. The vessel package weighed 2.63×10^5 kg (290 tons), not including tie-downs or other supports. The package was transported by railcar as part of a special train from the Pathfinder site to Richland, WA. A special train was used because the package was high and wide, not because of nuclear concerns. The reactor vessel package was unloaded from the railcar and transported a short distance to the disposal site.

The following paragraphs summarize some of the technical details involved in certifying the Pathfinder reactor vessel as a Type A package. The reactor vessel and internals activated inventory constituted most of the radioactivity of the package. The total activation inventory, as shown by analysis, was 2.08×10^{13} Bq (562 curies), consisting primarily of cobalt-60, iron-55, nickel-59 and nickel-63. In addition, approximately 3.52×10^9 Bq (95 millicuries) of the same radionuclides were present in the form of surface contamination on the interior surfaces of the internals. The total amount of decay heat generation for the vessel and internals package was calculated from the activation analysis to be 4.67 W. Therefore, there were no significant internal thermal gradients that would lead to differential thermal expansion that would, in turn, result in stresses that might be considered in evaluating the structural integrity of the package. Since the package did not contain spent fuel, the release of fission products from a fuel source because of excessive temperatures did not need to be considered. The package contained no free-standing pools of contaminated liquids and no explosive mixtures or potential aerosol particles that could be considered a radiological hazard. The exterior of the containment boundary was a steel structure that contained no valves or leak test ports. Leak test criteria or leak rate limits were not applicable to this package as a quantitative measure of containment integrity. Analysis showed that there would be no rupture of the vessel because of normal transport conditions from either structural or thermal stresses, and consequently, there would be no release of activated or contaminated radioactive material. The containment boundary consisted of the reactor vessel, vessel head, and the nozzle closure plates welded to the nozzle openings. Welding and weld examination complied with NUREG/CR-3019 and were done under an approved QA program. Other technical details considered in certifying the Pathfinder reactor vessel as a Type A package included the following: closure, requirements for normal transport conditions, activated materials, corrosion product layer, pressurization of the containment vessel, shielding evaluation and effectiveness, and source and model specification tests and inspections.

A.6.4 Pathfinder Transitioning Facility Risk Issues

The only accidents that occurred during the SAFSTOR and decommissioning phases were normal industrial-type accidents. Training and protective equipment (e.g., safety glasses and steel-toed boots) were used to help alleviate these types of accidents.

Nothing that would deteriorate during the SAFSTOR period, as long as no water was present, was left. Even though very little water was present, some equipment did rust. However, it was never going to be used again, so the rusting was inconsequential. In case it became necessary during the SAFSTOR period to enter the areas in storage, a breaker was left in place. One of the requirements for SAFSTOR was that an operator or security person be present at the site 24 hours a day. NSP employed one operator during the day and security for the remainder of the 24-hour period.

For the SAFSTOR and decommissioning phases, the activities that had the most risk, albeit small, were those involved in preparing the vessel for shipping and the shipping itself. No emergency plan was on file at the plant, since this was not a requirement when the plant was originally built. A mini-plan was drafted to cover shipment of the reactor vessel, addressing what would happen if the contents of the vessel leaked out. Hospitals and emergency personnel were contacted along the shipment route to ensure that the vessel contents were known and preparations could be made for potential accidents.

Preparations for vessel shipment included stabilizing the gravel in the vessel by adding grout, cutting off attached piping, and sealing openings. The vessel was lifted from the reactor cavity, moved through the open reactor building dome, and laid on its side within a temporary enclosure, and any remaining attachments were cut away. The external asbestos insulation was removed and the vessel certified clean of asbestos. A cylindrical steel shield was welded to the vessel shell. An impact limiter consisting of Hexcel (a trademark of the Hexcel Corporation, Dublin, CA) and wood was installed on the vessel shell surface to protect the vessel from postulated transportation accidents. The outer 6-mm (1/4 in.) shell protected the package during normal transport conditions. The vessel package was lifted horizontally and placed on saddles installed on a flatbed railcar for transport to the US Ecology, Inc., disposal facility near Richland, WA. The tie-downs used for the package shipment consisted of two 10-cm (4-in.) steel bands.

The 50-mm (2 in.) of steel shielding added to the vessel package was sufficient to reduce the external exposure rate to less than 0.1 mSv (10 mRem/h) at 2m (without counting the grout), assuming a 40 percent void fraction in the gravel.

A.6.5 Pathfinder Cost Increases and Uncertainty

Tom LaGuardia, of TLG Engineering, was contracted in 1988 to perform an independent cost estimate for decommissioning the Pathfinder Plant. His estimate was \$16 million, which coincided with the original estimate made by plant personnel. The actual decommissioning

costs were \$13 million. The cost breakdown for Pathfinder decommissioning was about a third for planning and engineering, a third for waste, and a third for labor.

Plant personnel emphasized how important it is to know what the disposal costs will be. Without knowledge of disposal costs, optimal decommissioning strategies cannot be chosen. The landfill costs charged by US Ecology were \$30/ft³ for burial plus a \$40/ft³ surcharge.

A.6.6 Pathfinder Stakeholder Concerns

Public relations (PR) are important. NSP PR personnel were involved in the decommissioning project from the beginning. The Governor of South Dakota and the head of the Department of Human Services (which is equivalent to the head of the Department of Health in other states) toured the plant. Plant personnel explained what was going on and future plans. The NRC was also present during these tours. Later, local officials were also invited to the plant. The plant tours helped alleviate concerns, and frequently, the response on leaving the plant was, "So, what's the big deal?" Plant personnel also kept these individuals informed about decommissioning activities. During the interview performed by the authors at the plant, plant personnel emphasized the importance of having the support of state and federal regulators and the importance of treating the public as a significant contributor. Also of importance is to never surprise the regulator.

Communications were set up with senators, NRC staff, reporters, and many others. These individuals were contacted six months before an activity was to be performed to allow time for questions to be asked and answered. The Pathfinder Plant did have public intervenors who were concerned about whether the plant was *doing it right* (i.e., performing appropriate decommissioning activities safely). A local woman was kept in the decommissioning information loop. She was shown around the plant, and time was taken to explain what was going to be done and why. Plant personnel felt that she asked many good questions, all of which they answered. She was given *status*. A "written agreement" was made between her and the plant, which committed the two parties to work together to resolve concerns. Her concerns were basically the same as the plant's, so the only change for the plant involved adding her to their mailing list. Another intervenor was Donald Pay (an anti-nuclear proponent) from Pierre, SD, but he was given no standing by the NRC because he lived too far from the plant.

The NRC was very interested in making the decommissioning project a success, and a Branch Chief consistently sat in on meetings. If there were problems, the NRC was there quickly.

Once the shipment route was chosen, plant personnel offered to make a presentation and answer questions in all states that the shipment would pass through. It paid off. The route was not a matter for negotiation. NSP felt that transport of the container was safe, no matter what route was taken. They felt that if they yielded on this point, people would interpret it as verification of the *badness* of the container.

NSP's South Dakota Region personnel made considerable efforts to keep the Sioux Falls media fully informed on decommissioning progress. As a result, the vessel shipment started smoothly. This positive reporting at the beginning of the transit resulted in keeping the whole shipment in perspective. NSP invited members of the Sioux Falls media to the Pathfinder site for the vessel sendoff, that is, reactor vessel shipment. Later, during the transit, most TV and radio stations knew that the train was coming through their town, so they carried a story about it on their local news broadcasts. For the most part, they did so factually and fairly. Beyond Sioux Falls, outside interest was generally confined to curiosity seekers and passersby. The public treated the shipment for what it was; a big, heavy package that was not a problem. It was not a radiation threat, and it did not endanger their health and safety.

Pathfinder decommissioning baseball caps were made up and given out to the involved public. This helped make the public an owner in the project. During vessel shipment, a satellite tracking system was used to maintain contact with the train at all times. Three NSP SD Region personnel were on the train for the entire trip. Frequent communications with Burlington Northern Railroad (BN) system dispatchers and asset protection personnel, DOE Transportation and Communications (TRANSCOM) operators, state radiation inspectors, federal railroad inspectors, Westinghouse (the vessel car's owner), and US Ecology (the disposal site operator) were maintained by NSP. Courtesy and information calls were made before, during, and after the shipment to cognizant state and federal agencies. One question NSP was determined to be able to answer was, "Do you know where the train is right now?"

Numerous DOT Federal Railroad Administration (FRA) inspections were conducted before and during the transit. The NRC conducted radiation surveys in Sioux Falls, SD, before the vessel's departure and the Washington Department of Health conducted its own radiation surveys in Spokane and Richland, WA.

The only significant delay encountered during the transit was in Havre, MT. An FRA inspector reported deficiencies in the vessel car's braking system, which had to be repaired before the train could proceed. NSP coordinated communications between BN, the DOT inspection team and their management, Westinghouse, and ITEL (Westinghouse's contractor during the vessel railcar's most recent overhaul). The railcar's braking system was modified and the discrepancies corrected to the satisfaction of the FRA inspectors. All repair work was conducted by BN's repair shop in Havre.

NSP believes that the lack of concern exhibited during transport can be attributed to advance publicity and communications. For over a year, state and local officials, as well as news media and the public, were kept informed on NSP's plans. Maps, pictures, descriptive data, question-and-answer sessions, local visits, and public meetings helped answer concerns and alleviate potential problems.

A.6.7 Pathfinder Waste Minimization and Avoidance of Mixed-Waste Generation

The first activity performed by NSP personnel involved ensuring that there was no mixed waste potential at the site. If the potential to create mixed waste was found, it was eliminated as quickly as possible. In some cases, on-site decontamination was done. The main types of mixed wastes were mercury and lead. In addition, there was 4,000 ft³ of contaminated asbestos. However, after compaction, only 600 ft³ was left for burial at a local landfill.

A.6.8 Pathfinder Industry Involvement

NSP managed and conducted the SAFSTOR and decommissioning activities, only hiring contractors and laborers when expertise or resources were not available within the company. Subcontractors used by NSP included BN for shipping, US Ecology for the landfill, some specialty organizations, such as a specialty crane company for moving the reactor vessel to the railcar, and Energy Services Group (ESG) for health physics.

BN was selected to transport the reactor vessel between Sioux Falls, SD, and Richland, WA. NSP leased a 12-axle heavy-haul railcar from Westinghouse, WECX 305, to transport the vessel. The vessel shipment took place between August 7 and 11, 1991. For most of the trip, the train consisted of an engine, an idler car for weight distribution, the Pathfinder vessel on WECX 305, another idler car, BN's "Yellowstone River" business car, and a caboose.

Besides the BN crew, NSP staffed the train with three employees in the business car to provide technical expertise, maintain communications, and conduct radiation surveys. These personnel were not required by regulations to accompany the vessel during transit, but NSP considered it prudent to do so.

A Shipping Coordinator's Office (SCO) was established at the International Centre Building in Minneapolis, MN, and was staffed by several NSP employees. A two-way communications and tracking network was established by NSP's Tele-Communications Department. The network incorporated the DOE TRANSCOM Version 2.2, a laptop computer for off-hour home use, cellular and Improved Mobile Telephone Service (IMTS) telephones (which did not function properly during the shipment), fax equipment, and an autopaging arrangement.

A.6.9 Pathfinder Recycle and Reuse Opportunities

For SAFSTOR, the reactor vessel was filled with gravel, which resulted in immobilizing it and preventing it from ever being resurrected. The fuel was removed. The control blades were cut off at the top of the vessel and left in the reactor. The control rod drives were cut and placed in the storage pool. The turbine and condenser were chemically cleaned to support the repower effort.

As the actual Decommissioning Plan took shape, two vessel removal alternatives were considered (1) one-piece removal and disposal and (2) segmentation of the vessel and internals

and transport for disposal in shielded shipping containers. The segmentation alternative would require extensive remote tooling and individual segment handling to cut and load the shipping casks for disposal. The cutting process would generate large quantities of smoke and debris that would require extensive contamination and control measures such as control access tents, high efficiency particulate air (HEPA) filters, and remote handling devices. There would have been additional worker exposure because of the extensive time required to segment, load, and ship each piece. The alternative, one-piece shipment, did not require extensive tooling, handling contamination controls, or high worker radiation exposure. However, there were considerable costs associated with building and certifying the package that would be shipped.

Contaminated materials went to Allied Technology Group, based in Richland, WA. NSP paid Allied Technology to take the contaminated material, which was then decontaminated and sold or volume reduced and disposed of. Allied Technology had a base charge, based on weight. Noncontaminated materials were sold by the plant. NSP's goal was always to be economical. At the conclusion of the decommissioning activities, the site could be released to unrestricted use.

A.6.10 Pathfinder Technology Development or Enhancement Needs

The only *unique* or state-of-the-art technology used in the decommissioning of the Pathfinder Plant was DOE's TRANSCOM system. TRANSCOM is a satellite-based transportation and communications system that had been used by DOE to track shipments of spent nuclear fuel and HLW throughout the U.S. NSP was actively seeking back-up communications capability for areas not covered by the nation's cellular phone network, TRANSCOM met this need beautifully. DOE wanted to demonstrate the system on an actual rail shipment. They had used the system to monitor truck shipments, but had limited experience with rail shipments. In addition, DOE wanted to demonstrate a solar-powered TRANSCOM unit. DOE considered the use of TRANSCOM by NSP as a research and development effort to test the feasibility of tracking by rail. It was a success.

The TRANSCOM system used in the shipment of the Pathfinder vessel consisted of two separate units. One unit was mounted on the business car and used to maintain two-way communications between personnel on the car and the Shipping Coordinator stationed in Minneapolis, MN. A second solar-powered unit (used for tracking) was mounted on the vessel itself. The solar unit was designed to be self-sustaining with a rechargeable, battery back-up power supply.

A.6.11 Pathfinder Lessons Learned

The first step in any SAFSTOR or decommissioning project involves characterizing the site. Sufficient time and funding to survey the site must be allotted. However, it is important to use intelligence when selecting survey points. The Pathfinder Plant used a color code for the survey points. Areas anticipated to be contaminated used a smaller grid (and different color) than those areas that were unlikely to be contaminated. There is not enough money or time to be

absolutely certain that characterization of every possible area at a site has been done. Surprises must be expected and accommodated.

During SAFSTOR activities, locations of inactive piping, cables, equipment, etc., that are being stored should be documented. Items removed from their original locations should be stored efficiently to preserve space. Before the area is sealed, circulation should be prevented that will allow radionuclides to move to unexpected locations.

Before establishing values for background radiation levels that will ultimately be the targets for final decommissioning, the background levels of structures built of similar materials and at the same time should be known.

Characterization determines what SAFSTOR and decommissioning activities will be required. For example, if a contaminated material at a site is classified as Class A LLW, it can be placed in a Type A container, which is significantly cheaper and easier to use than Type B containers.

For the Pathfinder Plant, the approximately 20 years in SAFSTOR resulted in significantly reducing radiation and contamination levels from the short-lived radionuclides present at the plant. If the SAFSTOR period is too long, expertise, in the form of personnel who have worked at the site for 20 or 30 years, will be lost. The experienced personnel know where the undocumented problem areas are located.

NSP had three levels of management at the site, which meant that one *always knew whom to call* when a problem developed. NSP Headquarters stayed in the background, providing funding and then trusting personnel at the site to get the job done. Site personnel resolved the details. NSP managed Pathfinder decommissioning with its own employees rather than hiring a contractor. The on-site crew remained lean throughout the project. When assets were not available, NSP hired outside labor for the duration of the need. This management philosophy resulted in considerable savings to NSP.

Decommissioning was treated as little more than a typical outage at one of NSP's operating nuclear plants. However, stringent requirements were adjusted to reflect the less stringent decommissioning environment. NSP viewed decommissioning as a high volume of low technology work in a relatively clean environment.

During the D&D phase, power was restored by running new lines. Battery-powered emergency lighting was also installed. It was clear what to remove and what to leave alone; all new systems were painted orange, which meant *do not touch*. There were no other active systems in the decommissioning areas. The sequence used during the decommissioning phase was to remove (1) asbestos, (2) hazardous material, (3) cables, (4) piping, (5) equipment, (6) concrete and rebar, and (7) structures.

The decision to switch from a nuclear facility to a fossil-fueled plant was primarily economic. The costs for modifications to bring the plant up to code with respect to new safety

requirements were prohibitive. In addition, in 1964, NRC specifications were constantly changing, and NSP saw that *many* regulations would be added to the nuclear industry in the future, which would lead to cost increases.

With the passage of the 1980 LLW Act and its 1985 Amendment, plant owners were looking at losing access to LLW burial and a significant increase in LLW burial costs (which would continue to escalate as time passed). In addition, by waiting, it was highly possible that the reactor vessel could no longer be packaged in a Type A container. If a Type B container had been required, costs would have risen significantly, and transportation of the package by railcar would not have been possible. Many analyses are the result of requirements and regulations for waste packages.

The only accidents during the SAFSTOR and decommissioning phases were normal industrial-type accidents. Training and protective equipment (e.g., safety glasses and steel-toed boots) were used to help alleviate these types of accidents.

Nothing that would deteriorate during the SAFSTOR period, as long as no water was present, was left. In case it was necessary to enter the SAFSTOR areas during the storage period, one active lighting circuit was left in place in each building.

During the SAFSTOR and decommissioning phases, the activities that had the most risk, albeit small, were those involved in preparing the vessel for shipping and the shipping itself. A mini-emergency plan was drafted to cover shipment of the reactor vessel, addressing what would happen if the contents of the vessel leached out. Hospitals and emergency personnel were contacted along the shipment route to ensure that the vessel contents were known and that preparations could be made for potential accidents.

The actual decommissioning costs of the Pathfinder Plant were \$13 million. The cost breakdown amounted to about one-third each for engineering and planning, waste disposal, and labor. Pathfinder Plant personnel emphasized how important it is to know what the disposal costs will be. Without knowledge of disposal costs, optimal decommissioning strategies cannot be chosen. The landfill costs charged by US Ecology were \$30/ft³ for burial plus a \$40/ft³ surcharge.

NSP believes that the lack of concern exhibited by regulators and the public to the Pathfinder Plant's SAFSTOR and decommissioning projects can be attributed to good communications between the plant and concerned regulators and the public and to advance publicity. NST also distributed Pathfinder Decommissioning baseball caps, which were well received by the public. State and local officials, as well as news media and the public, were kept informed (well in advance) about NSP's plans. This advance notice allowed questions to be raised and answered satisfactorily. Maps, pictures, descriptive data, question-and-answer sessions, local visits, and public meetings helped answer concerns and alleviate potential problems. It is vitally important to have the support of state and federal regulators and to treat the public as a significant contributor. (Also of importance is to never surprise the regulator.)

Advanced public relations and ongoing discussions with BN Asset Protection, state agencies, and law enforcement officials during the shipment of the vessel was invaluable. Early in the transit process, information became available about a Spokane television station's announcement on the approaching vessel that linked it to anti-nuclear protests (including historical footage of protestors lying on railroad tracks in front of a train). Several agencies pressured the station to pull the story and report it responsibly.

Although extensive on-site volume reduction was not practical, off-site volume reduction efforts paid big dividends. The main types of mixed wastes present at the plant were mercury and lead. In addition, there was 4000 ft³ of contaminated asbestos. However, after compaction, only 600 ft³ was left for burial.

NSP managed and conducted the SAFSTOR and decommissioning activities, only hiring contractors and laborers when expertise or resources were not available within the company. Subcontractors used by NSP included BN for shipping, US Ecology for the landfill, some specialty organizations, such as a specialty crane company for moving the reactor vessel to the railcar, and ESG for health physics.

Contaminated plant materials went to Allied Technology Group, based in Richland, WA. NSP paid Allied Technology to take the contaminated material, which was then decontaminated and sold or volume reduced and disposed of. Allied Technology had a base charge, based on weight. Noncontaminated materials were sold by the plant. NSP's goal was always to be economical.

NSP relied on the TRANSCOM system as its primary means of communication during the reactor vessel shipment. It provided accurate tracking and near-continuous two-way communications. Cellular phones were available for less than one-third of the trip. IMTS, a one-way phone link available on the business car, was not functional even though several attempts to use the system were made. TRANSCOM was used often, even when the cellular phone was available.

A.7 Rancho Seco

On June 6, 1989, the public voted to recommend that the Sacramento Municipal Utility District (SMUD) no longer operate the Rancho Seco Nuclear Generating Station as a nuclear power plant. However, the vote did not prohibit the sale to another qualified operator or operation. Plant operators shut down the plant on June 7, 1989. Reactor defueling was completed on December 8, 1989, and a total of 493 spent fuel assemblies are stored in the Spent-Fuel Pool in the Fuel Storage Building. During its lifetime, Rancho Seco operated for about 51,595 hours and generated about 44 billion kWh of electricity. At plant shutdown, the radioactivity inventory was estimated to be in excess of 9 million Ci.

Rancho Seco was a single nuclear generating unit designed and constructed by Bechtel; the pressurized water reactor was supplied by Babcock and Wilcox. The plant site is on 2480 acres

of rolling farmland terrain with a low population density. The unit had a thermal output of 2772 MW and a net electrical output of 913 MW. SMUD received a construction permit in October 1968; actual site preparation began in March 1969. Construction was completed in August 1974 after six years and a total cost of \$350 million. The plant began commercial operation in April 1975.

Today the plant is in a custodial SAFSTOR phase with off-loaded fuel stored in the plant spent-fuel pool. The plant has an NRC POL and is operated by about 150 staff. Current plans are to store the fuel in dry casks in an on-site IFSFI. Custodial SAFSTOR will continue until the fuel is located at the ISFSI in about 1998, at which time the plant will move to a hardened SAFSTOR mode. DECON is expected to take place after 2009, subject to the availability of sufficient funds. Site restoration is expected sometime after 2011.

The information in this section reflects the authors' understanding, and in some cases, interpretation of the discussions held on September 8, 1993, with four Rancho Seco management personnel. To try to ensure accuracy, the responses were reviewed by SMUD.

A.7.1 Rancho Seco Hazard Characterization

At the Rancho Seco site, existing and enhanced radiological surveys were used to establish the radiation hazards. Concrete and asphalt core bores were performed, and analysis showed that most of the activity is located in the top 1/4 inch. Cracks in the radwaste areas will require more decontamination effort.

The key decision to defer major decontamination during deactivation to SAFSTOR until years later, during DECON, reduced the worker dose. Because of natural decay processes, the final worker dose should be less, even though less knowledgeable workers will be involved in final decontamination activities. SMUD chose to rely on the negative pressure ventilation system to contain contamination rather than perform decontamination prior to entering SAFSTOR. The NRC questioned SMUD's decision and asked why SMUD did not chemically decontaminate plant systems. SMUD studies concluded there was no economic or safety benefit in an early decontamination.

A.7.2 Rancho Seco Management/Programmatic Issues

After the decision was made to shut down the plant, SMUD established system lay-up plans to allow for possible future startup. The initial effort was to allow for plant preservation, so wet chemical lay-up, similar to that used during outages, was employed. In addition, dry air was pumped through the secondary side of the plant.

When it was certain that the plant would never be restarted, planning took place to evaluate decommissioning options. Because of limited funds and the lack of suitable high-level waste (HLW) storage facilities, the decision was made to transition to custodial SAFSTOR, build the

independent fuel storage facility, transition to hardened SAFSTOR, and, finally, to transition to D&D. To satisfy the NRC, SMUD committed to running the containment exhaust fans.

SMUD used the "Temporary Alteration" process to achieve lay-up. It developed a SAFSTOR Modification process for resource recovery and still maintains a Plant Safety Review Committee and a Corporate Safety Review Committee. SMUD felt that it needed safety oversight to satisfy the NRC as well as SMUD customers.

Deactivation activities are being controlled via the same processes used when the plant was in operation. The same work control, temporary alteration, preventive maintenance, surveillance procedure, and processes are used. To ensure safety, both a Plant Safety Review Committee and a Corporate Safety Review Committee were used in accordance with the technical specifications. In addition, a Quality Control activity is still in place. Sign-offs for activities are reduced as a result of managers filling more than one role.

GET and RP training are still required and provided. Staffing levels were based on the estimated reduction in work load consistent with the reduction in technical specification requirements. Current staffing is about 150 (i.e., for custodial SAFSTOR). In 1998, when the plant achieves hardened SAFSTOR, employment will be down to about 30 people and about six of those will be security personnel.

Initially, low morale was a problem. Amazingly, SMUD never had to lay anyone off, even though site employment dropped from nearly 1000 in 1989 to about 150 today. SMUD was able to transfer people to other jobs within the utility or allow them time to find a suitable job elsewhere. Management provided financial incentives to certain key people to encourage them to stay to help with various deactivation phases. Other people were given one- or two-year contracts. Other incentives were the continuation of the operational nuclear pay bonus as well as a four-day work week.

The plant organizational structure consists of a Nuclear Plant Closure Manager with three direct reportees: an Operations and Maintenance Superintendent, an RP and Chemistry Superintendent, and a Quality/Licensing/Administrative Superintendent. These individuals manage all remaining operational activities.

One of the activities undertaken to achieve SAFSTOR was a study of heat generation in the spent-fuel pool. The study concluded that there was no safety requirement for the emergency diesel generators or for a backup cooling system. The study also concluded that the auxiliary building exhaust fan must be placed into service if spent-fuel cooling is lost. This study required about 1.5 man-years of work. Throughout the planning process, SMUD had to fight the "nuclear safety mentality" to identify new design-basis accidents or to upgrade the importance of various systems, such as spent-fuel cooling.

TLG performed cost/benefit studies for about eight different decommissioning scenarios for Rancho Seco. When putting the decommissioning plan together, the involvement of key personnel (operations, maintenance, and health physics) was essential.

A.7.3 Rancho Seco Requirements and Regulatory Issues

One of the major problem areas for a nuclear power plant facing decommissioning is the lack of guidance for SAFSTOR radiological limits. Each facility seems to be defining its own SAFSTOR consistent with its situation with NRC concurrence. Since there is no radiological guidance, SMUD chose to basically leave the plant as it was during operations for SAFSTOR.

A.7.4 Rancho Seco Transitioning Facility Risk Issues

The only safety related equipment kept operational at the plant is that associated with operation of the spent-fuel pool. The fire protection plan was rewritten. However, there were no fires identified that created a safety concern.

There were no significant risks to surveillance and maintenance personnel from placing the facilities into SAFSTOR. Hot spots will continue to be a radiological concern that will reduce with time. There is some potential for equipment degradation and leaks because of reduced preventive maintenance. SMUD knows that certain roofs leak, but no effort is being undertaken to improve the situation. There are some problems with pigeons. As part of the SAFSTOR decision, SMUD chose to maintain containment ventilation to prevent the buildup of molds and fungi and avoid future health risks that might increase if things were welded shut.

SMUD had some advice regarding accident analyses. Don't spend time trying to "create or invent" new hazards or scenarios. Remember that the plant was licensed to operate and that bounding accident analyses were performed to obtain that operating license. Long-term operation of the spent-fuel pool was considered in the operating license. The current safety basis is (1) loss of spent-fuel pool inventory, (2) dropped assembly, and (3) station blackout or loss of off-site power.

A.7.5 Rancho Seco Cost Increases and Uncertainty

Uncertainties in LLW costs are the major factor in the overall decommissioning of Rancho Seco. Original estimates were \$1.00/ft³. Current estimates are upwards of \$440/ft³ at Ward Valley, assuming a 1996 opening. Based on an estimated 7300 yd³ of LLW, SMUD estimates about \$100 million for LLW disposal costs, but costs could go higher. If funding and the DOE high-level storage facility were available, SMUD would prefer to decontaminate immediately, since this provides the lowest cost option.

To further address the uncertainties associated with LLW storage, SMUD constructed a \$5 million LLW storage building in case Ward Valley does not open or is delayed. The present capacity of the building is 50,000 ft³, which should be sufficient for five years.

To reduce SAFSTOR costs, SMUD is planning on building an on-site ISFSI to store the reactor fuel in dry casks that would be transportable in the future to a permanent DOE high-level storage facility. SMUD wants the dry storage casks to be certified to 10 CFR 71 for transport and final storage. SMUD estimates that it will cost \$16 million to build the ISFSI. The ISFSI operating costs will be about \$2.6 million/yr as compared with \$10.6 million/yr to keep the spent-fuel pool operating. The major cost savings will be from a reduction in operating and maintenance personnel.

SMUD used TLG Engineering to provide cost estimates for the entire decommissioning effort, including custodial and hardened SAFSTOR. For custodial SAFSTOR, TLG estimated \$10.6 million/yr in 1991 dollars. For hardened SAFSTOR, TLG estimated \$2.5 million/yr in 1991 dollars.

Because of the premature shutdown of the plant and the lack of funds set aside for decommissioning, a delay in final decommissioning was necessary. In addition, the lack of a final repository for the spent fuel necessitated a deferred decommissioning effort. SMUD chose not to do extensive decommissioning activities during deactivation to SAFSTOR to avoid what they considered to be unnecessary radiation exposure. Deferring decontamination activities until the actual decontamination phase will reduce exposure overall.

Initially, SMUD considered selling the plant to a third party to operate but was unsuccessful in finding a buyer and proceeded with decommissioning efforts. SMUD hired S. Levy and TLG Engineering to perform decommissioning alternative studies. Numerous approaches were considered, including various combinations of SAFSTOR, DECON, and ENTOMB. Funding for final decommissioning is by a set-aside external trust paid for by the ratepayers over the planned life of the plant. When the plant was prematurely shutdown, there was only \$61 million in trust, and \$121 million was needed. Currently, \$12 million/year is being added to the trust. In addition, \$13-14 million is being added to cover anticipated LLW costs.

The major economic consideration that influenced SMUD's decommissioning decision was the lack of set-aside decommissioning funds to fund the effort properly and potential rate shock if an aggressive decommissioning were undertaken.

When developing its SAFSTOR plans, SMUD considered waste volume reduction and the benefit of waiting until natural radioactive decay allows possible release of waste to help reduce the final D&D costs.

A.7.6 Rancho Seco Stakeholder Concerns

SMUD held public meetings to discuss its decommissioning plans, but there was little public concern or interest. This was in contrast to the interest by the public and anti-nuclear proponents in shutting down the plant. SMUD also used newspaper advertisements to try to identify any public concerns.

The stakeholder that has the greatest impact is the Environmental and Resource Conservation Organization, and their concerns are apparently still not resolved. These concerns have arisen because, adjacent to the plant, SMUD has a lake and public park. In addition, SMUD is in the process of building a public golf course adjacent to the park and lake.

A.7.7 Rancho Seco Waste Minimization and Avoidance of Mixed-Waste Generation

SMUD has used some volume reduction activities. In addition, it has had limited luck with its Asset Recovery Program. Before implementing an asset recovery program, SMUD studied similar efforts at other sites and determined that many times, more money was spent trying to dispose of materials than was gained through sales or through reductions in disposal costs. Hence, they approached the Asset Recovery Program on a low-key basis. They sold some equipment and bulk acid to sister utilities. In addition, they went out for bid on salvage; bidders included General Physics, Pacific Nuclear, Joe Boyle (an auctioneer), and American Export Co., which sells salvage material overseas.

In addition, SMUD hired a company that specializes in decontaminating equipment. Several companies will accept decontaminated materials and decontaminate and reuse them. These companies included Quadrex, ALARON, Scientific Ecology Group - Westinghouse at Oak Ridge (SEG), and Allied Technical Group in Richland, WA. SEG can incinerate wastes as well as smelt low-level (LL) contaminated metals.

The site survey performed at the Rancho Seco plant initially identified some 20 nonlisted EPA chemicals that were potential mixed-waste concerns. Eventually, only two materials appeared to be of concern. Some mercury that was used in manometers and was slightly contaminated was identified. However, the major concern was cartridge filters used in a freon tool decontaminating unit. SMUD has accumulated two 55-gallon drums of filters (20 mRem/h) that must be disposed of as mixed waste. EPA regulations require that once a listed 002 freon solvent has contacted a filter, the filter is always considered to be contaminated. Currently, SMUD has exceeded the EPA 90-day storage limit for these filters. SMUD feels there needs to be some flexibility in the interpretation of EPA regulations.

There are no approved sites to permanently dispose of LLW or HLW that SMUD can use without paying exorbitant surcharges.

A.7.8 Rancho Seco Industry Involvement

Contractors used by SMUD to support deactivation activities included TLG Engineering, S. Levy, and Bechtel. TLG Engineering provided all the cost estimates, and there was no independent validation. SMUD felt that TLG had the best reputation in the D&D area. According to SMUD, TLG has done cost estimating for approximately 95% of the industry and is good at it. By using TLG to estimate costs, SMUD felt that they achieved credibility with their board of directors and the NRC.

SMUD has shared their experiences with other utilities and DOE through NUMARC, papers, and on-site visits. Short courses that SMUD found useful were those provided by the Institute of Nuclear Materials Management.

A.7.9 Rancho Seco Recycle and Reuse Opportunities

A number of alternatives were considered for use of the site. SMUD considered repowering the plant as a fossil plant, but this was eventually deemed unfeasible. They also attempted to sell the plant to a third party, but had no offers. The only recycling option SMUD considered was recycling stainless steel for spent-fuel canisters.

A.7.10 Rancho Seco Technology Development or Enhancement Needs

SMUD did very little "decommissioning" work to deactivate the plant to custodial SAFSTOR.

A.7.11 Rancho Seco Lessons Learned

Final decommissioning costs are dominated by the projected costs of LLW disposal. The escalation in LLW disposal costs as well as the uncertainty in future costs make it extremely difficult to plan and schedule. Federal and state leadership is needed to solve this problem. Fortunately, DOE facilities are not impacted by this.

Existing decommissioning techniques and methods appear to be sufficient to meet the needs of the commercial nuclear power industry. However, the projected high LLW waste disposal costs may provide economic incentives to develop other disposal options, investigate new decontamination processes that reduce waste, encourage recycling, incinerate, or reuse equipment where possible. Cooperation from various governmental regulatory bodies will be needed to be successful.

The lack of a defined radiological endpoint for SAFSTOR and particularly for final site restoration presents major uncertainties for planning and cost estimating. The EPA, NRC, and DOE are working to define radiological endpoints for site remediation activities.

An asset recovery program can be worthwhile if pursued on a low-key level. Care must be taken to avoid spending more money trying to sell assets than will be received from the actual sale or through elimination of disposal costs.

Focusing efforts on attempts to identify new hazards or create new accident scenarios for facilities in SAFSTOR is not recommended. Recall that the plant spent-fuel pool was considered in the original plant operating license and design/operating basis.

Providing various incentives retains key staff during deactivation to SAFSTOR. Such things as implementing a four-day work week, operating bonuses, contract incentives, job guarantees, etc., should be considered.

The existing facility operating/maintenance infrastructure can be utilized, with some streamlining, to manage deactivation and decontamination activities. Personnel are accustomed to the existing facility work control processes, or procedures, safety review processes, "plan-of-the-day" meetings, etc. Changing the existing work processes, even though it seems cumbersome, may create more operational problems than the change attempts to solve. For instance, preventive maintenance procedures should not be rewritten.

Planning for facility decommissioning should begin when the facility is still in operation. To improve the decommissioning planning process, "up front" identification of where the facility will go is needed, as well as a focus on the plan, while avoiding distraction.

SMUD would like to see the NRC/EPA/DOE develop a protocol to achieve flexibility in dealing with various complex waste issues.

If a decision is made to place a facility in SAFSTOR, consider keeping ventilation systems on and not welding or "bottling up" systems. This will help avoid buildup of bacteria, molds, etc., which may attack metal or form sludges and present health hazards in the future.

The establishment of, and participation in, a decommissioning support group, where similar facilities undergoing decommissioning can share experiences, lessons learned, etc., is recommended.

In establishing radiological clean-up levels for a facility or site, the Aerial Gamma Surveys performed by DOE before the plant was built should be used to identify or establish the basis for pre-existing radiation levels.

Although the operational phase of Rancho Seco was the subject of considerable public debate, there does not appear to be much stakeholder interest in decommissioning of the plant. SMUD appears to be continuing its community relations programs through development and maintenance of a public park, lake, and golf course adjacent to the reactor facility.

A.8 Shippingport

The Shippingport Atomic Power Station is located on the south bank of the Ohio River at Shippingport, PA, approximately 25 miles northwest of Pittsburgh. It was built on approximately seven acres of land leased from Duquesne Light Company (DLC) by the AEC.

The station was constructed during the mid-1950s as a joint project of the federal government and DLC. The project had several purposes; one was to develop and demonstrate PWR technology and the other was to generate electricity. The reactor and steam-generating portions of the station are owned by DOE; the electrical generating portion is owned by DLC.

The station achieved criticality in December 1957 and was operated by DLC under supervision of DOE-Naval Reactors (NR) until operations were terminated on October 1, 1982. End-of-life

testing as well as reactor defueling were conducted in the following two years. The reactor utilized three cores of reactor fuel; the first two were PWR cores, and the third was a light water breeder reactor (LWBR) core. The LWBR core was installed in 1977 to demonstrate the thermal breeding principle in a light water reactor. Responsibility for the station was transferred from NR to Richland, WA, within DOE, on September 6, 1984. In addition, General Electric (GE) replaced DLC as the Operations Contractor. A summary of operational data can be found in Table A.1. Table A.2 displays a chronological sequence of operations at Shippingport.

Table A.1 Summary of Operational Data for Shippingport

Core	Total Operation Effective Full Power Hour	Total Gross Generation (kWh)
Core 1 (PWR)	27,780.9	1,793,581,700
Core 2 (PWR)	23,812.0	3,476,592,300
Core 3 (LWBR)	28,730.4	2,103,833,029
Total	80,323.3	7,374,007,029

Table A.2 Operations Chronology for Shippingport

Pressurized Water Reactor Project Authorized	July 1953
Ground Broken	September 6, 1954
Construction Started	March 1955
Initial Core 1 Criticality	December 2, 1957
Core 1 Operations Complete	February 9, 1964
Initial Core 2 Criticality	April 9, 1965
Core 2 Operations Complete	February 4, 1974
Initial Light Water Breeder Reactor Criticality	August 26, 1977
Light Water Breeder Reactor Operations Complete	October 1, 1982
Defueling and End-of-Life Testing	September 6, 1984
Turnover for Decommissioning	September 6, 1974

A.8.1 Shippingport Hazard Characterization

Initially, the site dose assessment was accomplished by plant radiological control personnel by scheduling the radiological surveys around other radiological work. A surface survey began in June 1985. Two isotopes, cobalt-60 and cesium-137, were found but not iodine-125 as

expected. Next, on-site concrete surfaces were surveyed. Cobalt-60 made up more than 99% of the measured activity. Finally, subsurface soil sampling was done in September 1986. Fifty 10-cm holes were drilled to depths ranging from 0.5 to 4 meters. Sb-125 was detected in these samples.^{A-21}

The Decommissioning Plan estimated that a 1000 man-Rem total radiation exposure for the work force would occur during the project. The actual total personnel exposure accumulated was 155 man-Rem. Although the original estimate was conservative, dramatic reductions in exposures were because of good planning and ALARA practices.

Work on asbestos was performed at airborne concentration levels well below (i.e., one-tenth) the industry standards. At a later date, OSHA adopted standards comparable to those used at the plant. There were no cases of personnel overexposure at the stricter standards.

A.8.2 Shippingport Management/Programmatic Issues

Because of the research and demonstration nature of Shippingport, DOE used an elaborate management structure to decommission the plant. DOE used more than eight contractors to conduct the physical activities and three other contractors to oversee those activities. According to DOE's Program Manager, DOE recognized that utilities may not be able to institute the same type of management structure to decommission commercial plants. At least 30% of DOE's costs related to physical decommissioning activities; the remaining 70% included engineering, oversight, management, and other activities such as waste disposal. Utilities, faced with setting aside funds to decommission their plants and subject to scrutiny by public service commissions when doing so, are not likely to incur as high a level of oversight and management costs relative to physical decommissioning costs as occurred with Shippingport.

The mission for the Shippingport Decommissioning Project was to decommission only the government-owned portions of the plant, thereby:

- Demonstrating that a large nuclear reactor plant could be decommissioned and decontaminated (D&D) in a safe and cost effective manner and
- Developing D&D data from this experience that could form the basis of a technology transfer program to use in future D&D projects and to help develop industry standards and standardized approaches.

As described in A-19, the D&D work at Shippingport could be characterized with the following features:

The reactor vessel, internals, and the neutron shield tank were removed from the plant as one package and shipped for burial by barge. Shielding was provided by installing concrete in the neutron shield tank.

The steam generator heat exchangers, the pressurizer, and other major contaminated plant components were shipped as their own containers.

The primary systems were not given a general decontamination prior to dismantling since a pre-D&D study showed this was not cost effective.

Table A.3 summarizes the chronology of the decommissioning project.^{A-18}

Table A.3 Chronology of Shippingport Station Decommissioning Plan	
Phase I - Engineering and Planning	1979 - 1983
Phase II - Decommissioning	1983 - 1989
Award DOC Contract	March 84
Headquarters Approval to Start	June 84
Site Turnover	September 84
Start Decommissioning Operation	January 85
Initiate Physical Decommissioning	September 85
Irradiated Components Loaded into RPV	March 86
Complete Removal of Asbestos	July 86
A/C and B/C Chamber:	
• Removed Primary Components	March 87
• Removed Pipe and Equipment	March 88
• Removed Steel Chambers	March 89
First Backfill	March 88
Lift and Load RPV/NST	December 88
Ship RPV/NST	February 89
Complete Physical Decommissioning	July 89
Stop Decommissioning Operations	September 89
Headquarters Approval to Release Site	November 89
Complete Archive Records	December 89

Liquid wastes were processed by filtration and dilution. The existing filters were used to process liquid wastes. Final waste quantities were processed by a small temporary filtration system. Radioactive wastes were buried at Hanford.

Tank bottoms and sludge were solidified with a cement/silicate process in steel drums. Spent resins were placed in shielded high-integrity containers and dewatered.

Underground structures, after decontamination to unrestricted release levels, were removed to three feet below grade. Underground spaces were filled with granular fill. The top six inches was covered with topsoil. The ground surface was contoured for drainage, and erosion control vegetation was planted.

A.8.3 Shippingport Requirements and Regulatory Issues

Most often cited in the Shippingport literature regarding requirements and regulatory issues was a lack of a complete set of reasonable and acceptable criteria that covered the release of materials. Realistic standards for shipping D&D waste, especially oversize packages with large curie contents, were needed.^{A-18} In October 1984, DOE specified that Regulatory Guide 1.86 would be used for defining allowable surface contamination limits.

At that time, the D&D contractor was also asked to estimate the cost trades for reducing future doses from the site to no more than 100, 25, and 10 mRem/year to the public. One of the interesting goals of this site release criteria effort was to develop what was, at once, a criterion that would result in low cost of remediation and a low dose to the public. The studies for Shippingport indicated that doses to the public could be limited to 10 mrem/year.^{A-21} The release criterion was finally established for the site based on a dose of 100 mRem/year to maximum exposed individuals plus ALARA (to 10 mRem/year).

The establishment of release criteria was not a "cut and dried" procedure based solely on regulations. Maximum limits and ALARA obviously should be applied. However, the establishment of a release criterion could be the most sensitive parameter in the cost-benefit equation of any D&D site. No other future D&D operation is likely to spend 6% of its total funds on LLW disposal.^{A-22}

A.8.4 Shippingport Transitioning Facility Risk Issues

No discussion was available of the risk-based methodologies in the deactivation plan.

A.8.5 Shippingport Cost Increases and Uncertainty

In the Shippingport literature, the most often discussed cost element that affects the overall D&D cost is the cost of LLW storage. The 216,000 ft³ of LLW from Shippingport was buried at Hanford at a cost of approximately \$5/ft³ (in 1986).^{A-22} Current estimates for commercial (i.e., non-DOE) disposal range up to \$400/ft³. At the going rate, this amount of waste disposal

could, in today's dollars, add \$86M to the cost to of D&D operations. The cost to the Shippingport D&D project was \$2.25M. Obviously, the quantity of LLW present at a site is a major cost driver for any D&D operation. Since it is difficult to predict future costs, accurate planning for needed levels of D&D funding is very inexact and subject to gross miscalculations.

D&D costs for this operation were reported in 1989 by the GAO as \$91.3M, which was \$7M under its 1986 projected costs of \$98M.^{A-21} Over 18 separate contractors and subcontractors were used on the project, enabling DOE to accomplish its goal of transferring as much Shippingport D&D data to industry as possible.^{A-18} A cost breakdown by phase and category is included in Table A.4. This cost breakdown shows that the cost estimates were in good agreement with eventual expenditures.

A.8.6 Shippingport Stakeholder Concerns

There was no discussion of how stakeholder concerns were addressed in the literature.

A.8.7 Shippingport Waste Minimization and Avoidance of Mixed-Waste Generation

The discussion of waste in the SHIP-5 reference centers on how waste is likely to be a much larger problem for any future D&D operations than it was for Shippingport. This is because of the lower LLW storage costs in the past and the fact that Shippingport was "cleaner" than other similar facilities.^{A-21} It was also noted^{A-22} that waste disposal operations are highly sensitive to changes in regulation and are the area of D&D most likely to be affected by public opinion. All in all, in any D&D operation, there is a strong intrinsic motivation to minimize LLW.

A.8.8 Shippingport Industry Involvement

In November 1983, DOE selected GE, with its integrated subcontractor, MK-Ferguson Company, to be the DOC. The decommissioning operations contractor (DOC) was responsible for site operations and management support, directing decommissioning activities, and obtaining and managing the decommissioning subcontractors. DOE then established a Shippingport Station Decommissioning Project Office (SSDPO) responsible for project execution and on-site administration. Effective June 29, 1987, UNC was consolidated into Westinghouse Hanford Company (WHC). WHC was the technical support contractor (TSC) and provided technical, cost, and schedule support to DOE project management at the site.

An overview of functional relationships for the SSDP is shown in Figure A.1.

Table A.4 Shippingport Project Cost Summary (\$ in thousands)		
	PLAN	ACTUAL
Phase I Engineering		
A/E - BRISC	4,669	4,669
TSC - UNC	1,397	1,397
Phase I Total	6,066	6,066
Phase II Decommissioning Operations		
TSC - WHC/UNC	8,330	5,560
Duquesne Light Company (DLC)	1,000	1,000
DOC - GE/MK-F		
Management	6,348	5,975
Operations/Support	25,535	27,895
Decommissioning	35,016	36,373
Fee	5,225	6,153
Other	0	2,925
Contingency	10,780	6,353*
Phase II Total	92,234	92,234
Project Totals	98,300	98,300

* Indicates Total Project Underrun

A/E - Architect/Engineer

TSC - Technical Support Contractor

DOC - Decommissioning Operations Contractor

Figure A.1 Shippingport Station Decommissioning Project Functional Relationships
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A.8.9 Shippingport Recycle and Reuse Opportunities

There were no recycle and reuse opportunities noted in the literature.

A.8.10 Shippingport Technology Development or Enhancement Needs

One objective of the Shippingport project was to demonstrate that a nuclear power plant could be safely and economically decommissioned using existing technology, such as manually dismantling radioactive piping systems and components. Thus, DOE did not design the project to increase the basic research and development knowledge on methods or equipment needed to decommission a large plant. According to DOE officials, they relied on technology the nuclear industry used for the last 30 years to construct, maintain, or demolish plant systems and components. As a result, DOE did not need, nor was it required, to develop new technology, such as robotics, to decommission Shippingport.^{A-20}

A.8.11 Shippingport Lessons Learned

Many of the lessons learned stated in this section follow directly from A-20.

DOE recognizes that the nuclear industry could benefit from information in such areas as: (1) decontamination methods, (2) waste reduction and minimization techniques, (3) methods to determine the specific radioactive materials and levels of contamination in waste, and (4) robotics for facility and plant equipment disassembly. DOE recognizes that the development of robotics and/or remote systems may be the only means to conduct decommissioning activities safely in highly radioactively contaminated facilities and minimize worker exposures.^{A-20}

DOE's activities at Shippingport increased the base of knowledge for decommissioning commercial nuclear power plants. However, because of significant differences between Shippingport and other reactors and the manner in which Shippingport was decommissioned, it is questionable whether the lessons learned can be extensively applied to larger, more contaminated nuclear power plants that will be decommissioned in the future. For example, Shippingport was different from commercial plants because (1) the plant was radiologically cleaner than other plants at the time of its shutdown, (2) DOE disposed of the pressure vessel in one piece instead of cutting it up or letting the radiation decay over many years before starting decommissioning, (3) DOE had predetermined sites to dispose of the spent fuel, and LLW^{A-20} and mixed waste, and (4) DOE had an elaborate management structure to conduct and oversee the decommissioning activities.^{A-20}

Over the plant's lifetime, some decontamination activities had been conducted; therefore, Shippingport -including the reactor pressure vessel^{A-21} - was radiologically cleaner than might be expected for a commercial plant. DOE estimates that at the time of shutdown, the reactor pressure vessel contained about 30,000 curies of radioactive material.^{A-20}

DOE removed the pressure vessel from Shippingport in one piece. The pressure vessel is the most highly contaminated part of the nuclear power plant. Although removing the vessel in one piece minimized worker exposure to radiation and reduced costs by about \$7 million, DOE's approach did not provide the nuclear industry with information on the problems that may be encountered if utilities must cut up this component. According to utility executives from FSV, Peach Bottom, and Rancho Seco, the size of the pressure vessel and the radioactive contamination it contains will preclude shipping and disposing of this component in one piece. Only the utility that owns Pathfinder, whose reactor pressure vessel (32 ft by 12 ft) was about the same size as Shippingport's reactor pressure vessel (25 ft by 10 ft), disposed of the vessel in one piece at a commercial site operated by U.S. Ecology in Richland, WA.^{A-20}

A well-established conduct of operations and incident reporting system is needed for the entire D&D process to maintain a safe working environment and to reduce costs.^{A-23} Detailed planning was determined to be the key to minimizing abnormal occurrences in the D&D process.

A.9 Shoreham

On May 15, 1968, the Long Island Lighting Company (LILCO), an investor-owned electric and gas utility serving a little over a million customers, formally applied to the AEC for a construction permit to build the first nuclear power station on Long Island. The plant, to be built in Suffolk County near the village of Shoreham, was expected to cost between \$65 million and \$75 million, and to be on-line by 1973.^{A-26}

LILCO had initially filed its licensing application documents with the AEC for a 540-MW GE BWR design with a MARK II containment. A cost analysis indicated that a 540-MW nuclear plant would be no more economical than a fossil-fuel plant at the same rating. Then, in the hot summer of 1968, electricity demand surged, and a study based on load-growth projections called for a plant with more capacity than 540-MW to be added by the mid-1970s. The study also indicated that a larger nuclear plant would be more economical than a comparable fossil-fuel plant at the same rating because it could take advantage of economies of scale. LILCO's architect-engineer advised LILCO that the bigger 820-MW reactor would fit within the reactor building already designed for the 540-MW reactor. Because of this change, LILCO had to refile much of the application to the AEC to reflect the design change.

The loss of the months required to rewrite and file the construction license application to reflect the bigger reactor ultimately caused significant delays in issuance of the construction permit. There were, of course, design changes necessary to upgrade the reactor from 540-MW to 820-MW, but in addition, the utility now faced strong public opposition to the reactor. The hearings before the AEC lasted three years, the longest construction permit hearings ever held for a nuclear power plant. In July 1971, the U.S. Court of Appeals ruled that the AEC was not complying with the 1969 NEPA, a decision that applied to any plant that had not yet received a permit. This decision meant LILCO had to file a much more comprehensive environmental

impact statement than before and enter into yet another set of hearings on NEPA. Because of these delays, the Shoreham construction permit was not issued until April 1973.^{A-26}

With the issuance of the construction permit, LILCO felt that the worst was behind them, a feeling soon reinforced by energy shortages in late 1973 that escalated into the energy crisis. Nuclear energy suddenly became favored as the means to energy independence in the United States.

However, as it turned out, LILCO's problems were only beginning. The AEC adopted American Society of Mechanical Engineers' (ASME) new piping codes, known as ASME III, just prior to LILCO's engineering shutdown in 1971, but LILCO did not implement them until 1973. As a result, LILCO suffered delays in construction while awaiting the new piping. More importantly, ASME III and other AEC regulations issued shortly after the project started up again in late 1972 directed nuclear reactor designers to guard against pipe breaks outside the containment building. Compliance with the new regulations meant that the already marginally sized reactor containment building at Shoreham became even more crowded with piping and restraints. Even worse, LILCO incorporated the corrective measures before submitting them for approval by the AEC in 1974. In 1976, the NRC rejected LILCO's proposed solution. Therefore, in 1977, LILCO had to make further modifications to satisfy the NRC after the plant was already four years into construction.^{A-26}

In 1973, GE's Mark III containment structure failed to pass verification testing for withstanding extreme hydrodynamic loads that might be experienced during an accident. This meant that the GE Mark II containment structure used at Shoreham was not designed to withstand the hydrodynamic loads during an accident and had to be retrofitted to satisfy the AEC. The hydraulic load problem was not remedied until 1982.

In March 1979, when Shoreham was approximately three-quarters completed, the Three Mile Island (TMI) accident occurred. In the aftermath of TMI, the NRC was determined to prevent the reoccurrence of another accident like TMI and imposed more than 130 new regulatory requirements on the commercial nuclear power industry. This further impacted and delayed the completion of the Shoreham plant.

At approximately the same time as TMI, the Suffolk County and New York State governments withdrew their support for the plant. In 1981 investigations began into the management of the Shoreham Plant project and, in 1985, \$1.4 billion of Shoreham's \$4.6 billion was disallowed from the rate base.

In February 1983, one of the backup generators at Shoreham broke in two during testing and the incident made national headlines. Also in February 1983, the Suffolk County legislature voted to withdraw its emergency evacuation plan for Shoreham, and New York Governor Mario Cuomo refused to intervene on LILCO's behalf. The county and state governments gave safety and emergency planning concerns as reasons for the withdrawal of support. Without an

NRC approved emergency plan, issuance of a full-power license to LILCO for the operation of Shoreham became doubtful.

In mid-1985, the NRC granted LILCO a license to test its operation at 5% of full power. Shoreham was tested briefly at low power. Due to this brief operating history, the extent of radioactive contamination at Shoreham is very limited. Aside from the nuclear fuel, which is stored in the spent-fuel pool. It is estimated that the total radioactive inventory at Shoreham is about 602 curies, almost all of which is located in the reactor pressure vessel and its internals. The radioactive inventory of the remaining structures and systems is about 3 millicuries.^{A-24}

After receiving a full power operating license on April 21, 1989, the Shoreham Nuclear Power Station shut down in June 1989 pursuant to an agreement between the State of New York and LILCO. The agreement provided that LILCO would cease operations at Shoreham and sell the facility to the Long Island Power Authority (LIPA), a New York state agency, for decommissioning. Soon thereafter, LILCO removed all fuel from the reactor, stored the fuel in the spent-fuel pool as permitted under its full-power license, and, under regular procedures, began to seek a series of license amendments and exemptions to allow it to reduce staffing and other requirements applicable to operation. In February 1992 the LIPA team was formally organized to decommission Shoreham. The license was transferred the same month to LIPA, which received the decommissioning order from the NRC in June 1992.^{A-25}

DECON was the decommissioning alternative chosen for Shoreham. The DECON alternative involves the immediate dismantling and removal of contaminated equipment, structures, and portions of the facility containing radioactive contaminants. The DECON alternative was selected over the SAFSTOR and ENTOMB alternatives because Shoreham had developed relatively low radiation levels over its brief operating history.^{A-25} LIPA has estimated the cost of decommissioning Shoreham as \$186 million in 1991 dollars.^{A-24}

A.9.1 Shoreham Hazard Characterization

The principal buildings and structures at the Shoreham site include the reactor building, which contains virtually all of the contaminated systems and structures to be decontaminated and/or removed during decommissioning, including the reactor pressure vessel (RPV), piping systems, floor drains, and sumps; the turbine building contains only one structure, a drain sump, that is known to be contaminated; and the radwaste building contains some slightly contaminated structures and systems, such as floor drain sumps and radwaste tanks. The processing of waste generated during decommissioning will be handled by portable radwaste equipment to minimize further contamination of these structures and systems and to avoid contamination of systems that are presently clean. The control building will be needed to operate various systems and equipment in support of plant decommissioning (it houses three emergency diesel-generator units, station air conditioning equipment, and electrical relay and switchgear equipment). The security building will be used throughout decommissioning to provide access control for personnel and vehicles in support of decommissioning activities.

The Shoreham Plant was tested by LILCO only briefly at low power (under 5%). Because of this limited operating history, the extent of radioactive contamination is quite limited. Aside from the nuclear fuel stored in the spent-fuel pool, LIPA estimates that the total radioactive inventory at Shoreham is about 602 curies, almost all of which is located in the RPV and its internals. Outside the RPV, the radioactive inventory of the remaining structures and systems is about 3 millicuries. This relatively small and localized amount of radioactive material should facilitate expeditious and safe decommissioning of the plant.

LILCO is cooperating with LIPA to facilitate the prompt and orderly transfer of Shoreham Plant ownership from LILCO to LIPA. LILCO, working closely with members of LIPA's project team, was responsible for planning and implementing a program to radiologically characterize the Shoreham plant. By June 1990, LILCO's comprehensive site characterization study, which included a comprehensive walkdown of the plant, was largely complete. The data acquired by LILCO through this undertaking have been used extensively by LIPA in the development of the Decommissioning Plan. LILCO remains cooperative and supportive in acquiring additional radiological data as needs have been identified.

A final radiation survey will be conducted on all suspected and known contaminated structures, systems, components, equipment, grounds, and adjacent environments upon completion of the decontamination and dismantlement activities. The final survey will demonstrate that any residual contamination is within the criteria for unrestricted release. The final plan is based largely on the statistical and sampling methodology developed in NUREG/CR-2082. This methodology will provide a basis for determining that a decommissioned site meets the criteria for unrestricted release.

The survey will involve a full evaluation of the site, and a sampling program and the controls will be developed for use over virtually all aspects of the survey to assure valid results. The site will be divided into survey blocks and characterized. Specific media to be sampled will be determined, and the methods of sampling will be evaluated. Instrumentation appropriate to detecting gamma or beta/gamma radiation in and on various media will be used. Limitations of processes and instruments will be evaluated. Laboratory analysis will incorporate statistical methods in evaluations, and all data will be taken, collected, processed, analyzed, stored, retrieved and interpreted consistent with LIPA's QA program.

LLW expected to be generated during decommissioning of the Shoreham Plant will include the following: RPV and internals, spent-fuel racks and appurtenances, system piping and equipment, sludge, liquid process waste, and dry active waste. Items not included as decommissioning waste are the spent fuel and fuel support casings, traveling in-core probes, in-core instrumentation, control rod blades and drives, and any radioactive fluids, resins, filter media, and sludge currently contained within systems. Spent-fuel disposition is not considered to be a part of decommissioning.

Radiation exposures were estimated using a combination of measured and calculated exposure rates and prospective stay times. By far the largest contributor to occupational radiation

exposure will be from the tasks associated with the removal of the activated portions of the RPV and its internals. The remaining occupational exposure will be because of surveys, and decontamination and dismantling of other Shoreham Plant systems and structures. Measured exposure rates for these systems and structures were used along with prospective man-hours to compute person-Rem for system and structure decommissioning. A conservative factor was applied to account for the transport and concentration of radioactivity within these systems and structures during decommissioning.

The total exposure is approximately 190 person-Rem. The RPV removal accounts for 158 person-Rem, which is 83% of the total. By comparison, the average annual exposure at operating BWRs is about 440 person-Rem. Given these relatively small exposures, craft and skilled labor availability should not be affected by 10 CFR Part 20 exposure limits.

A.9.2 Shoreham Management/Programmatic Issues

There were three decommissioning alternatives considered for the Shoreham Plant, DECON, SAFSTOR, and ENTOMB. The limited operating history of the Shoreham Plant and the resulting low levels of contamination and activation support the use of DECON. According to the NRC,

DECON is the alternative in which the equipment, structures, and portions of the 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.

Given the limited amount and extent of contamination and activation, DECON will be much easier and more cost-effective to implement at Shoreham than at other plants with more substantial operating histories.

By use of DECON, the existing radiation hazards at the Shoreham Plant can be eliminated in the near term, releasing the site for alternative uses in the relatively near future. This will maximize flexibility in selecting future uses for the site. [LIPA has retained consultants to analyze the possible conversion of Shoreham to a natural-gas fired electric generating facility or other non-nuclear use.] Furthermore, the selection of the DECON alternative will enable LIPA to use existing LILCO personnel, who are familiar with the Shoreham Plant and its brief period of operation to perform many of the decommissioning activities. LIPA will develop a QA plan to assure that decommissioning and other related specified activities described in the Decommissioning Plan are accomplished in accordance with the license, applicable codes and standards, and regulatory requirements, and in a manner that will protect the health and safety of the general public and personnel working at the Shoreham Plant. All structures, systems, and components considered "safety related" for the safekeeping and storage of nuclear fuel in the spent-fuel storage pool will be governed by a QA program. While LIPA will retain ultimate responsibility for the QA program, contractors and suppliers providing services or equipment for decommissioning or related activities will be required to implement a QA program approved by LIPA or to conduct work according to LIPA's QA program.

It is expected that the tasks and activities described in the Decommissioning Plan will be further developed as additional detailed engineering and planning are performed. Both conceptual and detailed engineering and planning have and will incorporate such considerations as regulatory guidance, maintenance of occupational radiation exposure ALARA, occupational radiation exposure, management of LLW, industrial safety, environmental impacts, costs, and schedule. Another aspect considered is the use of fieldproven and state-of-the-art decontamination and dismantlement techniques.

LILCO's decontamination program will use "soft" decontamination techniques (i.e., techniques that will not irreversibly damage plant systems and components) such as chemical decontamination and high-pressure water hydrolances for mechanical decontaminants that can be carried out under an operating license or POL. The program is designed to achieve levels of contamination that are near or below the release criteria.

After NRC approval of the LIPA Decommissioning Plan, those systems or structures that do not meet the release criteria after "soft" decontamination is completed will be dismantled/removed or decontaminated using more aggressive techniques. Pipe and metal dismantlement/removal will be performed using either portable bandsaws, diamond wire saws, abrasive wheel cutting, plasma-arc and/or oxy-fuel cutting techniques. Scabblers, ultra-high-pressure water and vacuum grit-blasters, are being evaluated for possible use to remove contamination from concrete. Aggressive decontamination techniques include the use of concentrated acids or other chemical solutions to be applied by spray or recirculation. Evaluations of the best alternatives will be performed as part of the further detailed engineering and planning.

The major tasks associated with LIPA's decommissioning of these systems after "soft" decommissioning is completed are as follows:

- (1) Radiological characterization to determine the residual contamination levels, if any, after "soft" decontamination.
- (2) Dismantlement and removal of all piping and other portions of systems that are not at or below the release criteria. This includes the dismantlement and removal of all 3-inch and smaller diameter piping that cannot be characterized properly or in a practical manner. It is LIPA's intent to ship such small-bore piping to a licensed vendor for further decontamination, radiological surveys, segregation, and ultimate disposal. Also, any embedded piping will be aggressively decontaminated in an attempt to obviate removal.
- (3) Decontamination of surfaces that do not meet the release criteria using ultra-high-pressure water techniques, mole nozzles, hand wiping techniques, and local removal of coating systems where necessary.
- (4) Decontamination of surfaces that do not meet the release criteria using hand wiping, grinding, ultra-high-pressure water or chemical techniques.
- (5) Radiological characterization of the portions of the systems remaining at the site to ensure that all contamination is above the release criteria.

All work performed as part of the plant decommissioning will be consistent with current industry standards and practices. These include appropriate radiological controls, such as health physics support, monitoring, contamination control envelopes, local ventilation control with HEPA filters, etc., as required to prevent the spread of contamination.

All activities and tasks with the exception of RPV segmentation and project critical path activities will be performed during an eight-hour workday, five days a week, with no planned overtime. RPV segmentation and critical path activities are performed on the basis of a 10 hour workday, two shifts per day, five days a week.

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

The Independent Review Panel (IRP) will provide an independent review of the overall safety, regulatory compliance, and effectiveness of the LIPA maintenance and decommissioning activities associated with the plant. The IRP consist of five members appointed by the LIPA Board of Trustees with demonstrated expertise in areas of utility nuclear operations, academia and/or research in nuclear fields, and nuclear regulation. The IRP will meet as required, but not less than quarterly, and at any time upon the request of a member of the IRP, the LIPA Chairman, or the LIPA Board of Trustees. However, it is desired that the panel remain independent and flexible with respect to review areas and with respect to the amount of detail evaluated.

Generally, the IRP will focus on conformance of the plant decommissioning activities with nuclear safety objectives and decisions which could affect the health and safety of the public or the environment. Specific IRP activities are expected to include:

- (1) Review the adequacy of work plans and activities from a technical and safety perspective.
- (2) Anticipate problem areas and concerns (e.g., activities that may not have been addressed or were overlooked).
- (3) Recommend additional resources in areas of specific expertise that may have been unknown to the project team.
- (4) Review, at the panel's discretion, various periodic reports generated by the Site Review Committee (SRC) and/or other reports or documents issued by LIPA or regulatory agencies.
- (5) Review QA/QC audit reports and other selected QA/QC documentation.
- (6) Review health and safety-related issues and plant material conditions, as well as other matters that appear appropriate, and make recommendations in such areas.
- (7) Tour and assess the Shoreham site.
- (8) Review violations of codes, regulations, orders, technical specifications, license requirements or internal procedures, or instructions potentially having nuclear safety significance.

- (9) Review significant deviations of station equipment from normal and expected performance that could affect nuclear safety.
- (10) Review all reportable occurrences.
- (11) Review unanticipated deficiencies in the design of structures and systems or operations that could affect nuclear safety.
- (12) Review SRC's activities, including review of meeting minutes, special reports, etc.
- (13) Review reports and meeting minutes issued by the SRC.

The SRC will be organized to oversee LIPA's maintenance and decommissioning activities at the plant. The committee is comprised of the resident manager (chairman), operations and maintenance department manager (vice chairman), decommissioning department manager, operations manager, fire protection and site safety supervisor, licensing/regulatory compliance department manager and NQA department manager. Special consultants may be used to provide expert advice as the needs arise. Meetings will be called by the chairman as occasions for review or investigation arise. However, meetings will be held at least once a month.

The scope of the SRC's oversight responsibility shall include but not be limited to the following:

- Review of all procedures and programs required by the Shoreham Plant technical specifications or other Shoreham regulatory documents, and changes thereto, in addition to any other proposed procedures, as determined by the Committee, that may affect nuclear safety,
- Review of all proposed tests and experiments that could affect nuclear safety,
- Review of all proposed changes to the Shoreham Plant licensee and technical specifications,
- Review of all proposed changes or modifications to plant systems or equipment that could affect nuclear safety,
- Investigations of all violations of the technical specifications, including the preparation and forwarding of reports covering evaluation and recommendations to prevent recurrence to the chairman of the IRP and to the Executive Vice President - Shoreham Project,
- Review of all reportable occurrences,
- Review of decommissioning activities and facility operations to identify potential safety hazards,
- Review of decommissioning procedures,
- Performance of special review investigations or analyses requested by the resident manager or the chairman of the IRP,
- Review of the security plan, emergency plan, fire protection plan and related implementing procedures, including changes thereto,
- Review of changes to the Process Control Program and Off-site Dose Calculation Manual,
- Review of every accidental, unplanned, or uncontrolled on-site release of radioactive material to the environs associated with Shoreham's decommissioning, including the

preparation of reports covering evaluation, recommendations, and disposition of the corrective action to prevent recurrence and the forwarding of these reports to the Executive Vice President-Shoreham Project and to the IRP.

LILCO modified the Shoreham training program to meet the reduced requirements associated with maintaining the plant in the defueled configuration. For decommissioning the Shoreham Plant, LIPA will augment the revised training program to include specific training commensurate with the varying requirements of the different stages of decommissioning.

All decommissioning personnel at Shoreham, whether employed by LIPA, NYPA, LILCO or other contractors, will receive appropriate training commensurate with potential hazards to which they may be exposed. Training will include, but not be limited to, the following: general employee training, first aid, fire brigade and fire protection, emergency plan (onsite), security (security areas, access control, badging, screening, etc.), QA, radwaste, ALARA practices, industrial safety, and hazardous materials handling (including asbestos).

Employees at the plant receive training commensurate with their job duties: general description of the plant and facilities; job-related policies, procedures and instructions; radiological health and safety; emergency plan; industrial safety, fire protection; security; and QA. Personnel will be assigned to one of three categories: visitors, plant staff, or decommissioning staff.

The radiological safety course required for decommissioning workers will include the following topics: ALARA practices, introduction to 10 CFR 19 and 10 CFR 20, prenatal radiation exposure, radiological instrumentation and controls, decontamination and radwaste procedures, and fire protection and emergency procedures. General subjects, such as the nature and sources of radiation and matter, biological effects of radiation, use of monitoring equipment, and risks from occupational radiation exposure, are also to be covered.

Radiological training for decommissioning workers that is directed toward specific planned work activities will be conducted prior to start of the activities. Additional training, including training with respect to characteristics of the facility and systems, principles of nuclear safety, and details of postulated accidents, will enable technicians to recognize potential problem areas and to identify when an unreviewed safety question may arise.

Workers will be given instructions regarding the hazards and safety precautions applicable to the type of work being performed and will be directed to read and follow applicable job procedures. Individuals will be instructed concerning workplace hazards (e.g., flammable liquids and gases, chemicals, hazardous materials, and confined spaces) and in procedures for preventing unsafe conditions and unsafe acts. Examples of activities requiring special training are crane/hoist operation, forklift operation, powered platforms and scaffolds, use of personal protective equipment, disposal of chemicals and hazardous materials, use of cutting and welding equipment, and confined space entry and ventilation. Workers will also be instructed in the use of ladders, in protecting floor and wall openings, in maintaining emergency egress capability, and in the proper use of scaffolding.

Although fuel disposal is not specifically considered part of decommissioning, LIPA recognizes that fuel disposal activities must be carefully integrated into the overall plan for decommissioning the Shoreham plant, since removal of the spent fuel is a prerequisite for complete release of the site for unrestricted use. LIPA and LILCO are considering three options for the Shoreham irradiated fuel: 1) shipment to a reprocessing facility; 2) transfer of the fuel to another licensed utility; and 3) on-site storage. Shipment to a reprocessing facility entails the transfer of the fuel from the storage pool to a licensed reprocessing facility. LIPA is considering two overseas vendors offering reprocessing services. The second option involves a similar scope of Shoreham plant activities, followed by cask shipment to another domestic licensee. On-site fuel storage is considered an option of last resort because it would not yield the desired result of removing all radioactive material from the Shoreham site.

A.9.3 Shoreham Requirements and Regulatory Issues

The actions taken by the licensee to decommission Shoreham soon after receiving its fullpower license, long before the expiration of the license, surfaced ambiguities and apparent deficiencies in the Commission's decommissioning regulations and associated guidelines regarding their application to a prematurely shutdown facility.

The procedure for decommissioning a nuclear power plant is set out principally in 10 CFR 50.82, 50.75, 51.53, and 51.95. The formal process begins with the filing of an application by the licensee for authority to surrender the plant license and to decommission the facility. Five years before the licensee expects to end operation of the plant, the licensee is obligated to submit a preliminary Decommissioning Plan containing a cost estimate for decommissioning and an up-to-date assessment of the major technical factors that could affect planning for decommissioning. Then, within two years following "permanent cessation of operations" but no later than one year prior to expiration of its license, a licensee must submit to the Commission an application for "authority to surrender a license voluntarily and to decommission that facility." The application must also be accompanied, or preceded, by a proposed Decommissioning Plan and an ER that includes the following:

- A description of the decommissioning alternative chosen and the activities involved. Generally, the alternative is acceptable if it provides for completion of decommissioning within 60 years.
- A financial plan showing a cost estimate for decommissioning, the amount of funds currently available for decommissioning, and plans for assuring the availability of adequate funds for completion of decommissioning.

The Commission reviews the Decommissioning Plan, prepares an environmental impact statement (EIS) or environmental assessment (EA), as appropriate (10 CFR 51.95), and gives notice to interested persons. If the Commission finds the plan to be satisfactory, it issues a decommissioning order that approves the plan, subject to any conditions or limitations it deems appropriate, and authorizes decommissioning. This does not mean that a licensee is precluded

from taking any steps toward decommissioning prior to receipt of such an order. The Statement of Considerations accompanying the Decommissioning Rule indicates that, under 10 CFR 50.59, a licensee generally has the authority to make certain changes to the plant, including decontamination, minor component disassembly, and shipment and storage of spent fuel, without prior Commission approval as long as the changes are permitted by the "operating license," do not involve "major structural changes to radioactive components of the facility or other major changes," do not preclude any decommissioning options, do not significantly increase the costs of decommissioning, and do not pose a significant environmental impact that has not been previously reviewed.

Upon completion of decommissioning activities, including the completion of a terminal radiation survey in accordance with the plan and the order authorizing decommissioning, the Commission will issue an order that terminates the license.

After cessation of permanent operations but before receiving the order authorizing decommissioning, the applicant may seek to amend its operating license to reduce it to a POL. The POL serves two principal purposes. It confirms the nonoperating status of the plant by removing the authority to operate. More significantly, it provides a basis to remove requirements that are not necessary for a plant that will no longer operate. Thus, a POL provides a basis for a licensee to begin eliminating personnel, equipment, and activities unnecessary for maintenance of the plant in a safe, shutdown status without endangering the public health and safety pursuant to 10 CFR 50.59 analyses and without materially affecting costs, methods, or options for decommissioning the facility.

The Commission has declared that a POL is not a necessary step in the decommissioning process. A POL is essentially an amended operating license. It is only one way of allowing a licensee to obtain relief from requirements applicable only to plant operation. A licensee may also obtain such relief through exemptions and waivers from the regulatory requirements, or other license amendments. However, obtaining a POL may be more efficient than other avenues for reducing regulatory requirements that are applicable for a fully-operational plant. Any amendment sought may be subject to a pre-effectiveness or post-effectiveness hearing, depending on whether the amendment involves a significant hazards consideration.

Although premature decommissioning can occur, the regulations and associated guidelines provide little guidance on when and to what extent the normal decommissioning procedures (such as the requirements for a preliminary Decommissioning Plan) are to be applied to premature decommissioning. The regulations themselves contain no mention of premature decommissioning. The Statement of Considerations accompanying the issuance of the final Decommissioning Rule, however, clearly indicates that premature decommissioning is covered by the rule. Nevertheless, there is little information concerning which steps in the regulatory decommissioning process, and their timing, apply to the decommissioning of a prematurely shutdown plant.

A.9.4 Shoreham Transitioning Facility Risk Issues

At the Shoreham plant security, surveillance, and maintenance functions must be maintained for transitioning facilities and throughout the decontamination process to reduce risks.

Throughout the decommissioning project, ALARA engineering and administrative controls will be evaluated and utilized to minimize collective and individual radiation exposures. Some of the techniques and controls anticipated during decommissioning are:

- Airborne radioactivity will be monitored and controlled during all decommissioning activities. When systems containing radioactive material are opened, precautions will be taken to prevent any unintentional release of airborne contamination.
- Decontamination and dismantlement activities will be controlled to minimize radiation exposure to personnel through the use of Radiation Work Permits (RWPs). RWPs will describe the work to be accomplished and the area and airborne radiation surveillance requirements. These tasks will be governed by procedures which have been reviewed for ALARA requirements.
- Personnel will be protected against airborne contamination by HP controls and by engineered control systems such as portable ventilation exhaust systems containing HEPA filters. Negative pressure containment tents may be installed to enhance the removal of airborne radionuclides in situations where high activity may occur. Engineering controls will be used whenever practical. When it is impracticable to apply engineering controls, respiratory protective devices will be used. Filtered ventilation systems will always be used in areas where the cutting or grinding of contaminated systems is planned - activities which frequently release airborne particulates.
- All components scheduled for disassembly will initially be assumed to be contaminated. Radiological surveys will be performed which will document conditions found. Where contamination is found, RWPs will be written and controls established to protect personnel.
- Cutting techniques will be used that have rapid setup and deployment as well as easy cleanup.
- Radioactive material storage areas will be used to ensure physical protection, exposure to personnel that is ALARA, and material control.
- Before performing decommissioning activities in or near radioactive systems and structures, the merits of ALARA alternatives will be considered. This will include consideration of measures such as installing shielding and/or using remotely

controlled shielding and/or using remotely controlled equipment versus the ability to perform the task quickly and thus minimize exposure.

- All preliminary work will be performed, where possible, in areas well isolated from radioactive material because this is an effective way to reduce personnel radiation exposure.
- Preplanning of all work activities will be performed for high projected exposure jobs and for work involving high dose rates and contamination levels. Preparatory meetings will be attended by HP personnel, the foreman and the workers directly involved with the job. Consideration will be given to the use of mock-ups or dry runs, especially when extremely complex tasks are to be performed. In some cases, photographs or closed-circuit TV and videotape recordings may be used to permit personnel outside the job area to give guidance while outside of the radiologically controlled area. After completion of the job, debriefing sessions will be held, and experience gained will be used to plan future similar work evolutions.

A Health Physics Program (HPP) will be established to translate the management commitment to the ALARA policy into a set of procedures and practices for the performance of tasks. LILCO currently has established radiation protection and ALARA programs, and these will be the basis for the decommissioning HPP.

An effective HPP consists of all actions and measures planned or taken to protect workers and the environment, monitor radiation and radioactive materials, control distribution and releases of radioactive material and keep radiation exposure (individual and collective) within the limits of 10 CFR 20 and ALARA.

LIPA will institute the following measures for control of radiological materials and areas:

- Perform radiation and contamination surveys
- Utilize RWPS to delineate controls, identify conditions and specify protective measures to prevent inadvertent exposure of personnel to radiation or radioactive contamination during decommissioning activities
- Arrange the available work areas into segregated sections (e.g., contaminated and "clean" working areas)
- Institute and implement access controls to:
 - control the spread of contamination from contaminated to "clean" areas
 - limit area access to personnel who are directly involved in the specific task

- Clearly identify and tag all contaminated items as they are removed and note their place of origin and pertinent radiological information
- Monitor work areas so as to alert personnel of any unexpected radiological conditions
- Maintain accurate and updated records of personnel exposure, surveys and lessons learned so as to improve and revise procedures as necessary
- Monitor effluent waste streams through radiation monitoring equipment, surveys and sampling.

LILCO currently uses and maintains a standard industry surveying and monitoring program for personnel and effluent monitoring. LIPA will utilize the existing LILCO program, which includes a wide range of portable and non-portable instruments and lab-counting equipment. The program will be applied during the decommissioning for radiological surveys, applied during the decommissioning for radiological surveys, personnel monitoring, area monitoring, air monitoring and sample analysis. On a daily basis, or as frequently as required, each type of instrumentation will be checked to verify that it is functioning properly. In addition, such instrumentation will be maintained and calibrated using proper procedures.

During Shoreham's decommissioning a significant amount of plant resources will be expended in disposing of the spent fuel and in the processing of liquid and solid radioactive wastes. Radioactive wastes include neutron activated materials, contaminated materials and site generated radioactive waste.

A.9.5 Shoreham Cost Increases and Uncertainty

Within two years following "permanent cessation of operations" but no later than one year prior to expiration of its license, a licensee must submit to the Commission an application for "authority to surrender a license voluntarily and to decommission that facility," together with an environmental report covering the proposed decommissioning activities. The application must also be accompanied, or preceded, by a proposed Decommissioning Plan that includes:

- A description of the decommissioning alternative chosen and the activities involved. Generally, the alternative is acceptable if it provides for completion of decommissioning within 60 years.
- A financial plan showing a cost estimate for decommissioning, the amount of funds currently available for decommissioning, and plans for assuring the availability of adequate funds for completion of decommissioning. Assurance that sufficient funds will be available to cover all future decommissioning costs may be provided through one or more of three basic funding mechanisms: prepayment, external sinking fund, and surety/insurance/guarantee. The cost of decommissioning does not include the cost of removal and disposal of spent fuel or of nonradioactive structures and

materials beyond that necessary to terminate the license and does not include costs for disposal of nonradioactive hazardous wastes not necessary for NRC license termination.

The estimated cost to decommission Shoreham is \$186 million in 1991 dollars. LIPA's cost estimate was prepared in a manner that is consistent with industry decommissioning studies that were used by the NRC in development of the Decommissioning Rule and reflects LIPA's Shoreham specific plan for plant decommissioning. The elements of work (i.e., work breakdown structure) comprising LIPA's costs estimate are consistent with the activities and tasks included in LIPA's schedule.

As specified in the Settlement Agreement, the Asset Transfer Agreement, and the Site Agreement, LILCO is responsible for providing all of the funds required for the Shoreham decommissioning.

A.9.6 Shoreham Stakeholder Concerns

After receiving a full power operating license on April 21, 1989, the Shoreham Nuclear Power Station shut down in June 1989 pursuant to an agreement between the State of New York and LILCO. The agreement provided that LILCO would cease operations at Shoreham and sell the facility to LIPA for decommissioning. Soon thereafter, LILCO removed all fuel from the reactor, stored the fuel in the spent-fuel pool (as permitted under its full-power license) and, under regular procedures, began to seek a series of license amendments and exemptions to allow it to reduce staffing and other requirements applicable to operation.

Beginning in July 1989, the School District and SE2 (jointly referred to as "Petitioners") filed petitions, pursuant to 10 CFR 2.206 and 2.714, opposing the defueling and destaffing activities that LILCO planned to undertake, and any actions that they believed would lead to decommissioning of the facility including the transfer of the license to LIPA. Petitioners claimed that (1) individual actions were attempts illegally to segment Commission consideration of the environmental consequences of the larger action of decommissioning the facility required by NEPA and (2) the Commission must consider resumed operation as an alternative to decommissioning Shoreham. Separately, the Secretary of Energy, through letters and other means, urged the Commission to preserve Shoreham as a nuclear facility and to prohibit LILCO from taking steps to dismantle the plant without first holding hearings and preparing an EIS on decommissioning. In addition, the Council on Environmental Quality (CEQ) wrote letters arguing that the NRC must prepare an EIS on decommissioning before authorizing any changes to the license. Uncertain as to whether the DOE would take steps to preserve Shoreham as a nuclear facility, the staff obtained a commitment from LILCO to maintain the plant in a defueled state and to preserve systems needed for operation.

LIPA and LILCO jointly applied to the NRC on June 28, 1990, to amend the license to allow transfer of the Shoreham Plant to LIPA. By law, LIPA is forbidden from operating a nuclear power station therefore, the following was proposed. The decommissioning project will be

established and in place prior to transfer of Shoreham to LIPA. As the licensee, LIPA will provide the overall management for the decommissioning project. Already in place at LIPA are the Board of Trustees, the Chairman and the Executive Director. The remaining positions in LIPA's organization will be filled with qualified personnel in three ways.

First, seven individuals with pertinent nuclear energy experience who are presently employed by NYPA will be employed directly by LIPA. The project positions to be held by these individuals are designated as LIPA/NYPA employees. The coemployment positions are those most vital to the conduct of safe and effective decommissioning activities at the plant, and LIPA therefore desires that such positions be filled by persons employed directly by LIPA and accountable directly to LIPA's executive director, LIPA's chairman and LIPA's Board of Trustees. These prospective LIPA employees are presently employees of NYPA during the Shoreham project. All coemployees except the Executive Vice President Shoreham Project will be dedicated full-time to the Shoreham project and will reside at Shoreham. The second source of qualified personnel to fill positions is provided by LIPA's Management Services Agreement with NYPA for technical and management services. It is planned that a number of positions will be filled by employees of NYPA in its capacity as prime contractor to LIPA (i.e., not on a coemployment basis).

The balance of the positions in the LIPA Shoreham organization will be staffed by personnel provided by other contractors or by LILCO personnel presently at Shoreham. The site agreement between LIPA and LILCO specifically provides that LIPA may request LILCO to assign its own Shoreham personnel to decommissioning activities to be conducted after transfer of Shoreham to LIPA. Such personnel would remain employees of LILCO and work under the supervision of LIPA and NYPA personnel.

LIPA will have overall authority and responsibility for the decommissioning of Shoreham. Responsibility and authority are delegated from LIPA's Board of Trustees through the LIPA Chairman to the Executive Director, to the Executive Vice President-Shoreham project, to the Resident Manager. The Resident Manager is the senior on-site LIPA manager and has ultimate on-site authority. There are five principal management functions that report directly to the Resident Manager. (1) Decommissioning Project Manager, (2) Operations, Maintenance, and Radiological Controls, (3) Licensing and Regulatory Compliance, (4) Station Services, and (5) Financial and Administrative Services. All of these personnel are members of the Site Review Committee.

LIPA Board and Chairman. The LIPA Board of Trustees is responsible for LIPA's overall direction, policy development, and policy implementation. Upon transfer of Shoreham to LIPA, the LIPA board will become responsible for the safe and cost-effective maintenance of Shoreham and the safe, cost-effective, and expeditious decommissioning of Shoreham. The Chairman's duties in this regard include overall responsibility for the administration and coordination of LIPA's activities. This includes overall responsibility for LIPA's adherence to the applicable requirements of federal, state, and possibly local regulatory bodies. The LIPA Chairman is appointed by the Governor of the State of New York.

LIPA Executive Director. The Executive Director is responsible for the day-to-day direction and administration of LIPA, including all matters involving asset transfer, license transfer, maintenance and decommissioning of the plant. In fulfilling these functions, the Executive Director will give direction to, and receive reports from, the Executive Vice President - Shoreham Project.

Other positions created include Executive Vice President-Shoreham Project, Resident Manager, Operations and Maintenance Department Manager, Decommissioning Department Manager, Nuclear Quality Assurance (NQA) Department Manager, Licensing/Regulatory Compliance Department Manager, Finance and Administration Department Manager, Station Services Department Manager, Operations Division Manager, Maintenance Division Manager, Radiological Controls Division Manager, Technical Services Division Manager, Nuclear Sire Security Division Manager, and Fire Protection and Site Safety Supervisor.

A.9.7 Shoreham Waste Minimization and Avoidance of Mixed-Waste Generation

LILCO has evaluated and is planning to implement a chemical decontamination program to decontaminate five of the nine contaminated plant systems. LILCO has selected a technique that has been used at operating nuclear plants, and has determined that this process can be used without causing irreversible damage or degradation to the plant equipment. In addition, LILCO is using the existing Shoreham Plant staff to manually decontaminate various areas of the plant, including the suppression pool and reactor cavity. It is anticipated that there will be several benefits to LIPA resulting from LILCO's decontamination program, including the possible reduction in the overall scope of decommissioning and dismantlement (i.e., under the assumption that levels of contamination in plant systems and structures are reduced below acceptable release criteria). These decontamination efforts are being closely monitored by LIPA and will be factored into LIPA's detailed engineering and planning activities for decommissioning. For purposes of the Decommissioning Plan, however, LIPA has assumed that LILCO's decontamination activities will not reduce contamination levels to below acceptable release criteria and that, accordingly, the Decommissioning Plan will address all presently contaminated systems.

LIPA has estimated that approximately 79,000 ft³ of LLW will be generated as a result of Shoreham's decommissioning. LIPA has plans for processing, packaging, shipping, and disposing of Shoreham's radwaste in accordance with applicable federal and state regulations. Radwaste-related activities will be subject to LIPA's QA program.

Volume reduction is a key aspect of LIPA's plan for managing Shoreham's radwaste. Through an aggressive campaign of decontamination, waste segregation and other industry proven waste processing techniques, LIPA anticipates that Shoreham's radwaste can be consolidated so that only a small fraction of the 79,000 ft³ estimate will require disposal at a licensed radwaste burial facility.

Precautions will be taken to preclude the spread of contamination to most plant areas that are presently clean. However, various areas throughout the plant affected by the decontamination and dismantlement activities will be surveyed and decontaminated, as required, following the completion of decommissioning activities.

A.9.8 Shoreham Industry Involvement

LIPA recognizes the potential benefits offered by the well-managed use of contractor assistance. Since project inception, LIPA has contemplated the use of qualified consultants and contractors to assist LIPA in carrying out the decommissioning of the Shoreham Plants. These initial intentions have resulted in the hiring of several contractors and consultants to assist LIPA.

NYPA is the prime contractor to LIPA for providing technical and management services for the maintenance and decommissioning of the Shoreham facility. As such, NYPA is responsible for Decommissioning Planning and preparations. NYPA will also supervise and direct work concerning the day-to-day maintenance and decommissioning of the facility.

Having been an NRC licensee since 1975, NYPA has considerable experience and a favorable record for conducting the activities at its nuclear facilities consistently with public health and safety and protection of the environment. As a result of this experience, NYPA offers an existing staff, programmatic infrastructure, and the range of resources requisite to the effective decommissioning planning and implementation at Shoreham. 112

During the summer of 1990, Bechtel was hired by LIPA to provide A/E services for the Shoreham decommissioning project. In this capacity, Bechtel is responsible for providing a comprehensive and broad range of decommissioning consultation services, including project conceptual design engineering, detailed engineering and design, and planning/scheduling. In addition, Bechtel is to provide engineering support to LIPA during the field implementation phase(s) of the project.

Having served as the prime contractor for the Three Mile Island recovery effort, Bechtel offers considerable experience that is directly applicable to the Shoreham decommissioning project. Moreover, Bechtel has performed numerous decommissioning engineering studies and evaluations for other utilities in the nuclear industry. Lastly, as the principal A/E for over one-half of the nuclear plants built in the U.S., Bechtel offers an enormous pool of resources in a wide variety of technical disciplines that can provide additional benefits to LIPA in resolving unforeseen technical issues that may be encountered during the course of Shoreham decommissioning.

In addition to its own expertise, Bechtel has TLG Engineering and Power Cutting, Inc. (PCI) as subcontractors. TLG Engineering is a consulting firm offering considerable experience with nuclear plant decommissioning engineering and cost studies. In addition, TLG offers field, hands-on experience through its participation in the Shippingport decommissioning project.

TLG is responsible for performing Shoreham decommissioning cost studies and is assisting LIPA, NYPA, and Bechtel with the development of the Shoreham decommissioning cost estimate.

PCI is a "specialty" contractor offering unique experience with field machining and cutting techniques in nonstandard applications. Much of its experience with "nondecommissioning" projects, such as steam generator replacement and reactor thermal shield repair, can be applied directly to many of LIPA's Shoreham decommissioning activities. PCI is responsible for assisting LIPA and Bechtel with a conceptual plan for segmenting the Shoreham RPV. PCI's involvement includes an evaluation of available technology in field-proven processes that can be used for RPV segmentation.

LIPA will continue to evaluate the need to acquire the services of additional contractors as the Shoreham project evolves.

Specific areas for which contractor assistance is being contemplated included the following:

- *Radwaste Management* - Packaging and handling; shipping casks and container suppliers; transportation; disposal; off-site laundry; liquid waste processing; and volume reduction
- *Decommissioning Specialist* - Planning engineering; decontamination; dismantling; and heavy rigging/handling, and
- *Radiation Protection* - Engineering; radiation protection staff augmentation; analytical laboratory services; dosimetry; and radiation surveys.

Radioactive wastes generated during decommissioning will be processed as necessary using temporary systems supplies by experienced vendors and contractors where appropriate. These systems may include temporary ventilation with filtration for airborne contamination, portable demineralizers for liquid waste processing and compactors for volume reduction DAW.

Radioactive liquid wastes will be generated by decontamination and dismantlement of the Shoreham plant systems and structures. Vendor supplied portable, temporary liquid radwaste equipment will be used to process this waste.

A.9.9 Shoreham Recycle and Reuse Opportunities

LILCO is pursuing the removal and disposal of several reactor components that are either normally removed and replaced during the course of plant operation or that can be readily removed without permanent, irreversible damage to the reactor. The start-up neutron source, in addition to start-up in-core instrumentation, has already been removed from the reactor, packaged, and shipped to off-site licensees.

A.9.10 Shoreham Technology Development or Enhancement Needs

Decontamination techniques to be employed by LIPA are consistent with those used routinely throughout the nuclear industry. In-situ chemical decontamination, ultra-high pressure water lancing, abrasive grit blasting, and a variety of manual techniques are all expected to be used by LIPA during the course of Shoreham's decommissioning. In addition, LIPA is closely evaluating off-site decontamination services.

LIPA similarly will apply industry-accepted and field-proven processes for the dismantlement of certain plant systems and structures. Such techniques will range from simple, manually operated power bandsaws used to sever small bore piping through more sophisticated techniques such as diamond wire saw cutting, which may be used to sever the large-bore piping connections to the RPV. The selected options, as well as LIPA's continued evaluation of available technology, will reflect careful consideration of the radiological conditions associated with their intended application.

Segmentation of the more highly activated reactor internals will be performed using underwater, semi-automatic plasma arc and metal disintegration machining equipment. The RPV will be severed into ring sections using the diamond wire saw. The ring sections will then be cut into pieces appropriately sized to permit their safe and efficient handling, packaging, and shipping using either the diamond wire saw or a thermal cutting technique.

A.9.11 Shoreham Lessons Learned

To avoid further contamination of structures and systems, the processing of waste generated during decommissioning will be handled by portable radwaste equipment.

A final radiation survey will be conducted on all suspected and known contaminated structures, systems, components, equipment, grounds, and adjacent environments upon completion of the decontamination and dismantlement activities to demonstrate that any residual contamination is within established criteria for unrestricted release. The survey will involve a full evaluation of the site. The site will be divided into survey blocks and characterized. Laboratory analysis will incorporate statistical methods in evaluations.

Measured exposure rates for various systems and structures were used along with prospective man-hours to compute person-Rem for system and structure decommissioning. A conservative factor was applied to account for the transport and concentration of radioactivity within these systems and structures during decommissioning.

LILCO's decontamination program will use "soft" decontamination techniques (i.e., techniques that will not irreversibly damage plant systems and components) such as chemical decontamination and high-pressure water hydrolances for mechanical decontaminants. Those systems or structures that do not meet the release criteria after "soft" decontamination is completed will be dismantled/removed or decontaminated using more aggressive techniques.

Aggressive decontamination techniques include the use of concentrated acids or other chemicals solutions to be applied by spray or recirculation. Evaluations of the best alternatives will be performed as well.

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

An independent review panel was used to anticipate problem areas and concerns, e.g., activities that may not have been addressed or were overlooked, review significant deviations of station equipment from normal and expected performance that could affect nuclear safety, among other things.

The training program was modified to meet the reduced requirements associated with maintaining the plant in the defueled configuration. The revised training program was augmented to include specific training commensurate with the varying requirements of the different stages of decommissioning. All decommissioning personnel receive appropriate training commensurate with potential hazards to which they may be exposed. Training will include, but not be limited to, the following: general employee training, first aid, fire brigade and fire protection, emergency plan, security, QA, radwaste, ALARA practices, industrial safety, and hazardous materials handling (including asbestos).

Radiological training for decommissioning workers is directed toward specific planned work activities will be conducted prior to start of the activities. Additional training, including training with respect to characteristics of the facility and systems, principles of nuclear safety, and details of postulated accidents, will enable technicians to recognize potential problem areas and to identify when an unreviewed safety question may arise.

Radiation Work Permits (RWPs) were used to minimize radiation exposure to personnel. RWPs described the work to be accomplished and area and airborne radiation surveillance requirements.

Planning for personnel protection against airborne contamination included health physics controls and engineered control systems such as portable ventilation exhaust systems containing HEPA filters. Negative pressure containment tents may be installed to enhance the removal of airborne radionuclides in situations where high activity may occur. In addition, engineering controls will be used whenever possible. When engineering controls are not possible, respiratory protective devices will be used. Filtered ventilation systems are always used in areas where the cutting or grinding of contaminated systems is planned activities which frequently release airborne particulates.

All components scheduled for disassembly are initially assumed to be contaminated. Cutting techniques used are those that have rapid setup and deployment as well as easy cleanup.

Preplanning all work activities will be performed for high projected exposure jobs and for work involving high dose rates and contamination levels. Preparatory meetings will be attended by HP personnel, the foreman and the workers directly involved with the job. Consideration will be given to the use of mock-ups or dry runs, especially when extremely complex tasks are to be performed. In some cases, photographs or closed-circuit TV and videotape recordings may be used to permit personnel outside the job area to give guidance while outside of the radiologically controlled area. After completion of the job, debriefing sessions will be held, and experience gained will be used to plan future similar work evolutions.

Some of the measures used to control radiological materials and areas included instituting and implementing access controls to control the spread of contamination from contaminated to clean areas and limit area access to personnel who are directly involved in the specific task and clearly identifying and tagging all contaminated items as they are removed and note their place of origin and pertinent radiological information.

Volume reduction is a key aspect of managing Shoreham's radwaste. Through an aggressive campaign of decontamination, waste segregation and other industry-proven waste processing techniques, it is anticipated that Shoreham's radwaste can be consolidated so that only a small fraction of the 79,000 ft³ estimate will require disposal at a licensed radwaste burial facility.

A continual evaluation of available technologies will occur during the project, reflecting careful consideration of the radiological conditions associated with their intended application.

A.10 Trojan

The Trojan Nuclear Power Station is located in Columbia County, in the State of Oregon, 42 miles north of Portland. The site consists of 623 acres incorporating a recreational area/park and various office buildings along with an industrial complex enclosed by a security fence. Surrounding the site is land used for residential, commercial, and agricultural purposes. The cooling water supply for the site is from the Columbia River. Drinking water is supplied from on-site wells.

The plant is jointly owned by Portland General Electric (PGE), Pacific Power (PG&E), and the Eugene Water and Electric Board. The plant was designed by Bechtel Power Corporation as a single generating unit with a PWR supplied by Westinghouse Corporation. The nuclear steam supply system was capable of a thermal output of 3423-MWt with a net electrical output of 1170-MWe. The Trojan Nuclear Plant received its operating license on November 21, 1975, was declared commercial on December 24, 1975, and formally began commercial operation on May 20, 1976.

The board of directors voted to close the Trojan Plant permanently on January 4, 1993. This decision was based on the results of least cost planning, regulatory uncertainty, and steam generator tube defects identified during the 1991 refueling shutdown, which were noted again in 1992. The plant was forced off-line on November 9, 1992, because of a steam generator

tube leak. PGE received a possession only license (POL) for the Trojan plant on May 5, 1993. The plant is currently in SAFSTOR awaiting a decision on possible future uses.

A.10.1 Trojan Hazard Characterization

A site radiological plan was developed to guide in the characterization of the Trojan Plant. The activity was divided into four major areas: environmental, structural, systems, and activated systems. The environmental area included outside areas such as roads, ponds, and yards. For this area, background radiation levels were measured; soil, sediment, and water samples were taken; and ambient radiation dose rates were computed. The structural area included all buildings on-site. Plant personnel determined background radiation levels and surveyed for fixed and loose radioactive material.

The plant systems area was divided into four categories. The C1 category was *known contaminated*. These areas were surveyed to characterize the activity present. The C2 category was *potentially contaminated* based on previous data. The I category was *indeterminate*; these areas had to be surveyed and data obtained to determine their actual status. The N category was *clean systems*. However, the clean systems were surveyed to verify cleanliness. To support these efforts, smears and direct radiation readings were taken at selected locations. The activated systems area included those components that had been subjected to neutron flux, such as the reactor vessel and shielding. Computer codes were used to verify activity and dose rates. The code output was then verified with actual surveys.

The bulk of the waste at the plant, approximately 400,000 ft³, was considered to be Class A radwaste and included trash, concrete, piping, etc. Class C waste included resins and filters. Class B included various metals. Greater than Class C waste included the fuel and some portions of the reactor internals. Hazardous material identified included some asbestos (note that radioactive asbestos is not considered mixed waste) and chemicals such as NaOH, hydrazine, and sulfuric acid. The total volume of mixed waste was small and included freon and freon filters, some oxalic acidem permanganates, and chromium.

A.10.2 Trojan Management/Programmatic Issues

PGE is required by the Oregon Public Utility Commission Guidelines to work with customers, regulators and citizens interested in energy and environmental policy to develop a least cost plan every two years. The creation of a least cost plan is an industry trend intended to open up the utilities' strategic planning process. It involves performing a 20-year projection of future power needs and determining how PGE will meet those needs in the most prudent, cost-effective way. The plan also documents decisions on the types of new resources necessary to best serve the interests of customers, shareholders, and society.

As part of the development of the least cost plan, two advisory committees are created, a Technical Advisory Group (TAG) and a Public Policy Group (PPG). The TAG includes representatives from other utilities, regulatory agencies (within the state), environmental groups,

the customer base, and the public. The TAG provides technical input into the methodology and assumptions underlying the plan. The PPG includes executives from business, the financial community, environmental organizations (such as the Sierra Club), the electric utility industry, and regulatory agencies. The PPG provides high-level policy advice, including consideration of the trade-offs implicit in making resource decisions.

The building blocks of the plan involve assembling data and performing the modeling necessary for decision-making with respect to future market demand, existing resources, demand-side and supply-side resources, environmental issues, and the financial viability of Trojan. Resource options, called trial plans, are evaluated to determine how well they perform when variations are made in assumptions. This sensitivity analysis includes varying load forecasts, fuel prices, capital costs, operating costs, and regulatory considerations. Uncertainties associated with the values used for these assumptions are also considered in the evaluation. Each trial plan is rated from the perspective of the customer, the shareholder, and society. A balanced plan is then selected.

During the development of the least cost plan, a wide variety of information and many "lessons learned" were collected. PGE determined that its existing market consisted of approximately 600,000 customers using an average of 1900-MW of electricity, with a peak usage of 3500-MW. PGE supplies approximately 40% of the energy consumed in Oregon.

A moderate growth, 2.1% average rate of increase in demand (which is above the national average), was projected.

Assuming that the Trojan Plant will be shut down, future resources must be found to meet the anticipated 80% increase in demand of 1500-MW of energy/load reduction. PGE explored both supply- and demand-side savings. With respect to the supply side, PGE plans to acquire 500-MW of electricity through natural gas-fired generation.

On the demand side, PGE plans to acquire up to 538-MW of peak load reduction and a 314-MW average load reduction via the following:

- Residential savings - This option includes a whole-house weatherization pilot project and low-flow showerhead distribution.
- Commercial/Industrial savings - This is a program being done with the state. It involves energy audits and incentives to recover construction inefficiencies in lighting, heating and ventilation, and plant equipment.
- Power smart - This is a marketing campaign targeted at raising customer awareness regarding energy efficiency.
- Research and Development - This examines customer practices, load-shaping options, and continued regional collaboration on energy efficiency, and
- Evaluation - This demonstrates sustainable energy savings from prudent investments in energy efficiency programs and technologies.

The least cost plan originally concluded that a four-year phase-out of the Trojan Plant was the most prudent course of action. However, new information supported immediate closure of the plant for the following reasons:

- Increased costs and loss of reliability of the plant because of steam generator tube degradation,
- Dissenting regulatory opinion on tube repair criteria, and
- Increased availability and lower-than-anticipated cost of replacement power.

Closing the plant immediately was anticipated to yield a savings of \$25 million to \$142 million when compared to continuing to operate the plant until 1996. The large variation in the savings values is from tube plugging criteria and forced outage assumptions.

The least cost plan was a way for PGE to make an informed choice among potential future energy options and still ensure that an adequate and reliable supply of energy at the least cost to the customer is available and consistent with public interest. The least cost plan is based on the best technical data available, the best advice that can be obtained from the experts and the public, and sophisticated analytical models. The plan is a dynamic process and changes as new information and conditions occur.

PGE defined deactivation as the process of removing from service components, structures, or systems no longer required to support the permanently defueled plant. Because of the lack of up-front decisions making it clear that the plant would not be restarted, there was considerable confusion about the planning for deactivation and SAFSTOR. There was a strong feeling among the employees that the plant would be restarted one way or another. It was hard for them to accept that a \$1 billion asset would be discarded and turned into a \$400 million liability for the utility.

The deactivation plan developed by PGE used a systems-engineering approach. The goal of the deactivation plan was to establish the administrative requirements governing the defueled plant systems and the process to deactivate systems that are not required to support the plant in its permanently defueled status. Trojan, in accordance with guidance in NUMARC 92-02, developed a procedure, TTP 30-1, "Nuclear Division Defueled Requirements and Defueled Systems List," which classifies plant systems as *Operable* (required by technical specifications); *Available* (not required by technical specifications); *Prudent* (try to keep operable); and *Not Required* (abandoned). The procedure provides general requirements associated with each type of system classification and a comprehensive list of technical specifications' applicability.

Trojan has implemented a procedure, TTP 30-2, "Plant System Deactivation," which identifies the process and requirements necessary to deactivate the Trojan Plant systems and/or portions of systems not required to support the permanently shutdown plant. The procedure has been broken into six phases:

PHASE I	Development of System Lay-up Plan
PHASE II	System Lay-up Implementation
PHASE III	Development of System Deactivation Plan
PHASE IV	Development of Administrative Plan
PHASE V	System Deactivation Implementation
PHASE VI	System Deactivation Turnover

In Phase I, requirements for interim lay-up of systems were evaluated using outage experience and ideas from engineers on staff. Engineering developed lay-up instructions and evaluated fluid systems (wet versus dry) requirements. In addition, de-energizing major equipment (such as pumps, fans, and motor operated valves (MOVs)) and isolating system boundary valves were included in the lay-up phase. Phase II involved implementing Phase I plans. In this phase, operations used existing clearance tagging, and engineering canceled maintenance and plant modification requests. In Phase III, engineering developed detailed system plans including identification of combustible materials to be removed from the system, marking up applicable drawings (e.g., P&IDs and electrical), identifying the location of "de-activated" and "boundary" tags, and preparing a 10 CFR 50.59 safety evaluation of the deactivation plan. In Phase IV, engineering identified procedures that required deletion or revisions based on system deactivation. Actual implementation of the Deactivation Plan began in Phase V, where operations implemented the plan using clearance tags and hanging "boundary" and "deactivation" tags. In Phase VI, engineering coordinated turnover of the plant and updated drawings and procedures with respect to the deactivation status of the plant; maintenance updated their procedures; and operations updated their procedures and removed clearance tags.

The use of six phases allows the deactivation process to be broken into discrete segments for which individuals are assigned responsibility. The phases provide a well-documented decision process, afford deactivation of the entire plant via 10 CFR 50.59, and provide a communication and coordination pathway between plant groups during a very dynamic period of time.

A major effort went into laying up the turbine and steam generators because these portions of the plant had commercial value if the plant could be repowered. The plant elected to maintain chemistry in the steam generators; therefore, wet lay-up was used. The reactor vessel was filled with water, thus providing shielding. Both TVA and INPO provided good sources of information on how to preserve and lay-up components, corrosion processes, galvanic issues, etc. EPRI was a good source of information on how to preserve turbine and oil systems. To lay-up the turbine, fans and heaters were installed to keep the systems dry and minimize corrosion.

Deactivation activities at the plant are controlled via the same processes used when the plant was in operation. The same work control, temporary alteration, preventive maintenance, and surveillance procedures are being used. In addition, daily status and work control meetings are being held. A plant safety review process and corporate safety review activity are still in place.

Staffing needs are continually re-evaluated as equipment and systems are taken out of service. Initial large decreases in personnel were handled via layoffs. For example, security personnel went from 175 in 11/92 to 25 in 12/93. Because of the limited availability of jobs within PGE, redeployment was limited to approximately 100 people, most of whom were moved laterally or demoted. Currently, there are monthly layoffs as the staff levels are approaching the near-term equilibrium level of about 200. A large number of licensed operators were able to move to TVA facilities.

PGE's initial staffing plan was based on a compromise between staffing data obtained from Rancho Seco and Yankee Rowe, as well as the staffing needs requested by individual managers. Considerable discussion occurred among the senior managers regarding the final staff size and composition. The initial large layoffs were based on the curtailment of power generation and the need to continue to satisfy regulatory requirements. Later layoffs were based on receiving specific license changes. To encourage people to stay for four years, a retention plan was introduced that amounted to a bonus of 30% per year for each of the four years. However, staff using this plan *took their chances*. Since there were no competing opportunities in the plant area for engineers, those who wished to stay were more willing to take a chance at not having a job the following week. Maintenance staffing reductions depended on system deactivation progress, the review and closeout of maintenance requests (they had approximately 5000), the review and reconfiguration of the preventive maintenance program (approximately 10,000 activities), and procedure revisions to reflect the plant's shutdown status. Operations staffing reductions depended on system deactivation progress, elimination of technical specifications license requirements (as a minimum, shift manning and fire brigade requirements were kept), and the procedure revisions to reflect the plant's shutdown status. Engineering staffing reductions depended on system deactivation progress, the review and closeout of design packages, drawing changes and design documents, and the deletion of engineering programs (such as ASME Section XI R&R/ISI/IST, Station Blackout, Snubbers, Appendix R, Appendix G/H, Appendix J, Appendix K, etc.). Security staffing reductions depended on the approval of a security plan for defueled plant. QA staffing depended on the approval of a revised QA program. Administrative staffing reductions depended on streamlining the administrative processes and the overall size of the staff.

Radiation protection staffing reductions depended on the level of work activities and deactivation progress, the scope of the site characterization surveys, and approval of an emergency response plan for the defueled plant.

A draft long-term Trojan plant organization chart shows that about 105 people are needed to maintain the plant in SAFSTOR. About 60 people are required for operations, maintenance, and radiation protection, 23 for security and administration, plus 19 in licensing and QA.

The NRC requires the submittal of a Decommissioning Plan. The plan must contain information on DECON versus SAFSTOR, a description of the activities, a description of the controls, the planned final radiation survey, cost estimates, and a funding plan.

Decommissioning clean-up criteria included the following:

- Adhering to Regulatory Guide 1.86 and $<5 \mu\text{R/h}$ above background at one meter direct reading (from NUREG 0586).
- Evaluating both *Greenfield* and industrial use as final site options, and
- Burying waste as LLW if any detectable beta-gamma contamination, based on GeLi detection, is present.

PGE looked at four decommissioning scenarios: Dry Storage (or Prompt Decon - to begin in 1998), Decom (1998-2002); Dry Storage and Decom (2011-2014); Dry Storage and Decom (2018-2021); and, Wet Storage and Decom (2018-2021).

A.10.3 Trojan Requirements and Regulatory Issues

Trojan aggressively pursued obtaining a POL although it felt that it really was not necessary. The POL simply says that the plant will not operate again as a nuclear plant. It also formally identifies Trojan as a decommissioning liability. The NRC granted the POL in 98 days.

Once the POL was granted, PGE revised the emergency and fire protection plans to be consistent with the new defueled condition of the plant. Significant monetary savings were related to reducing the scope of these plans. No off-site emergency plans, sirens, or support were kept. The SAR was reissued and technical specifications prepared for the new plant status. The revised SAR or Defueled Safety Analysis Report (DSAR) provides a revised design basis for the plant on which the 10 CFR 50.59 change process can be based. The NRC raised the question of loss of all water in the spent-fuel pool as a "beyond design basis" accident.

Trojan went from 146 technical specifications to four. The NRC approved "Certified Fuel Handler" program, which does not require licensed operators or simulator training, was adopted. In fact, only general employee training is provided to employees at this time.

In the area of fire protection, PGE went from an Appendix R program to a NFPA industrial program. Property insurance for the Trojan Plant averages \$4000 per day, which PGE is attempting to change since the hazards have been reduced significantly. PGE believes that, after a three-year hold period, they may be able to get relief from Price Anderson liability considerations. The Appendix B QA program has been maintained, again consistent with the plant status.

The NRC told PGE to maintain a fitness for duty program until the fuel is off-site or in dry cask storage. Both a plant and corporate safety review committee are maintained, consistent with operating technical specifications.

PG&E developed a listing of licensing actions planned for achieving the defueled status, which was revised weekly. The first part of the listing contains a list of *High Priority Pending*

Actions, followed by a longer list of *Other Pending Actions*, and, finally, by a list of *Completed Actions*. Table A.5 is an example of the format used for the tables.

A.10.4 Trojan Transitioning Facility Risk Issues

PGE worked with EPRI and a consultant, Decision Focus, Inc., to employ a decision analysis approach to prioritizing decommissioning alternatives. The prototype model performed a high-level economic analysis focused on timing and prioritizing decommissioning activities and understanding risks and uncertainties associated with decommissioning. Options such as SAFSTOR and DECON can be evaluated considering waste costs, timing of component removal, and radiation levels. The study also had the capability to evaluate transportation risk.

Table A.5 Trojan Licensing Actions

Permanently Defueled Technical Specifications		<u>PGE</u>	<u>NRC</u>
PGE Submittal			
Operational Requirements for Defueled Condition		3/16/93	
PGE Submittal			
Permanently Defueled Technical Specifications		7/31/93	
Federal Register Notice			11/01/93
PDTs Supplemental Information		10/28/93	
NRC Approval			12/15/93

PGE had recently completed a PRA to meet NRC IPE requirements. The PRA was under review by the NRC at the time the decision was made to shut down the plant.

To reduce radiation levels outside the RWST, the tank is kept full of water. Inside containment, all ventilation and lighting is off. Prior to anyone entering containment, the building ventilation system is turned on for a day. PGE felt no real incentive to do any upfront decontamination prior to entering SAFSTOR. About 4% of the facility was contaminated prior to SAFSTOR; the level is now around 3% and is decreasing because of natural decay processes.

The security plan before the plant was shut down encompassed a protected area and approximately 30 vital areas. There were approximately 10 areas established as critical sabotage targets. Once the plant shutdown was started, PGE reduced the number of vital areas and access to them, and re-evaluated the critical sabotage target areas.

A new long-term security plan was developed and a threat analysis was performed. An example of the matrix used in the evaluation of potential threats can be found in Table A.6.

Table A.6 Potential Threats Matrix

	Terrorist	Criminal	Psychotic	Disgruntled Employee	Demonstrator
Radiological Sabotage					
Theft					
Industrial Sabotage					
Loss of S&S Information					
Embarrassment					

0 = Very likely

1 = Possible

The sabotage targets were reviewed; sabotage scenarios were developed (there were fewer than five really probable scenarios); a review of 10 CFR 100, EPA release, and 10 CFR 73 B-H (in light of the reduction on the impact of the health and safety of the public) was done; a passive defense and response strategy was developed; a comparison was done with other similar sites; and, finally, PGE stood by its convictions.

During development of the safety plan, general considerations included the following:

- Retaining existing barriers and alarms and redesignating areas based on the contents,
- Keeping the boundaries the same for EP, RP and security areas,
- Co-assigning duties,
- Reducing service levels (i.e., "on-call" rather than "always there"), and
- Working with OPS, RP, maintenance engineering, EP, etc.

As a result of the security plan, the staffing levels went down dramatically with minimal impact on the work performed at the site.

A.10.5 Trojan Cost Increases and Uncertainty

Because the plant was shut down prematurely, Trojan has collected only about \$33 million of the estimated \$400 to \$415 million needed to decommission the site. Therefore, considerable effort has gone into repowering and other alternate site uses.

PG&E has submitted its least cost decommissioning option to the state public utility commission for review and approval. That option assumes Trojan's spent fuel will be stored

in dry casks in 1998, with immediate dismantling to follow. PG&E now expects to spend \$430 million to decommission Trojan, including radiological decontamination, disposal of hazardous wastes, demolition of several structures, and fuel management expenses. Current cost estimates to decommission Trojan radiologically are \$226 million, based on a study by TLG Engineering. This estimate does not include LLW disposal costs, demolition costs, or spent-fuel storage costs. Note that this current estimate is \$101 million more than the NRC's estimate in the draft generic report on PWR decommissioning, which used Trojan as the reference point.

The plant was shut down for economic considerations as well as political concerns. The plant's poor operating history and steam generator problems, as well as the availability of low-cost power available from neighboring Bonneville Power, led to the decision to shut down.

Spent-fuel disposal is anticipated to take 20.5 years to complete, with shipments beginning in 2012 (at the earliest - with a 12-year minimum delay). On-site dry storage of the fuel is significantly less expensive in all scenarios that were evaluated. For dry SAFSTOR, a staff of 20 is necessary, compared to 78 for wet SAFSTOR. In addition, the staff will decrease to five following demolition. One of the principal advantages of dry SAFSTOR is that there is no need to maintain and operate plant systems, which means that the annual operations and maintenance costs are 1/6 those of wet SAFSTOR. Dry storage of the fuel also puts the plant in a better position to handle delays in fuel shipment. However, dry storage requires construction of an ISFSI at \$33 million, and future decommissioning and demolition at \$5 million.

The cost of LLW disposal and storage is increasing. In February 1993, the rate charged by US Ecology was \$52.65/ft³; the rate at the time the authors received documentation was \$55.52/ft³. Future burial costs may be impacted by NUREG 1307, "Escalation of Decommissioning Waste Disposal Costs at Low-Level Waste Burial Facilities." Barnwell will add a fee of \$12.60/ft³ effective on January 1, 1994, for a Site Closure Fund. US Ecology's rates currently include a Perpetual Care and Maintenance Fee of \$1.75/ft³.

PGE has four steam generators and a pressurizer classified as Large Component Removal, with a burial volume of 48,000 ft³ (which is approximately 13% of the total decommissioning volume) and a cost estimate of \$15 million.

Decommissioning cost uncertainties are caused by the rate of escalation of burial costs, the storage period for the spent fuel, and changing NRC and other requirements. The largest cost uncertainties are associated with LLW. In 1993 dollars, the burial costs of the LLW at the Trojan Plant are \$30 million. As time passes, this estimate increases.

A.10.6 Trojan Stakeholder Concerns

The Oregon Public Utility Commission guidelines require PGE to work with the customers, regulators, and citizens interested in energy/environmental policy. PGE is required to prepare a least cost plan to meet future power needs every two years. The planning process involved creating two advisory committees - one is a TAG and the second is a PPG. The TAG includes

representatives from regulatory agencies, (industrial and residential) customer groups, the affected Indian nations, the Sierra Club, and other environmental groups. The PPG includes executives from the business and financial community, the electric utility industry, etc. These advisory committees provide technical input, policy advice, trade-offs, assumptions, etc., into the least cost plan. The least cost plan originally recommended a four-year phase-out of Trojan. However, the increased costs and loss of reliability of the plant because of steam generator tube degradation, dissenting regulatory opinion on the tube repair criteria, and increased availability and lower-than-anticipated cost of replacement power led to the immediate shutdown.

Of great importance to PG&E are gaining public acceptance and support, especially on environmental issues and regulatory support for the Decommissioning Plan.

A.10.7 Trojan Waste Minimization and Avoidance of Mixed-Waste Generation

To reduce waste, PGE proposed remelting stainless steel. In fact, PGE approached DOE with a joint proposal to perform a feasibility study to remelt contaminated stainless steel and fabricate spent-fuel containers. The effort included the Oregon Graduate Institute, Pacific Nuclear, and Teledyne Wah Chang. They were looking at a portable unit to melt and fabricate on-site.

A.10.8 Trojan Industry Involvement

Ed Abbott, of ABZ Co., calculates cost estimates for decommissioning activities similar to TLG Engineering and is challenging TLG's model. ABZ has a contract to provide cost estimates for decommissioning Calvert Cliffs.

A.10.9 Trojan Recycle and Reuse Opportunities

Trojan has established a formal asset recovery team to sell and/or dispose of surplus assets. An asset recovery plan has been created and includes a formal marketing analysis and marketing plan. The asset recovery plan is optimistic; there is a limited market for used nuclear components. Plants similar to Trojan have been identified and marketing efforts are being focused on those plants. Diablo Canyon is the plant closest to Trojan in design and age. The asset recovery plan formally established a hierarchy of decisions to maximize recovery of Trojan's assets. This hierarchy was as follows:

1. Sell the item for re-use at current market value for re-use within PG&E.
2. Return it to the supplier for cost.
3. Sell it to employees, other plants, organizations, countries, commission dealers, brokers or auction.
4. Donate it to educational or charitable organizations.
5. Scrap it.
6. Give it away.
7. Pay to dispose of it (as a last resort).

PGE reduced the number of occupied buildings from five to one and is looking at other uses for the buildings. Potential uses of the unoccupied buildings includes using them as a vocational technical school or environmental monitoring and training center. PGE also has Columbia River water rights of 55,000 gpm, an extremely valuable asset, which it does not want to give up at this time.

A.10.10 Trojan Technology Development or Enhancement Needs

No technology development or enhancement needs were identified.

A.10.11 Trojan Lessons Learned

A site radiological plan was developed to guide in the characterization of the Trojan Plant. The activities will divide into four major areas - environmental, structural, systems, and activated systems. The environmental area included outside areas such as roads, ponds, and yards. For this area, background radiation levels were measured; soil, sediment, and water samples were taken; and ambient radiation dose rates were computed. The structural area included all buildings on-site. Plant personnel determined background radiation levels and surveyed for fixed and loose radioactive material.

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Trojan staff emphasized the importance of limiting the number of survey points during radiological characterization, focusing primarily on beta/gamma surveys. However, the success of all deactivation and decommissioning activities depended on knowledge of what was present at the site.

PGE defined deactivation as the process of removing from service components, structures, or systems no longer required to support the permanently defueled plant. Because of the lack of up-front decisions making it clear that the plant would not be restarted, there was considerable confusion as to the planning for deactivation and SAFSTOR. There was a strong feeling among the employees that the plant would be restarted one way or another. It was hard for them to accept that a \$1 billion asset would be discarded and turned into a \$400 million liability for the utility.

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The use of six phases allows the deactivation process to be broken into discrete segments for which individuals are assigned responsibility. The phases provide a well-documented decision process, afford deactivation of the entire plant via 10 CFR 50.59, and provide a communication and coordination pathway between plant groups during a very dynamic period.

Deactivation activities at the plant are controlled by the same processes used when the plant was in operation. The same work control, temporary alteration, preventive maintenance, and surveillance procedures are used. In addition, daily status and work control meetings are held. A plant safety review process and corporate safety review activity are still in place.

Staffing needs are continually re-evaluated as equipment and systems are taken out of service. Initial large decreases in personnel were handled by layoffs. For example, security personnel decreased from 175 in 11/92 to 25 in 12/93. Because of the limited availability of jobs within PGE, redeployment was limited to approximately 100 people, most of whom were moved laterally or demoted. Monthly layoffs continue as the staff levels approach the near-term equilibrium level of about 200. A large number of licensed operators were able to move to TVA facilities.

PGE's initial staffing plan was based on a compromise between staffing data obtained from Rancho Seco and Yankee Rowe as well as the staffing needs requested by individual managers. Considerable discussion occurred among the senior managers regarding final staff size and composition. The initial large layoffs were based on the curtailment of power generation and the need to continue to satisfy regulatory requirements. Later layoffs were based on receiving specific license changes. To encourage people to stay for four years, a retention plan was introduced which amounted to a bonus of 30% per year for each of the four years. However, staff using this plan *took their chances*. Since there were no competing opportunities in the plant area for engineers, those who wished to stay were more willing to take a chance at not having a job the following week. Maintenance staffing reductions depended on system deactivation progress, the review and closeout of maintenance requests (they had approximately 5000), the review and reconfiguration of the preventative maintenance program (approximately 10,000 activities), and procedure revisions to reflect the plant's shutdown status. Operations staffing reductions depended on system deactivation progress, elimination of technical specifications license requirements (as a minimum, shift manning and fire brigade requirements were kept), and the procedure revisions to reflect the plant's shutdown status. Engineering staffing reductions depended on system deactivation progress, the review and closeout of design packages, drawing changes and design documents, and the deletion of engineering programs (such as ASME Section XI R&R/ISI/IST, Station Blackout, Snubbers, Appendix R, Appendix G/H, Appendix J, Appendix K, etc.). Security staffing reductions depended on the approval of a security plan for the defueled plant. QA staffing depended on the approval of a revised QA program. Administrative staffing reductions depended on streamlining the administrative processes and the overall size of the staff. Radiation protection staffing

reductions depended on the level of work activities and deactivation progress, the scope of the site characterization surveys, and approval of an emergency response plan for the defueled plant.

A draft long-term Trojan plant organization chart shows that about 105 people are needed to maintain the plant in SAFSTOR. About 60 people are required for operations, maintenance, and radiation protection, another 23 for security and administration, and 19 in licensing and QA.

PGE looked at four decommissioning scenarios: dry storage (or prompt decon - to begin in 1998), decon (1998-2002); dry storage and decon (2011-2014); dry storage and decon (2018-2021); and wet storage and decon (2018-2021).

Trojan staff emphasized the importance of having a well-established endpoint before deactivation and SAFSTOR planning begins. During the planning process, keep the perspective of "what's needed" versus "what's not needed"; be aware that the more future use options are left open, the greater the impact will be on deactivation planning; recognize that the facility will not be returned to *Greenfield*; decommissioning cleanup criteria must be defined; and a good framework for SAFSTOR and decommissioning activities must be developed at the start of the project. This allows efforts to be focused and approvals to be anticipated.

Once the POL was granted, PGE revised the emergency and fire protection plans to be consistent with the new defueled condition of the plant. There was a significant monetary savings related to reducing the scope of these plans. No off-site emergency plans, sirens, or support were kept.

The SAR was reissued and technical specifications prepared for the new plant status. The revised SAR or Defueled Safety Analysis Report (DSAR) provided a revised "design basis" for the plant on which the 10 CFR 50.59 change process could be based. Trojan went from 146 technical specifications to four and reduced training requirements. In fact, only general employee training is provided to employees.

Property insurance for the Trojan Plant averages \$4000 per day, which PGE is attempting to change since the potential hazards at the site have been reduced significantly. PGE believes that after a three-year hold period, relief from Price Anderson liability considerations may occur. The QA program has been maintained, again consistent with the plant status.

PGE worked with EPRI and a consultant, Decision Focus, Inc., to employ a decision analysis approach to prioritizing decommissioning alternatives. The prototype model performed a high-level economic analysis focused on timing and prioritizing decommissioning activities and understanding risks and uncertainties associated with decommissioning. Options such as SAFSTOR and DECON could be evaluated considering waste costs, timing of component removal, and radiation levels. The study was also capable of evaluating transportation risk.

The PRA was under review by the NRC at the time the decision was made to shut down the plant.

To reduce radiation levels outside the RWST, the tank is kept full of water. Inside containment, all ventilation and lighting is off. Prior to anyone entering containment, the building ventilation system is turned on for a day. PGE felt there was no real incentive to do any up-front decontamination prior to entering SAFSTOR. About 4% of the facility was contaminated prior to SAFSTOR. The level is now around 3% and is decreasing due to natural decay processes.

Before the plant was shut down, the security plan encompassed a protected area and approximately 30 vital areas. There were approximately 10 areas established as "critical sabotage" targets. Once the plant shutdown was started, PGE reduced the number of vital areas (and access to them) and re-evaluated the critical sabotage target areas.

A new long-term security plan was developed and a threat analysis was performed. The sabotage targets were reviewed; sabotage scenarios developed (there were fewer than five really probable scenarios); a review of 10 CFR 100, EPA release, and 10 CFR 73 B-H (in light of the reduction on the impact of the health and safety of the public) was done; a passive defense and response strategy was developed; a comparison check was made with other similar sites; and finally, PGE stood by its convictions.

When developing the safety plan, general considerations included the following:

- Retaining existing barriers and alarms and redesignating areas based on the contents,
- Keeping the boundaries the same for EP, RP, and security areas,
- Co-assigning duties,
- Reducing service levels (i.e., "on-call" rather than "always there"), and
- Working with OPS, RP, maintenance engineering, EP, etc.

As a result of the security plan, the staffing levels decreased from 175 to 110 to 36 to 25 (for fuel in wet storage). There was a minimal impact on work performed at the site.

PG&E expects to spend \$430 million to decommission Trojan, including radiological decontamination, disposal of hazardous wastes, demolition of several structures, and fuel management expenses. Current cost estimates to decommission Trojan radiologically are \$226 million, based on a study by TLG Engineering. This estimate does not include LLW disposal costs, demolition costs, or spent-fuel storage costs. Note that this current estimate is \$101 million more than the NRC's estimate in the draft generic report on PWR decommissioning, which used Trojan as the reference point.

Spent-fuel disposal is expected to take 20.5 years to complete with shipments beginning in 2012 at the earliest - with a 12-year minimum delay. On-site dry storage of the fuel is significantly less expensive in all scenarios that were evaluated. For dry SAFSTOR a staff of 20 is necessary compared to 78 for wet SAFSTOR. In addition, the staff will go to five

following demolition. One of the principal advantages of dry SAFSTOR is that there is no need to maintain and operate plant systems, which means that the annual operations and maintenance costs are 1/6 of wet SAFSTOR. Dry storage of the fuel also puts the plant in a better position to handle delays in fuel shipment. However, dry storage requires construction of an ISFSI at \$33 million and future decommissioning and demolition at \$5 million.

The cost of LLW disposal and storage is increasing. In February 1993, the rate charged by US Ecology was \$52.65/ft³; the rate at the time the authors received documentation was \$55.52/ft³. Future burial costs may be impacted by NUREG 1307, "Escalation of Decommissioning Waste Disposal Costs at Low-Level Waste Burial Facilities"; Barnwell will add a fee of \$12.60/ft³ effective on January 1, 1994, for a site closure fund. US Ecology rates currently include a perpetual care and maintenance fee of \$1.75/ft³.

Decommissioning cost uncertainties result from the rate of escalation of burial costs, the storage period for the spent fuel, and changing NRC and other requirements. The largest cost uncertainties are associated with LLW. In 1993 dollars, the burial costs of the LLW at the Trojan plant are \$30 million. As time passes, this estimate continues to increase.

An issue of great importance to PG&E is public acceptance and support for the Decommissioning Plan, especially gaining public support on environmental issues and regulatory support for the plan.

To reduce waste, PGE proposed remelting stainless steel. In fact, PGE approached DOE with a joint proposal to perform a feasibility study to remelt contaminated stainless steel and fabricate spent fuel containers. The effort included the Oregon Graduate Institute, Pacific Nuclear, and Teledyne Wah Chang. They were looking at a portable unit to melt and fabricate on site.

Trojan has established a formal asset recovery team to sell and/or dispose of surplus assets. An asset recovery plan has been created and includes a formal marketing analysis and marketing plan. The asset recovery plan is optimistic; there is a limited market for used nuclear components. Plants similar to Trojan have been identified and marketing efforts are being focused on those plants. Diablo Canyon is the plant closest to Trojan in design and age. The asset recovery plan formally established a hierarchy of decisions to maximize recovery of Trojan's assets. This hierarchy was as follows:

1. Sell the item for re-use at current market value for re-use within PGE.
2. Return it to the supplier for cost.
3. Sell it to employees, other plants, organizations, countries, commission dealers, brokers or auction.
4. Donate it to educational or charitable organizations.
5. Scrap it.
6. Give it away.
7. Pay to dispose of it (as a last resort).

Asset recovery programs may experience marginal success due to the limited market for used nuclear equipment. Sales of non-nuclear equipment, such as computers, desks, cars, etc., may be more successful.

PGE reduced the number of occupied buildings from five to one and is looking at other uses for the buildings. Potential uses of the unoccupied buildings include a vocational technical school or environmental monitoring and training center. PGE also has Columbia River water rights of 55,000 gpm, an extremely valuable asset that they do not want to give up at this time.

Trojan management felt that there was little to be gained by waiting for new technologies to "reduce" decommissioning costs; the technology is available to cut up and remove large components, and decontaminate components and structures.

A.11 Yankee Rowe

Construction of the Yankee Rowe Nuclear Power Station (YNPS) began in 1956. YNPS was placed into commercial operation in 1960. YNPS's original license expiration date was November 4, 1997; however, in 1988, the term of the license was extended to July 9, 2000, to reflect recapture of the construction period.

During its lifetime, YNPS, which was rated at 185-MWe, generated over 30 billion kwh. While operating, YNPS ranked among the top performing nuclear plants in the world by maintaining a lifetime capacity factor of over 70%.

YNPS permanently ceased power operation on February 26, 1992, mainly because of the economic outlook for the plant and the uncertainty associated with the resolution of reactor vessel integrity issues and restart of the plant. YNPS voluntarily shut down on October 1, 1991, as a result of NRC's concern regarding the unresolved reactor vessel integrity issues. The Yankee Atomic Electric Company (YAEC) indicated that it made more economic sense to close the plant than to shoulder the multi-million dollar cost of proving to the NRC that the unit's radiation weakened reactor pressure vessel could withstand a severe accident. In addition, a glut of relatively cheap power in New England made continued operation of the unit uneconomic. YAEC claimed that shutting the unit would save consumers more than \$130 million. On March 27, 1992, YAEC requested that the license for the Yankee plant be amended to a POL. On August 5, 1992, the NRC approved the requested POL amendment.

Prior to NRC approval of the POL amendment, YAEC requested and received regulatory relief on containment testing, off-site emergency planning, FSAR annual updates, shift staffing, and training and qualification of operators. Subsequent to issuance of the POL, the NRC approved technical specification amendments that allowed for the transfer of fire protection technical specifications to a manual and revision of technical specification requirements regarding the Plants Operations Review Committee.

YAEC also submitted to the NRC proposed emergency and security plans for a defueled plant, and a technical specification amendment, which transferred radiological effluent requirements into a manual. YAEC has also submitted a letter to the NRC stating that the requirements of 10 CFR 171.15 (annual fees) no longer apply. YAEC intends to submit additional regulatory relief requests regarding deletion of chemistry requirements for the main coolant system and secondary water monitoring program, and property insurance. YAEC is continuing to evaluate applicability of the financial protection requirements of Part 140, as well as other regulatory requirements to YNPS.

To support the regulatory relief requests and changes to the emergency plan and security plan, YAEC evaluated all plant systems to identify the availability and classification requirements corresponding to the permanently shutdown and defueled status. All transient analyses were reviewed to determine which design basis events applied to the permanently shutdown and defueled status and to determine what the potential consequences of such an accident would be. In addition, YAEC evaluated the likelihood and potential consequences of a loss of spent-fuel pool inventory. For purposes of the Defueled Security Plan, YAEC conducted additional radiological sabotage event analyses.

In late November 1993, YAEC took a major step toward decommissioning Yankee Rowe by shipping two of four steam generators to Chem Nuclear Systems low level radioactive waste disposal facility at Barnwell, SC. YAEC plans to move all steam generators, the pressurizer, and reactor internals to Barnwell before June 1994.

YAEC intends to submit a Decommissioning Plan to the NRC by February 1994.

A.11.1 Yankee Rowe Hazard Characterization

YAEC hopes to remove over 90% of the YNPS residual LLW (by curie content) and 15% by volume before it gets final approval from the NRC to decommission the plant.

A.11.2 Yankee Rowe Management/Programmatic Issues

As mentioned, YAEC is currently removing four steam generators, the pressurizer, and reactor internals. The schedule for completing these activities is June 1994, which coincides with the date Barnwell is expected to close to out-of-Compact generators. Note that YAEC currently plans to conduct the necessary analyses supporting certification of the steam generators and pressurizer as their own shipping containers under the provisions of 10 CFR 71.12. Timely review and approval by the NRC staff of the shipping container configuration is essential for successful project completion.

Description of the Yankee Engineering Design Change Process. YAEC plans to utilize the same engineering design change process employed during plant operation, and currently employed by YAEC, in its services to operating nuclear plants in New England. This process has been the subject of numerous NRC and industry inspections and audits. The NRC regional

office has access to all plant engineering, design, and operations procedures, records, and documentation.

The YNPS program, as defined in plant administrative and implementing procedures, will be maintained and applied to all phases of decommissioning. The Corporate Environmental Engineering Department provides input and critical review of all design changes for ALARA and Environmental issues.

YNPS Defueled Organization. The plant organization for the permanently defueled condition includes a plant superintendent with three groups reporting to him. These three groups include an administrative group, a maintenance group, and an assistant superintendent. The assistant superintendent is responsible for radiation protection, operations chemistry, etc. All key plant positions have been filled with senior level experienced individuals. YAEC plans to augment the plant staff, as necessary, by personnel from the corporate office or contractor personnel, to ensure adequate staff is available to safely complete all planned component removal activities.

YEAC will apply the existing quality assurance program requirements as defined in the *Yankee Quality Assurance Program Manual* YOQAP-1A, to all applicable portions of the design change program as currently defined in corporate project and plant procedures.

A.11.3 Yankee Rowe Requirements and Regulatory Issues

Release of the Facility for Unrestricted Use. By definition, decommissioning means to remove the facility from service safely and to remove radioactivity to residual levels permitting release of the facility for unrestricted use regardless of the decommissioning alternative chosen. None of the proposed activities will preclude the facility from being released.

Environmental Impact of the Proposed Removal Activities. The NRC requested that YAEC evaluate the environmental impact of the proposed activities relative to the conclusions in the NRC final Generic Environmental Impact Statement (GEIS) (NUREG-0586). The important GEIS conclusions, as they relate to component removal activities being considered by YAEC, are as follows:

- The environmental impact of decommissioning nuclear facilities is similar to or less than those during construction and operation.
- Both DECON and SAFSTOR are reasonable alternatives for decommissioning light water power reactors.
- The occupational exposure for DECON is higher than for SAFSTOR, but similar to routine operation.
- The higher DECON occupational exposure has marginal significance to health and safety.
- The LLW burial volume is typically less for SAFSTOR than DECON because of the decay of radioactivity from the time the plant shuts down until final

dismantlement begins (burial volume reduction is recognized in the GEIS after a 50-year SAFSTOR period). This benefit is not uniquely compelling when selecting a decommissioning alternative.

In 1988, the NRC amended the YNPS facility operating license to permit operation for a full 40 years from the date of issuing the operating license. In the proposed documentation, YAEC provided the NRC staff with an ER that addressed all important aspects of the environmental impact from operation of YNPS, including plant modifications. In granting the license extension, the NRC concluded in its environmental assessment that the plant had operated for more than 27 years with no significant radiological or nonradiological impacts and that the proposed extension would not have any significant impact on the environment.

The NRC environmental assessment included an evaluation of the following considerations:

- Radiological Impacts of the Hypothetical Design Basis Accident
- Radiological Impacts - Annual Releases
- Environmental Impact of the Uranium Fuel Cycle
- Nonradiological Impacts
- Plant Modifications

These licensing basis considerations are evaluated in the YAEC 10 CFR 50.59 design change process, which is being implemented for the component removal activities currently in progress. It is fully expected that the environmental impact of the component removal activities will be bounded by the conclusions in the EIS for the following reasons:

1. The GEIS conclusions are based in part on the assumption that programs and procedures to minimize environmental impact during plant operation are fully effective during decommissioning. YAEC will ensure that these programs are maintained during all phases of decommissioning.
 - a. Occupational exposure at YNPS is controlled through existing programs and procedures. The design change process ensures that ALARA considerations are integrated into the final design and implementation plan from the outset. The radiation protection and ALARA programs used during plant operation will continue through all phases of decommissioning.
 - b. The YNPS Environmental Monitoring Program will continue to be implemented through all phases of decommissioning. Plant effluent discharges will continue to be controlled and monitored under existing programs and procedures.
 - c. Both liquid and solid radwaste processing, handling, packaging, and transportation will continue to be controlled by existing programs and procedures.
2. The potential environmental impacts of postulated accidents are thoroughly evaluated and documented during the design change development process. The

safety evaluation, conducted in accordance with 10 CFR 50.59 and in conjunction with the design change development, will ensure that the proposed activities requiring NRC approval prior to implementation are properly identified and documented.

3. The activities under consideration have been completed under 10 CFR 50.59 by operating facilities using a process similar to the YAEC design change process.

A.11.4 Yankee Rowe Transitioning Facility Risk Issues

YAEC is removing the components under 10 CFR 50.59, which allows utilities to remove and dispose of major equipment without first obtaining NRC permission, bypassing any opportunity for a formal public hearing. YAEC concluded that it could proceed with component removal since the activity was not one that required NRC approval prior to implementation for one or more of the following reasons:

- The activity is determined to involve an unreviewed safety question as defined in 10 CFR 50.59,
- The activity requires a change to the plant technical specifications,
- The activity will substantially increase the cost of decommissioning the facility, or The activity materially or demonstrably affects the options available for decommissioning the facility or may affect the ability to release the site for unrestricted use.

Decommissioning Option Foreclosure. The NRC has concluded in its GEIS on decommissioning that both DECON and SAFSTOR are reasonable alternatives for decommissioning commercial light water reactor facilities. Although there are advantages and disadvantages to either option, none is compelling enough to cause either option to be preferred from an environmental impact perspective.

The choice of a particular decommissioning alternative is generally driven by influences such as the availability of funds to complete decommissioning, the availability of a LLW disposal facility for decommissioning wastes, or safety issues associated with decommissioning a unit at a multi-unit site. The multi-unit site issue is clearly not applicable to YNPS and will not be discussed further. The impact of the remaining two considerations on public health and safety is discussed below.

The availability of sufficient funds could adversely affect a licensee's ability to decommission the facility safely. It may be necessary to SAFSTOR the facility until adequate funds are available to ensure completion of the process. YAEC will continue to ensure that adequate funds are available to complete all plant closure and decommissioning activities safely.

Although sufficient funds may be available to complete decommissioning, a LLW site may not be available for disposal of decommissioning waste. This is the primary reason for YAEC's

decision to SAFSTOR YNPS until the year 2000. Until recently, access to all of the existing LLW burial facilities was closed to out-of-Compact generators, such as YNPS, beyond January 1, 1993. The State of South Carolina has recently indicated that the Barnwell facility will remain open to Massachusetts generators through June 30, 1994. This decision allowed YAEC to consider equipment removal and disposal activities designed to take full advantage of the burial site availability.

In discussing component removal activities with the NRC, the staff questioned whether an activity such as removal of steam generators would preclude the SAFSTOR option because the component is no longer stored within the confines of the containment building. If such an activity were to be viewed in such a literal sense, then removal of any component (regardless of its characteristics) would indeed preclude the SAFSTOR option. Therefore, no component removal activities could be conducted prior to approval of the Decommissioning Plan. Finally, as a practical matter, component removals are safely performed for operating reactors, and it seems logical to conclude that in the permanent plant shutdown condition, the components can be removed as safely.

The primary objective of the SAFSTOR alternative is to preclude inadvertent public exposure or inadvertent spread of contamination while awaiting final dismantlement. This objective remains as long as the plant contains radioactivity above residual levels permitting unrestricted use of the facility. This safety objective continues until the final radiation surveys are completed to demonstrate that the radioactivity has been removed to residual levels permitting unrestricted use of the facility. Therefore, appropriate controls, programs, procedures, systems, structures, and components necessary to preclude inadvertent exposure or spread of contamination must be maintained until the site is released for unrestricted use.

Removal of these components does not foreclose the SAFSTOR option since the need to protect the worker, the public, and the environment will remain after the components are removed and until the site has been restored to residual levels permitting unrestricted use of the facility and termination of the license.

Fundamental to this discussion is that either decommissioning alternative, DECON or SAFSTOR, is acceptable provided it is implemented in a way that protects the public, the worker, and the environment during execution, and ultimately results in release of the facility for unrestricted use. The choice of either alternative will generally be made because of extenuating circumstances surrounding a licensee's unique situation at the time the decision is made to cease power operations and begin decommissioning.

In reality, the decommissioning alternatives defined and evaluated in the GEIS have identical safety objectives, and with both alternatives, ultimate site release goals are met. Under the POL authority, these objectives can be satisfied for many decommissioning activities prior to approval of the decommissioning plan.

A.11.5 Yankee Rowe Cost Increases and Uncertainties

YAEC intends to access the YNP \$100 million decommissioning fund to pay for legitimate decommissioning activities such as the Barnwell disposal. This is consistent with fund access requirements as specified in the YNPS Decommissioning Fund Trust Document, which was previously provided to the NRC for review.

The fund will not be reduced below an amount estimated to place the plant in a safe condition at any time during plant modifications.

YAEC is presently in the process of collecting all of the funds needed to complete decommissioning of YNPS. Furthermore, YAEC has in place the assurance necessary to guarantee that all costs of decommissioning are paid, whether or not funds are accessed prior to approval of a decommissioning plan. In particular, YAEC has approved power contracts which assure collection of all funds needed prior to final dismantlement.

The cost of disposing of the steam generators, the pressurizer, and reactor internals is estimated to be about \$30 million. YAEC estimates the cost of decommissioning YNPS to *Greenfield* at about \$27 million, including \$60 million for dry cask storage of spent fuel.

A.11.6 Yankee Rowe Stakeholder Concerns

The YAEC Public Affairs Department is currently developing a comprehensive public information program regarding decommissioning activities. The program will include the following:

- Meetings with local, state, and federal elected officials,
- Meetings with representatives of federal, state, and local agencies responsible for public health and safety,
- Public information forum(s) held in the vicinity of the plant site,
- Briefings to the local, regional, and/or national news media, and
- Slide presentation(s), information packets, and news media kits.

YAEC will ensure dissemination of information to elected officials, general public, and news media regarding activities that YAEC believes would elicit public interest. In addition, YAEC will be working with the administration of the Greenfield Community College to improve the organization and documentation access capabilities in the Public Document Room at the college.

The shipping of the two steam generators to Barnwell in November 1993 generated some public interest and concerns, as evidenced by about 50 protesters following the dedicated shipment train. Protestors were from the Citizens Awareness Network and Greenpeace International.

A.11.7 Yankee Rowe Waste Minimization and Avoidance of Mixed-Waste Generation

No information was obtained that specifically addressed waste minimization and avoidance of mixed waste generation.

A.11.8 Yankee Rowe Industry Involvement

No information was obtained that addressed industry involvement.

A.11.9 Yankee Rowe Recycle and Reuse Opportunities

No information was obtained that discussed recycle and reuse opportunities.

A.11.10 Yankee Rowe Technology Development or Enhancement Needs

No information on technology development or enhancement needs was obtained.

A.11.11 Yankee Rowe Lessons Learned

Prior to NRC approval of the POL amendment, YAEC requested and received regulatory relief on containment testing, off-site emergency planning, FSAR annual updates, shift staffing, and training and qualification of operators. Subsequent to issuance of the POL, the NRC approved technical specification amendments that allowed for the transfer of fire protection technical specifications to a manual and revision of technical specification requirements regarding the Plants Operations Review Committee.

YAEC also submitted to the NRC a proposed Defueled Emergency Plan, a proposed Defueled Security Plan, and a technical specification amendment, which transferred radiological effluent requirements into a manual. YAEC has also submitted a letter to the NRC stating that the requirements of 10 CFR 171.15 (annual fees) no longer apply. YAEC intends to submit additional regulatory relief requests.

To support the regulatory relief requests and changes to the emergency and security plans, YAEC evaluated all plant systems to identify the availability and classification requirements corresponding to the permanently shutdown and defueled status. All transient analyses were reviewed to determine which design basis events applied to the permanently shutdown and defueled status and to determine what the potential consequences of such an accident would be. In addition, YAEC evaluated the likelihood and potential consequences of a loss of spent-fuel pool inventory. For purposes of the security plan for a defueled plant, YAEC conducted additional radiological sabotage event analyses.

YAEC plans to utilize the same engineering design change process employed during plant operation and currently employed by YAEC in its services to nuclear plants operating in New

England. The YNPS Program, as defined in plant administrative and implementing procedures, will be maintained and applied to all phases of decommissioning.

The plant organization for the permanently defueled condition includes a plant superintendent with three groups reporting to him. These three groups include an administrative group, a maintenance group, and an assistant superintendent. The assistant superintendent is responsible for radiation protection, operations chemistry, etc. All key plant positions have been filled with senior-level experienced individuals. YAEC plans to augment the plant staff as necessary with personnel from the corporate office or contractor personnel to ensure adequate staff is available to complete all planned component removal activities safely.

By definition, decommissioning means to remove the facility safely from service and to remove radioactivity to residual levels permitting release of the facility for unrestricted use regardless of the decommissioning alternative chosen. None of the proposed activities will preclude the facility from being released.

The NRC requested that YAEC evaluate the environmental impact of the proposed activities relative to the conclusions in the NRC Final Generic Environmental Impact Statement (GEIS), (NUREG-0586). The important GEIS conclusions, as they relate to component removal activities being considered by YAEC, are discussed below.

In the GEIS, the NRC concluded the following:

- The environmental impact of decommissioning nuclear facilities is similar to or less than those during construction and operation.
- Both DECON and SAFSTOR are reasonable alternatives for decommissioning light water power reactors.
- The occupational exposure for DECON is higher than for SAFSTOR, but similar to routine operation.
- The higher DECON occupational exposure has marginal significance to health and safety.
- The LLW burial volume is typically less for SAFSTOR than DECON because of the decay of radioactivity from the time the plant shuts down until final dismantlement begins (burial volume reduction is recognized in the GEIS after a 50-year SAFSTOR period). This benefit is not uniquely compelling when selecting a decommissioning alternative.

It is fully expected that the environmental impact of the component removal activities will be bounded by the conclusions in the EIS for the following reasons:

1. The GEIS conclusions are based in part on the assumption that programs and procedures designed to minimize environmental impact during plant operation are fully effective during decommissioning. YAEC will ensure that these programs are maintained during all phases of decommissioning.

- a. Occupational exposure at YNPS is controlled through existing programs and procedures. The design change process ensures that ALARA considerations are integrated into the final design and implementation plan from the outset. The Radiation Protection and ALARA programs used during plant operation will continue through all phases of decommissioning.
 - b. The YNPS Environmental Monitoring Program will continue to be implemented through all phases of decommissioning. Plant effluent discharges will continue to be controlled and monitored under existing programs and procedures.
 - c. Both liquid and solid radwaste processing, handling, packaging, and transportation will continue to be controlled by existing programs and procedures.
2. The potential environmental impacts of postulated accidents are thoroughly evaluated and documented during the design change development process. The safety evaluation, conducted in accordance with 10 CFR 50.59 and in conjunction with the design change development, will ensure that the proposed activities requiring NRC approval prior to implementation are properly identified and documented.
3. The activities under consideration have been completed under 10 CFR 50.59 by operating facilities using a process similar to the YAEC design change process.

YAEC is removing the components under 10 CFR 50.59, which allows utilities to remove and dispose of major equipment without first obtaining NRC permission, bypassing any opportunity for a formal public hearing. YAEC concluded that they could proceed with component removal since the activity was not one which required NRC approval prior to implementation for one or more of the following reasons:

- The activity is determined to involve an unreviewed safety question as defined in 10 CFR 50.59,
- The activity requires a change to the Plant Technical Specification,
- The activity will substantially increase the cost of decommissioning the facility, or
- The activity materially or demonstrably affects the options available for decommissioning the facility or may affect the ability to release the site for unrestricted use.

The NRC has concluded in its GEIS on decommissioning that both DECON and SAFSTOR are reasonable alternatives for decommissioning commercial light water reactor facilities. Although there are advantages and disadvantages to either option, none is compelling enough to cause either option to be preferred from an environmental impact perspective.

The choice of a particular decommissioning alternative is generally driven by influences such as the availability of funds to complete decommissioning, the availability of a LLW disposal

facility for decommissioning wastes, or safety issues associated with decommissioning a unit at a multi-unit site. The multi-unit site issue is clearly not applicable to YNPS and will not be discussed further. The impact of the remaining two considerations on public health and safety is discussed below.

The availability of sufficient funds could adversely affect a licensee's ability to decommission the facility safely. It may be necessary to SAFSTOR the facility until adequate funds are available to ensure completion of the process.

Although sufficient funds may be available to complete decommissioning, a LLW site may not be available for disposal of decommissioning waste. This is the primary reason for YAEC's decision to SAFSTOR YNPS until the year 2000. Until recently, access to all of the existing LLW burial facilities was closed to out-of-Compact generators such as YNPS beyond January 1, 1993. The State of South Carolina has recently indicated that the Barnwell facility will remain open to Massachusetts generators through June 30, 1994. This decision allowed YAEC to consider equipment removal and disposal activities designed to take full advantage of the burial site availability.

In discussing component removal activities with the NRC, the staff questioned whether an activity such as removal of steam generators would preclude the SAFSTOR option because the component is no longer stored within the confines of the containment building. If such an activity were to be viewed in such a literal sense, then removal of any component, regardless of its characteristics, would indeed preclude the SAFSTOR option. Therefore, no component removal activities could be conducted prior to approval of the decommissioning plan. Finally, as a practical matter, component removals are safely performed for operating reactors. It seems logical to conclude that in the permanent plant shutdown condition, the components can be removed as safely.

The primary objective of the SAFSTOR alternative is to preclude inadvertent public exposure or inadvertent spread of contamination while awaiting final dismantlement. This objective remains as long as the plant contains radioactivity above residual levels permitting unrestricted use of the facility. This safety objective continues until the final radiation surveys are completed to demonstrate that the radioactivity has been removed to residual levels permitting unrestricted use of the facility. Therefore, appropriate controls, programs, procedures, systems, structures, and components necessary to preclude inadvertent exposure or spread of contamination must be maintained until the site is released for unrestricted use.

Removal of these components does not foreclose the SAFSTOR option since the need to protect the worker, the public, and the environment will remain after the components are removed and until the site has been restored to residual levels permitting unrestricted use of the facility and termination of the license.

Fundamental to this discussion is the fact that either decommissioning alternative, DECON or SAFSTOR, is acceptable provided it is implemented in a way that protects the public, the

worker, and the environment during execution, and that ultimately results in release of the facility for unrestricted use. The choice of either alternative will generally be made because of extenuating circumstances surrounding a licensee's unique situation at the time the decision is made to cease power operations and begin decommissioning.

In reality, the decommissioning alternatives defined and evaluated in the GEIS have identical safety objectives, and with either alternative ultimate site release goals are met.

Under the POL authority, these objectives can be satisfied for many decommissioning activities prior to approval of the decommissioning plan.

YAEC estimates the cost of decommissioning YNPS to *Greenfield* at about \$27 million, including \$60 million for dry cask storage of spent fuel.

The YAEC Public Affairs Department is currently developing a comprehensive public information program regarding decommissioning activities. The program will include the following:

1. Meetings with local, state, and federal elected officials,
2. Meetings with representatives of federal, state, and local agencies responsible for public health and safety,
3. Public information forum(s) held in the vicinity of the plant site,
4. Briefings to the local, regional, and/or national news media, and
5. Slide presentation(s), information packets, and news media kits.

YAEC will ensure dissemination of information to elected officials, the general public, and news media regarding activities which YAEC believes would elicit public interest. In addition, YAEC will be working with the administration of the Greenfield Community College to improve the organization and documentation access capabilities in the Public Document Room at the college.

The shipping of the two steam generators to Barnwell in November 1993 generated some public interest and concerns, as evidenced by about 50 protesters following the dedicated shipment train. Protestors were from the Citizens Awareness Network and Greenpeace International.

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APPENDIX B

Fort St. Vrain Applicable Regulations, Regulatory Guidance, and Industry Standards

10 CFR ENERGY Part	Title
1	Statement of Organization and General Information
2	Rules of Practice for Domestic Licensing Proceedings
19	Notices, Instructions, and Reports to Workers; Inspections
20	Standards for Protection Against Radiation
21	Reporting of Defects and Noncompliance
50	Domestic Licensing of Production and Utilization Facilities
51	Licensing and Regulatory Policy and Procedures for Environmental Protection
61	Licensing Requirements for Land Disposal of Radioactive Waste
70	Domestic Licensing of Special Nuclear Material
71	Packaging of Radioactive Material for Transport and Transportation of Radioactive Material Under Certain Conditions
72	Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste
73	Physical Protection of Plants and Materials
100	Reactor Site Criteria
140	Financial Protection Requirements and Indemnity Agreements
150	Exemptions and Continued Regulatory Authority in Agreement States Under Section 274
170	Fees for Facilities and Materials Licenses and Other Regulatory Services Under the Atomic Energy Act of 1954
30	Rules of General Applicability to Domestic Licensing of By- Product Material

ANSI STANDARDS Part	Title
A10.6 - 1983	Demolition operations - Safety requirements
N13.12	Control of Radioactive Surface Contamination of Materials, Equipment, and Facilities To Be Released for Uncontrolled Use (Aug. 1981)
N14.10	Administrative Guide for Packaging and Transportation of Radioactive Material (1973)
N15.26	Physical Protection of Special Nuclear Materials Within a Facility
N18.1 - 1971	Personnel Selection & Training Reg. Guide 1.8
N18.17 - 1973	Security
Z88.2	Practices for Respiratory Protection (1980)
N45.2.6 - 1973	Inspection & Test Qualification Reg. Guide 1.58
N45.2.9 - 1974	Records - Reg. Guide 1.88
N45.2.10 - 1973	Terminology - Reg. Guide 1.74
N45.2.12 - 1974	Audit - Reg. Guide 1.144
N45.2.13 - 1976	Procurement
N45.2.23	Qualification of Audit Personnel - Reg. Guide 1.146
ANSI/ANS -3.1 - 1981	Selection, Qualification, and Training of Personnel for Nuclear Power Plants.

REGULATORY GUIDES Part	Title
1.8	Personnel Selection and Training
1.16	Reporting of Operational Information - Appendix A, Technical Specifications
1.17	Protection of Nuclear Plants Against Industrial Sabotage
1.21	Measuring, Evaluating, and Reporting Radioactivity in Solid Waste and Releases of Radioactive Material in Liquid and Gaseous Effluents from Light-Water- Cooled Nuclear Power Plants
1.33	QA Operational Program - Implementing ANSI/NQA
1.58	Qualification of Nuclear Power Plant Inspection, Examination and Testing Personnel
1.86	Termination of Operating Licenses for Nuclear Reactors
1.88	Power Plant Quality Assurance Records
1.109	Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents
1.144	Auditing of Quality Assurance Programs for Nuclear Power Plants
1.145	Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants
1.146	Qualification of QA Program Audit Personnel for Nuclear Power Plants
3.42	Emergency Planning for Fuel Cycle Facilities and Plants Licensed Under 10CFR50 and 70
3.65	Standard Format and Content of Decommissioning Plans for Licenses Under 10CFR Parts 30, 40, and 70

REGULATORY GUIDES Part	Title
4.15	Quality Assurance for Radiation Monitoring Programs
5.7	Control of Personnel Access to Protected Areas, Vital Areas, and Material Access Areas
5.14	Visual Surveillance of Individuals in Material Access Areas
5.43	Plant Security Force Duties
5.47	Control and Accountability of Plutonium in Waste Material
7.1	Administrative Guide for Packaging and Transportation of Radioactive Material
7.2	Procedure for Picking Up and Receiving Packages of Radioactive Material
7.7	Administrative Guide for Verifying Compliance with Packaging Requirements for Shipments of Radioactive Material
7.9	Standard Format and Content of part 71, Applications for Approval of Packaging of Type B, Large Quantity, and Fissile Radioactive Materials
7.10	Quality Assurance for Packing Used in Transportation
8.2	Guide for Administrative Practices in Radiation Monitoring
8.3	Film Badge Performance Criteria
8.4	Direct-Reading and Indirect-Reading Pocket Dosimeters
8.6	Standard Test Procedure for Geiger-Muller Counters
8.7	Occupational Radiation Exposure Records System
8.8	Information Relevant to Ensuring that Occupational Radiation Exposures at Nuclear Power Stations will be as low as Reasonably Achievable

REGULATORY GUIDES Part	Title
8.9	Acceptable Concepts, Models, Equations, and Assumptions for a Bioassay Program
8.10	Operating Philosophy for Maintaining Occupational Radiation Exposures as Low as Reasonably Achievable
8.15	Acceptable Programs for Respiratory Protection
8.20	Application of Bioassay for I-125 and I-131
8.25	Calibration and Error Limits of Air Sampling Instruments for Total Volume of Air Sampled
8.26	Application of Bioassay for Fission and Activation Products
8.29	Instructions Concerning Risks from Occupational Radiation Exposure
1.159	Assuring the Availability of Funds for Decommissioning Nuclear Reactors
DG-1005	Standard Format and Content for Decommissioning Plans
DG-1006	Records Important for Decommissioning
DG-3001	Records Important for Decommissioning for Licenses Under 10CFR Parts 30, 40, 70 and 72
DG-3002	Standard Format and Content of Financial Assurance Mechanisms Required for Decommissioning Under 10 CFR Parts 30, 40, 70 and 72

NUREG and NUREG/CR	Title
NUREG-0041	Manual of Respiratory Protection Against Airborne Radioactive Wastes
NUREG-0172	Age Specific Radiation Dose Commitment Factors for a One-Year Chronic Intake
NUREG-0554	Single-Failure-Proof Cranes for Nuclear Power Plants
NUREG-0584	Financial
NUREG-0586	Final Environmental Impact Statement on Decommissioning Nuclear Reactors
NUREG-0612	Control of Heavy Loads at Nuclear Power Plants
NUREG-0613 (Draft 10/79)	Residual Radioactivity Limits for Decommissioning
NUREG-0654	Criteria for Preparation and Evaluation of RERP's and Preparedness
NUREG-0696	Functional Criteria for Emergency Response Facilities
NUREG-0761	Radiation Protection Plans for Nuclear Power Reactor Licensee
NUREG-0767	Criteria for Selection of Fuel Cycle and Major Materials Licenses Needing Radiological Contingency Plans
NUREG-0800	Standard Review Plan
NUREG-1221	Comments on Decommissioning Rule
NUREG-1307	Waste Buried Charges
NUREG-1407 (Draft)	Individual Plant Examination of External Events (IPEEE)
NUREG/CR 0130	Financial
NUREG/CR 0569	Facilitation of Decommissioning

NUREG and NUREG/CR	Title
NUREG/CR 0672	Financial
NUREG/CR 1370	Financial
NUREG/CR 1481	Financial
NUREG/CR 1755	Financial
NUREG/CR 1756	Financial
NUREG/CR 2082	Terminal Radiation Survey
NUREG/CR 2241	Terminal Radiation Survey
NUREG/CR 2370	Insurance
NUREG/CR 3293	Technology, Safety, and Costs of Decommissioning Reference Nuclear Fuel Cycle and Non-Fuel Cycle Facilities Following Postulated Accidents
NUREG/CR 3474	Long-Lived Activation Products in Reactor Materials
NUREG/CR 3587	Facilitation Techniques
NUREG/CR 3899	Supp. 1 (Financial)
NUREG/CR 4289	Residual Radiation
NUREG/CR 4519	Technology, Safety, and Costs of Decommissioning Reference Nuclear Fuel Cycle Facilities
NUREG/CR 5512	Residual Radioactive Contamination Levels from Decommissioning

ASME, BTP, NRC Generic Letters, NEPA, and Others	Title
EPA-520/1-75-001A	Manual of Protective Action Guides and Protective Actions for Nuclear Incidents
	FERC
BTP ASB 9.5-1	Guidelines for Fire Protection for Nuclear Power Plants
ASME SECT III	NATD ASME Quality Program
ASTM-E 119-88	Standard Test Methods for Fire Tests of Building Construction and Materials
ASTM STND E 1034	Specification for Nuclear Facility Transient Worker Records
ASTM STND E 1167-87	Guide for Radiation Protection Program for Decommissioning Operations
ASTM STND E 1168	Guide for Radiological Protection Training for Nuclear Facility Workers
ASTM STND E 1281-89	Standards Guide for Nuclear Facility Decommissioning Plans
DOE 89-10	Waste Isolation Pilot Plant Integrated Risk Assessment
DOE Order 5820.2	Radioactive Waste Management, Chapter V, Decontamination and Decommissioning of Surplus Facilities
EPRI NP-2005	Tornado Missile Simulation and Design Methodology, Volume 2: Model Verification and Data Base Updates
Generic Letter 89-02	Commercial Grade Components
Info. Notice 85-92	Surveys of Wastes Before Disposal from Nuclear Reactor Facilities
NFPA	Special Analysis: Heavy Truck Fires (1982-1986)
NOAA NWS-33	Evaporation Atlas for the 48 contiguous United States (NOAA Technical Report)
NRC Circ 87-07	Control of Radioactively Contaminated Material
SNT-TC-1A	Society for Nondestructive Testing Guidelines for Qualification of NDT Personnel
	NRC Policy Statement: Below Regulatory Concern

1. Occupational Safety and Health Standards

Subpart A - General:

- 29 CFR Part 1910.1 - Purpose and Scope - 31:4102
- 29 CFR Part 1910.2 - Definitions - 31:4102
- 29 CFR Part 1910.5 - Applicability of Standards - 31:4103

Subpart B - Adoption and Extension of Established Federal Standards:

- 29 CFR Part 1910.19 - Special Provisions for Air Contaminants - 31:4304

Subpart C - General Safety and Health Provisions:

- 29 CFR Part 1910.20 - Access to Employee Exposure and Medical Records - 31:4501

Subpart E - Means of Egress:

- 29 CFR Part 1910.38 - Employee Emergency Plans and Fire Prevention Plans - 31:5103

Subpart G - Occupational Health and Environmental Control:

- 29 CFR Part 1910.94 - Ventilation - 31:5343
- 29 CFR Part 1910.96 - Ionizing Radiation - 31:5368
- 29 CFR Part 1910.97 - Nonionizing Radiation - 31:5372
- 29 CFR Part 1910.98 - Effective Dates - 31:5373
- 29 CFR Part 1910.99 - Sources of Standards - 31:5373
- 29 CFR Part 1910.100 - Standards Organizations - 31:5373

Subpart H - Hazardous Materials:

- 29 CFR Part 1910.120 - Hazardous Waste Operations and Emergency Response - 31:5573

Subpart I - Personal Protective Equipment:

- 29 CFR Part 1910.134 - Respiratory Protection - 31:5801

Subpart Z - Toxic and Hazardous Substances:

- 29 CFR Part 1910.1000 - Air Contaminants - 31:8103
- 29 CFR Part 1910.1001 - 1048 - Various Contaminants
- 29 CFR Part 1910.1101 - Asbestos - 31:8801
- 29 CFR Part 1910.1200 - Hazard Communication - 31:9101
- 29 CFR Part 1910.1450 - Occupational Exposures to Hazardous Chemicals in Laboratories
- 29 CFR Part 1910.1499 - Source of Standards - 31:8803
- 29 CFR Part 1910.1500 - Standards Organizations - 31:8803

Part 1926 - Safety and Health Regulations for Construction

Subpart D - Occupational Health and Environmental Controls

- 29 CFR Part 1926.53 - Ionizing Radiation - 31:3114
- 29 CFR Part 1926.54 - Nonionizing Radiation - 31:3114
- 29 CFR Part 1926.55 - Gases, Vapors, Fumes, Dust, and Mists - 31:3114
- 29 CFR Part 1926.57 - Ventilation - 31:3115
- 29 CFR Part 1926.58 - Asbestos, Tremolite, Anthophyllite and Actinolite - 31:3116
- 29 CFR Part 1926.59 - Hazard Communication - 31:3116.34

Subpart E - Personal Protective and Life Saving Equipment

- 29 CFR Part 1926.103 - Respiratory Protection - 31:3116.34 (1910.94 and 1910.134 apply to 1926.103 - 31:3117)

Subpart J - Welding and Cutting

- 29 CFR Part 1926.353 - Ventilation and Protection in Welding, Cutting, and Heating - 31:3146

2. Hazardous Substance Programs

A. Resource, Conservation, and Recovery Act (RCRA) and the Implementing Regulations

B. Solid and Hazardous Wastes:

- 40 CFR Part 260 - Hazardous Waste Management System - General
- 40 CFR Part 261 - Identification and Listing of Hazardous Wastes
- 40 CFR Part 262 - Standards Applicable to Generators of Hazardous Wastes
- 40 CFR Part 263 - Standards Applicable to Transporters of Hazardous Wastes
- 40 CFR Part 264 and 265 - As they apply to SQG's and LQG's
- 40 CFR Part 266 - Standards for the Management of Specific Hazardous Wastes
- 40 CFR Part 268 - Land Disposal Restrictions
- 6 CCR 1007-3, Part II - Colorado Rules and Regulations Pertaining to Hazardous Waste in addition to the Federal Requirements

C. Toxic Substances Control Act (TSCA) and the Implementing Regulations

PCB's:

- 40 CFR Part 761 - All - EPA Rules for Controlling PCB/s under TSCA

D. The Hazardous Materials Transportation Act and Implementing Regulations

- 49 CFR Parts 171, 172, 173, and 177
- 49 CFR Parts 383, 390-397, and 399
- Emergency Response Guidebook
- 4 CCR Part 723-17 and 18
- 8 CCR Part 1507-1, 7 through 9
- Colorado Hazardous Materials Route Designation Map
- 49 CFR Part 263 - Standards Applicable to Generators of Hazardous Waste

E. Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and Implementing Regulations

Most Important Sections of CERCLA:

- National Oil and Hazardous Substances Pollution Contingency Plan
- National Priorities List
- EPA Designation, Reportable Quantities, and Notification Requirements for Hazardous Substances under CERCLA, 40 CFR Part 302.

F. Oil Spill Plans - Federal Water Pollution Control Act

- Materials Containment Plans - Colorado, Section 6.9.3 (5) and 6 (6) - Regulations for the State Discharge Permit System
- 33 CFR Part 153 - Oil and Hazardous Substance Discharge Reporting Requirements (Coast Guard /DOT)
- 40 CFR Part 110 - EPA Discharge of Oil
- 40 CFR part 112 - Oil Spill Prevention

3. **Water Quality Programs**

A. Federal Water Pollution Control Act and the Implementing Regulations

Water Discharge Permits

- 40 CFR Part 122 - National Pollutant Discharge Elimination System - Federal Regs, Volume 3, Page 131:1001
- 40 CFR Part 125 - Criteria and Standards for the NPDES System - Federal Regs, Volume 3, Page 131:2501
- 40 CFR Part 401 - EPA General Provisions for Effluent Guidelines and Standards - Federal Regs, Volume 4, Page 135:0101
- 40 CFR Part 423 - EPA Guidelines and Standards for Steam Electric Power Generating - Federal Regs, Volume 4, Page 135:0541
- 5 CCR 1002-2 - State Discharge Permit System
- 5 CCR 1002-3 - Effluent Limitations
- 5 CCR 1002-8 - Water Quality Standards and Stream Classifications

B. The Safe Drinking Water Act (SDWA) and the Implementing Regulations

Drinking Water:

- 40 CFR Parts 141, 142, 143 - Primary and Secondary Drinking Water Regulations
- 40 CFR Parts 144-148 - EPA Underground Injection Control Program
- 5 CCR 1003-1 - State Drinking Water Regs

4. Air Quality Programs

A. The Clean Air Act (CAA) and the Implementing Regulations

Air Quality:

- 40 CFR Part 60 - New Source Performance Standards - Federal Regs, Volume 1, page 120:0301, especially Subparts A, B, C, D, Da, K, Ka, Kb, GG
- 40 CFR Part 61 - National Emissions Standards for Hazardous Air Pollutants - Federal Regs, Volume 1, page 120:1001, especially Subparts A, E, H, J, M, V
- 40 CFR Part 50 - Primary and Secondary Ambient Air Quality Standards - Federal Regs, Volume 2, page 121:0101
- 40 CFR Part 53 - Ambient Air Monitoring Monitoring Reference and Equivalent Methods - Federal Regs, Volume 2, page 121:1341
- 40 CFR Part 81 - Attainment/Non-attainment Areas - Federal Regs, Volume 2, page 121:0901, especially Sections 81:16, Denver, 81, 306, Colorado, 81:406, Colorado Class I Visibility
- 40 CFR Part 58 - Ambient AQ Surveillance Regs - Federal Regs, Volume 2, page 121:2301
- 40 CFR Part 51 - Preparation of State Implementation Plans - Federal Regs, Volume 2, page 125:0101, especially Subpart G - Colorado, page 125:0801
- 5 CCR 1001-2 - Common Provisions Regulations
- 5 CCR 1001-3 - Reg 1, Particulates, Smokes, Carbon Monoxide, and Sulfur Oxides
- 5 CCR 1001-5 - Reg 3, Air Contaminant Emission Notices
- 5 CCR 1001-8 - Reg 6, Standards of Performance for New Stationary Services
- 5 CCR 1001-9 - Reg 7, Volatile Organic Compounds
- 5 CCR 1001-10 - Reg 8, Control of Hazardous Air Pollutants
- 5 CCR 1001-12 - Reg 10, Conformity with Regs
- 5 CCR 1001-14 - Ambient Air Quality Standards

5. Transportation

- 49 CFR Parts 170-189

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