NUREG-0586, Supplement 1
Volume 1

Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities

Supplement 1

Regarding the Decommissioning of Nuclear Power Reactors

Main Report, Appendices A through M

Final Report

U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Washington, DC 20555-0001

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Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
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Abstract

This document is a supplement to the U.S. Nuclear Regulatory Commission (NRC) document *Final Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities* issued in 1988 (NUREG-0586, referred to here as the 1988 Generic Environmental Impact Statement [GEIS]). This Supplement was prepared because of technological advances in decommissioning operations, experience gained by licensees, and changes made to NRC regulations since the 1988 GEIS.

This Supplement updates the information provided in the 1988 GEIS. It is intended to be used to evaluate environmental impacts during the decommissioning of nuclear power reactors as residual radioactivity at the site is reduced to levels that allow for termination of the NRC license. This Supplement addresses only the decommissioning of nuclear power reactors licensed by the NRC. It updates the sections of the 1988 GEIS relating to pressurized water reactors, boiling water reactors, and multiple reactor stations. It goes beyond the 1988 GEIS to explicitly consider high-temperature gas-cooled reactors and fast breeder reactors. This document can be considered a stand-alone document for power reactor facilities such that readers should not need to refer back to the 1988 GEIS. The environmental impacts described in this Supplement supercede those described for power reactor facilities in the 1988 GEIS.

The scope of this Supplement is based on the decommissioning activities performed to remove radioactive materials from structures, systems, and components from the time that the licensee certifies that it has permanently ceased power operations until the license is terminated. The scope of the document was determined through public scoping meetings and meetings with other Federal agencies and the nuclear industry. An evaluation process was then developed to determine environmental impacts from nuclear power reactor facilities that are being decommissioned. The evaluation process involved determining the specific activities that occur during reactor decommissioning and obtaining data from site visits and from licensees at reactor facilities currently being decommissioned. The data obtained from the sites were analyzed and then evaluated against a list of variables that defined the parameters for facilities that are currently operating but which will one day be decommissioned. This evaluation resulted in a range of impacts for each environmental issue that may be used for comparison by licensees that are or will be decommissioning their facilities.

Contents

Volume 1
Main Report, Appendices A-M

Figures

Tables

Executive Summary

This document is a supplement to the U.S. Nuclear Regulatory Commission (NRC) document *Final Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities,* issued in 1988 (NUREG-0586, referred to hereafter as the 1988 Generic Environmental Impact Statement [GEIS]).[a] As a supplement, this document considers the technological advances in decommissioning, the experience gained by licensees, and changes made to NRC regulations since the 1988 GEIS. The information from the 1988 GEIS that is still current and applicable to permanently shut down and currently operating commercial nuclear power reactors is included here. This Supplement is intended to be used to evaluate environmental impacts during the decommissioning of nuclear power reactors as residual radioactivity at the site is reduced to levels that allow for termination of the NRC license.

The NRC elected to supplement the GEIS:

(1) to further the purposes of the National Environmental Policy Act (NEPA)

(2) to update the information in the GEIS

(3) to provide additional information to the public on decommissioning activities

(2) to establish an envelope of environmental impacts that could be associated with decommissioning activities.

Unlike the 1988 GEIS, which took a broad look at decommissioning of a variety of sites and activities, this Supplement addresses only nuclear power reactors licensed by the NRC. It updates the sections of the 1988 GEIS relating to pressurized water reactors, boiling water reactors, and multiple reactor stations. It goes beyond the 1988 GEIS and considers the existing permanently shut down high-temperature gas-cooled reactor and fast breeder reactor. It does not include research and test reactors or the power reactor facilities that have been involved in a significant accident resulting in large-scale contamination of structures, systems, and components (SSCs). It also does not include other types of fuel-cycle facilities, such as fuel-reprocessing plants or small mixed oxide fuel-fabrication plants.

The intent of this Supplement is to consider in a comprehensive manner all aspects related to the radiological decommissioning of nuclear reactor facilities by incorporating updated information, regulations, and analyses. Since the 1988 GEIS was written, the NRC and the industry have gained substantially more nuclear power facility decommissioning experience. Based on the number of reactors shut down and the date that they permanently ceased

(a) The GEIS is considered "generic" in that it evaluates environmental impacts from decommissioning activities common to a number of nuclear power facilities.

operations, over 200 facility-years' worth of decommissioning experience have accumulated since the NRC published the 1988 GEIS. Currently, there are 19 commercial power reactor facilities in the decommissioning process. This includes nine that permanently ceased operations after the NRC published the 1988 GEIS. Since the 1988 GEIS, there are three facilities that have completed decommissioning and terminated their licenses. There are also new technologies and approaches applicable to decommissioning that the 1988 GEIS does not address. The regulations for decommissioning reactors have also undergone significant changes since the 1988 GEIS.

Scope of the Supplement

The content of this Supplement was initially defined by the scope of the 1988 GEIS and was modified based on current decommissioning regulations, input received during four public scoping meetings, letters and comments received during the scoping period, and meetings between the NRC and the U.S. Environmental Protection Agency (EPA) and the Council on Environmental Quality (CEQ). The public comments received during the scoping process that were considered to be with the scope of the environmental review are provided in Volume 2 Appendix N. The NRC staff published for comment Supplement 1 to the GEIS in October 2001. Public meetings in San Francisco, California, Boston Massachusetts, Chicago, Illinois and Atlanta, Georgia were held in December, 2001 to describe the preliminary results of the NRC environmental review, to answer questions, and to provide members of the public with information to assist them in formatting comments on the draft Supplement. All comments received on the draft Supplement were considered by the staff in developing the final document and are presented in Appendices O and P.

The scope of this Supplement is based on the decommissioning activities performed to remove radioactive materials from SSCs from the time that the licensee certifies that it has permanently ceased power operations until the license is terminated. As a result, the activities performed before permanent cessation of operations (except for decommissioning planning) or impacts that are related to the decision to permanently cease operations (for example, the impact from the loss of generation capacity) are outside the scope of this document.

The Commission defines decommissioning as "to remove a facility or site safely from service and reduce residual radioactivity to a level that permits (1) Release of the property for unrestricted use and termination of the license; or (2) Release of the property under restricted conditions and termination of the license." The staff has included activities that are directly related to the removal of radioactive material from the facility or that must be performed in order to facilitate the removal of contaminated SSCs, as well as the activities and impacts related to the removal of uncontaminated SSCs (such as the intake structure or cooling towers) that were required for the operation of the reactor.

The decommissioning process continues until the licensee requests termination of the license and demonstrates that radioactive material has been removed to the levels that permit termination of the NRC license. At that point, the NRC no longer has jurisdiction over the site and the owner of the site is no longer subject to NRC regulations. As a result, activities performed after license termination and the resulting impacts are outside the scope of this Supplement. These activities may include any non-NRC required monitoring, site restoration (grading, planting of vegetation, etc.), continued dismantlement (removal of uncontaminated structures or those that have been radiologically decontaminated), or continued use of the site for activities such as power production using natural gas, oil, or coal.

Any potential radiological impacts following license termination that are related to activities performed during the decommissioning period are not considered in this Supplement. Those impacts are covered by the *Generic Environmental Impact Statement in Support of Rulemaking on Radiological Criteria for License Termination of NRC-Licensed Nuclear Facilities* (NUREG-1496). Nonradiological impacts following license termination that are related to activities performed during the decommissioning period are considered in this Supplement.

Levels of Significance and Applicability of Environmental Impacts

This Supplement provides a measure of (a) the significance and severity of potential environmental impacts and (b) the applicability of these impacts to a variety of plants both permanently shut down and operating. The significance of the environmental impacts is described as either SMALL, MODERATE or LARGE. The applicability of these impacts to a variety of plants is categorized as either generic or site-specific.

Levels of Significance: For decommissioning, the staff is using a standard of significance derived from the CEQ terminology for "significantly" (40 CFR 1508.27, which considers "context" and "intensity"). The NRC has defined three significance levels: SMALL, MODERATE, and LARGE.

SMALL - Environmental impacts are not detectable or are so minor that they will neither destabilize nor noticeably alter any important attribute of the resource. For the purposes of assessing radiological impacts in this Supplement, the NRC has concluded that those impacts that do not exceed permissible levels in the Commission's regulations are considered small.

MODERATE - Environmental impacts are sufficient to alter noticeably but not to destabilize important attributes of the resource.

LARGE - Environmental impacts are clearly noticeable and are sufficient to destabilize important attributes of the resource.

The discussion of each environmental issue in this Supplement includes an explanation of how the significance level was determined. In determining the significance level, the NRC staff assumed that ongoing mitigation measures would continue (including those mitigation measures implemented during plant construction and/or operation) during decommissioning, as appropriate. Benefits of additional mitigation measures during or after decommissioning are not considered in determining significance levels.

Applicability: In addition to determining the significance of environmental impacts, this Supplement includes a determination of whether the analysis of the environmental issues could be applied to all plants, and whether additional mitigation measures would be warranted. An environmental issue may be assigned to one of two categories:

- Generic - For each environmental issue, the analysis reported in this Supplement shows the following:

  (1) Environmental impacts associated with the issue have been determined to apply either to all plants, or for some issues to plants of a specific size, specific location or having a specific type of cooling system or site characteristics, and

  (2) A single significance level (i.e., SMALL, MODERATE, or LARGE) has been assigned to the impacts, and

  (3) Mitigation of adverse impacts associated with the issue has been considered in the analysis, and it has been determined that additional plant-specific mitigation measures are likely not to be sufficiently beneficial to warrant implementation.

- Site-specific - For each environmental issue that was determined to be site-specific, the analysis reported in this Supplement has shown that one or more of the generic criteria was not met. Therefore, additional plant-specific review is required. An example of a site-specific issue is threatened and endangered species.

Use and Development of this Supplement

This Supplement can be used by the public to understand the decommissioning process, the activities performed during decommissioning, and the potential environmental impacts resulting from these activities. It identifies activities that can be bounded by a generic evaluation. Licensees can rely on the information in this Supplement as a basis for meeting the requirements in 10 CFR 50.82(a)(6)(ii). This requirement states that the licensee must not perform any decommissioning activity that causes any significant environmental impact not previously reviewed. The NRC staff will also rely on this Supplement as a basis for determining if anticipated decommissioning impacts require an additional review.

The staff first created an initial list of environmental issues and activities that this Supplement should address. The initial list of environmental issues was developed from issues (such as air quality, aquatic ecology, and radiological impacts) identified in the 1988 GEIS and in the list specified in 10 CFR Part 51, Subpart A, Appendix B, for license renewal. This list was used because it represents the potential impacts associated with nuclear power facilities. The initial list of decommissioning activities was modified based on experience, public participation in the scoping process, site visits to six facilities currently being decommissioned, and meetings with EPA and CEQ. After compiling the issue and activity lists, the staff assessed which activities might have environmental impacts for each of the issues. The next step was to identify the variables that might affect the decommissioning impact for a specific issue and activity. For example, the proximity of the plant to a barge slip or railroad might affect the licensee's decision to remove the steam generator or other large components intact and ship them to a waste site. If the barge slip needs additional dredging, or an additional railroad line needs to be installed, then the environmental impacts may change.

The analyses in this Supplement include data from both operating and decommissioning facilities in order to appropriately span the range of impacts that could be expected. Data from decommissioning facilities was used to determine whether the potential impacts from decommissioning activities for the various issues are generic or site-specific. Data from operating facilities were used to ensure that this Supplement will be valid for all commercial nuclear power reactors.

Alternatives

The alternative to the action of decommissioning is not to decommission the facility. The option to restart the reactor is not considered to be an alternative to decommissioning because the decision to permanently cease operation prevents the licensee from operating the reactor without a significant safety and environmental review by the NRC staff.

The alternative to decommissioning at the end of the licensing period is a "no action" alternative, implying that a licensee would simply abandon or leave a facility after ceasing operations. NRC regulations do not allow the option of not decommissioning. Once the facility permanently ceases operation, if the licensee does not conduct decommissioning activities to an extent that meets the license termination criteria in 10 CFR Part 20, Subpart E, then the license will not be terminated (although the licensee will not be authorized to operate the reactor). The licensee will be required to comply with the necessary requirements for the operating license. As a result, the environmental impacts for maintaining the nuclear reactor facility will be considered to be in the bounds of the appropriate, previously issued Environmental Impact Statements. Under NRC regulations, the original operating license for a nuclear power plant is issued for up to 40 years. The license may be renewed for periods of up to 20 years if NRC requirements are met. However, at the end of the licensing period (whether it has been extended or not), the regulations require that the facility be decommissioned.

Conclusions

Table ES-1 presents each evaluated environmental issue and identifies whether the issue is considered generic or site-specific. If the issue is considered generic, then it is assigned a significance level of either SMALL, MODERATE or LARGE. Of the environmental issues assessed, most of the impacts are generic and SMALL for all plants regardless of the activities and identified variables (see Appendix E for a list of the variables). The two issues determined to be site-specific are threatened and endangered species and environmental justice. Four issues are considered to be conditionally site-specific.

- land use involving offsite areas to support decommissioning activities
- aquatic ecology for activities beyond the operational area
- terrestrial ecology for activities beyond the operational area
- cultural and historic resources for activities beyond the operational area with no current cultural and historic resource survey.

The operational area is defined as the portion of the plant site where most or all of the site activities occur, such as reactor operation, materials and equipment storage, parking, substation operation, facility service, and maintenance. This includes areas within the protected area fences, the intake, discharge, cooling, and associated structures as well as surrounding paved, graveled, maintained landscape, or other maintained areas.

Licensees undergoing or planning decommissioning of a commercial nuclear power reactor can use this Supplement in support of their evaluation of the environmental consequences from decommissioning. The impacts identified in this Supplement are designed to span the range of impacts from all plants that are currently permanently shut down as well as the plants that are currently operating, including the plants that have or may renew their licenses beyond the original 40-year license; a renewed license can be issued for a period not to exceed 20 years beyond the expiration of the operating license. When planning a specific decommissioning activity, licensees that fall within the bounds of the impacts, as described in Chapter 4, may proceed with the activity with no further analysis. However, if the planned activity could result in environmental impacts greater than those predicted by this supplement, then the activity cannot be performed until the licensee performs a site-specific analysis of the activity. Depending on the results of the site-specific evaluation, the staff may determine that it is appropriate to consult with another agency (such as the U.S. Fish and Wildlife Service or a State Historic Preservation Office). If the activity would result in an impact that is outside the bounds of the GEIS or other environmental assessments, the licensee would be required to submit a license-amendment request.

Table ES-1. Summary of the Environmental Impacts from Decommissioning Nuclear Power Facilities

Issue	Generic	Impact
Onsite/Offsite Land Use		
- Onsite land use activities	Yes	SMALL
- Offsite land use activities	No	Site-specific
Water Use	Yes	SMALL
Water Quality		
- Surface water	Yes	SMALL
- Groundwater	Yes	SMALL
Air Quality	Yes	SMALL
Aquatic Ecology		
- Activities within the operational area	Yes	SMALL
- Activities beyond the operational area	No	Site-specific
Terrestrial Ecology		
- Activities within the operational area	Yes	SMALL
- Activities beyond the operational area	No	Site-specific
Threatened and Endangered Species	No	Site-specific
Radiological		
- Activities resulting in occupational dose to workers	Yes	SMALL
- Activities resulting in dose to the public	Yes	SMALL
Radiological Accidents	Yes	SMALL
Occupational Issues	Yes	SMALL
Cost	NA[a]	NA
Socioeconomic	Yes	SMALL
Environmental Justice	No	Site-specific
Cultural and Historic Resource Impacts		
- Activities within the operational areas	Yes	SMALL
- Activities beyond the operational areas	No	Site-specific
Aesthetics	Yes	SMALL
Noise	Yes	SMALL
Transportation	Yes	SMALL
Irretrievable Resources	Yes	SMALL

(a)A decommissioning cost assessment is not a specific National Environmental Policy Act (NEPA) requirement. However, an accurate decommissioning cost estimate is necessary for a safe and timely plant decommissioning. Therefore, this Supplement includes a decommissioning cost evaluation, but the cost is not evaluated using the environmental significance levels nor identified as a generic or site-specific issue.

Abbreviations/Acronyms

µGy	microGray(s)
µSv	microSieverts
ac	acre(s)
AEA	Atomic Energy Act of 1954
AEC	U.S. Atomic Energy Commission
ALI	annual limits on intake
ALARA	as low as reasonably achievable
ANPR	advance notice of proposed rulemaking
BLM	Bureau of Land Management
BMP	best management practice
Bq	Bequerel(s)
BWR	boiling water reactor
C	Celsius
CAA	Clean Air Act
CDE	committed dose equivalent
CEDE	committed effective dose equivalent
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
Ci	Curie
CWA	Clean Water Act
DAC	derived air concentration
dB	decibel
dBA	A-weighted sound levels
dBC	C-weighted sound levels
DBA	design basis accident
DDREF	dose or dose rate effectiveness factor
DE	dose equivalent
DNL	day-night average sound level
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation

EA	environmental assessment
EDE	effective dose equivalent
EIS	environmental impact statement
EJ	environmental justice
EPA	U.S. Environmental Protection Agency
ER	environmental report
ESA	Endangered Species Act of 1973
ES&H	environment, safety and health
F	Fahrenheit
FAA	Federal Aviation Administration
FBR	fast breeder reactor
FES	final environmental statement
FHA	Federal Housing Administration
FR	Federal Register
FSAR	Final Safety Analysis Report
ft	foot/feet
FWPCA	Federal Water Pollution Control Act (also known as the Clean Water Act of 1977)
FWS	U.S. Fish and Wildlife Service
gal.	gallon(s)
GEIS	Generic Environmental Impact Statement
gpd	gallons per day
gpm	gallons per minute
GTCC	Greater-than-Class-C (waste)
Gy	gray(s)
ha	hectare(s)
HDA	high decommissioning activity
HEPA	high-efficiency particulate air (filter)
HLW	high-level waste
h	hour
HTGR	high-temperature gas-cooled reactor
HUD	U.S. Department of Housing and Urban Development
HVAC	heating, ventilation, and air conditioning
IAEA	International Atomic Energy Agency
in.	inch(es)
I&C	instrumentation and control

ICRP	International Commission on Radiological Protection
ISFSI	independent spent fuel storage installation
kg	kilogram(s)
km	kilometer(s)
kV	kilovolt(s)
kWh	kilowatt hour(s)
L	liter(s)
LDA	low-decommissioning activity
LER	licensee event report
LET	linear energy transfer
LLW	low-level waste
LOS	level of service
LRA	license renewal application
LTP	license termination plan
LWR	light water reactor
m	meter(s)
m^3/d	cubic meters per day
m^3/s	cubic meters per second
MARSSIM	Multi-agency Radiation Survey and Site Investigation Manual, NUREG-1575
MBTA	Migratory Bird Treaty Act of 1918
mi	mile(s)
mGy	milliGray(s)
MPC	maximum permissible concentrations
mrad	millirad(s)
mrem	millirem(s)
MRS	monitored retrievable storage
mSv	milliSievert(s)
MTHM	metric tonnes of heavy metal
MT	metric ton(s) (or tonne[s])
MTU	metric ton(s)-uranium
MW	megawatt(s)
MWd/MTU	megawatt-days per metric ton of uranium
MW(e)	megawatt(s) electric
MW(t)	megawatt(s) thermal
MWh	megawatt hour(s)

NA	not applicable
NAS	National Academy of Sciences
NBS	National Bureau of Standards

NCRP	National Council on Radiation Protection and Measurements
NEI	Nuclear Energy Institute
NEPA	National Environmental Policy Act of 1969
NHPA	National Historic Preservation Act of 1966
NIST	National Institute of Standards and Technology
NMFS	National Marine Fisheries Service
NO_x	nitrogen oxide(s)
NPDES	National Pollutant Discharge Elimination System
NRC	U.S. Nuclear Regulatory Commission
NRR	Nuclear Reactor Regulation
NWPA	Nuclear Waste Policy Act of 1982
ODCM	Offsite Dose Calculation Manual
OSHA	Occupational Safety and Health Administration
PAG	protective action guide
PCBs	polychlorobiphenyls
PEL	permissible exposure limit
POL	possession-only license
PPE	personal protective equipment
PSDAR	post-shutdown decommissioning activities report
PV	pressure vessel
PWR	pressurized water reactor
QA/QC	quality assurance/quality control
RCRA	Resource Conservation and Recovery Act of 1976
RCS	reactor coolant system
ROW	right-of-way/rights-of-way
RPV	reactor pressure vessel
SARA	Superfund Amendments and Reauthorization Act
SHPO	State Historic Preservation Officer
SI	Systeme Internationale (international system of units)
SO_2	sulfur dioxide
SO_x	sulfur oxide(s)
SSCs	structures, systems, and components
Sv	sievert(s)

TEDE	total effective dose equivalent
THPO	Tribal Historic Preservation Officer
UNSCEAR	United Nations Scientific Committee on The Effects of Atomic Radiation
USC	United States Code
USFWS	U.S. Fish and Wildlife Service
VOC	volatile organic compound
VRM	Visual Resource Management (system)
wk	week(s)
YNPS	Yankee Nuclear Power Station
yr	year(s)

1.0 Introduction

1.1 Purpose and Need for This Supplement

This document supplements the *Final Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities* (NRC 1988), issued in 1988 (NUREG-0586, referred to hereafter as the 1988 GEIS) for power reactor facilities. This Supplement updates information provided in the 1988 GEIS by considering technological advances in decommissioning activities gained since 1988 and changes in U.S. Nuclear Regulatory Commission (NRC) regulations and, where appropriate, other agency regulations. The NRC has adopted the following definition of the purpose and need of this Supplement:

> The purpose and need are to provide an analysis of environmental impacts from decommissioning activities that can be treated generically so that decommissioning activities for commercial nuclear power reactors conducted at specific sites will be bounded, to the extent practicable, by this and appropriate previously issued environmental impact statements.

This Supplement is intended to be used to evaluate environmental impacts during the decommissioning of nuclear power facilities as residual radioactivity at the site is reduced to levels that allow for termination of the NRC license. This Supplement can be considered a stand-alone document for power reactor facilities such that readers should not need to refer back to the 1988 GEIS. The environmental impacts described in this Supplement supercede those described in the 1988 GEIS for power reactor facilities.

The NRC elected to supplement the 1988 GEIS:

(1) to further the purposes of the National Environmental Policy Act (NEPA)

(2) to update the information in the 1988 GEIS

(3) to provide additional information to the public on decommissioning activities

(4) to establish an envelope of environmental impacts associated with decommissioning activities.

Unlike the 1988 GEIS, this Supplement covers only reactor facilities licensed by the NRC for commercial power production. It updates the sections of the 1988 GEIS relating to pressurized water reactors, boiling water reactors, and multiple reactor stations. It goes beyond the 1988 GEIS and considers the permanently shut down high-temperature gas-cooled reactors and fast breeder reactors. It does not cover research and test reactors or power reactor facilities that have been involved in a significant accident resulting in large-scale contamination of structures, systems, and components (SSCs). It also does not cover other types of fuel-cycle facilities, such as fuel-reprocessing plants or small mixed oxide fuel-fabrication plants.

This Supplement incorporates updated information, regulations, and analyses. Since the 1988 GEIS was written, the NRC and the industry have gained over 200 facility-years' worth of additional decommissioning experience. Currently, there are 19 nuclear power reactor facilities in the decommissioning process. This includes nine that permanently ceased operations after the NRC published the 1988 GEIS. Since the 1988 GEIS, three facilities have completed decommissioning and terminated their licenses: Pathfinder, Shoreham, and Fort St. Vrain. This Supplement addresses new decommissioning technologies and approaches that the 1988 GEIS did not address. Also, the decommissioning regulations have changed since the 1988 GEIS.

1.2 Process Used to Determine Scope of This Supplement

The content of this Supplement was initially defined by the scope of the 1988 GEIS and was modified based on current decommissioning regulations, inputs from the scoping process and the outcome of meetings between the NRC, the U.S. Environmental Protection Agency (EPA), and the Council on Environmental Quality (CEQ).

Four public scoping meetings were held between April and June 2000 as part of the scoping process. During the meetings, the NRC outlined the GEIS revision process and accepted comments regarding the scope of this Supplement. In addition to comments obtained during the scoping meetings, the NRC received 12 letters from industry groups, other interested organizations, and private citizens. A total of 397 comments were provided during the scoping process. The staff reviewed the comments and categorized them as either relevant to this Supplement or outside of its intended scope. The staff prepared and issued a scoping summary report on April 17, 2001 (NRC 2001), that summarized the comments and NRC responses to the comments. Appendix N is an extraction of comments from the scoping summary report that were considered to be within the scope of the environmental review. The NRC staff published for comment draft Supplement 1 to the GEIS in October 2001. Public meetings in San Francisco, California, Boston, Massachusetts, Chicago, Illinois and Atlanta, Georgia, were held in December 2001, to describe the preliminary results of the NRC environmental review, to answer questions, and to provide members of the public with information to assist them in formatting comments on the draft Supplement. All comments received on the draft Supplement were considered by the staff in developing the final document. Appendix O provides a compilation of comments received on the draft Supplement and staff responses to the comments. Originally, the staff planned to publish the scoping summary and the response to comments in Appendices A and B of this report. However, due to the length of these two appendices, the staff decided to publish these two appendices and the appendix containing the transcripts and comment letters in a second volume. In addition to the scoping meetings, meetings were held with EPA and CEQ between February and November 2000 to obtain input on the scope of the environmental review.

Site visits were conducted by the NRC staff and its contractor at six nuclear reactor facilities that are in various stages of decommissioning. The site visits were conducted to obtain information and to familiarize the NRC team with the current types of activities conducted and the resulting impacts during decommissioning. In addition to the site visits, the Nuclear Energy Institute arranged access to additional site-specific decommissioning data. In addition to the six sites visited, data was received for three other nuclear power reactor facilities.

Information used in this report was also obtained from docketed material, such as post-shutdown decommissioning activity reports (PSDARs), effluent release reports, license termination plans (LTPs), and decommissioning funding plans.

1.3 Scope of This Supplement

Except for decommissioning planning activities, this Supplement considers only activities that occur following certification that fuel has been removed from the reactor. Figure 1-1 illustrates the decommissioning process. Licensee decommissioning activities are listed in the top part of the timeline. Regulatory activities are summarized by the lower part of the timeline. This section discusses licensee decommissioning activities that are within scope and also explains why some activities and impacts are not in scope for this Supplement. Table 1-1 briefly lists decommissioning activities that are within and outside the scope of this Supplement. Additional discussion of the out-of-scope activities is provided in Appendix D.

Impacts related to the decision to permanently cease operations are outside the scope of this Supplement. This includes impacts that result directly and immediately from the act of permanently ceasing operations, regardless of when or why the decision was made. For example, when a reactor ceases operation, the flow of warmer water into the canal, lake, or river that receives the plant's thermal discharges is stopped, and this may impact the organisms in the vicinity of the thermal outfall. However, this impact is not within the scope of this Supplement because it is essentially a restoration of the existing conditions.

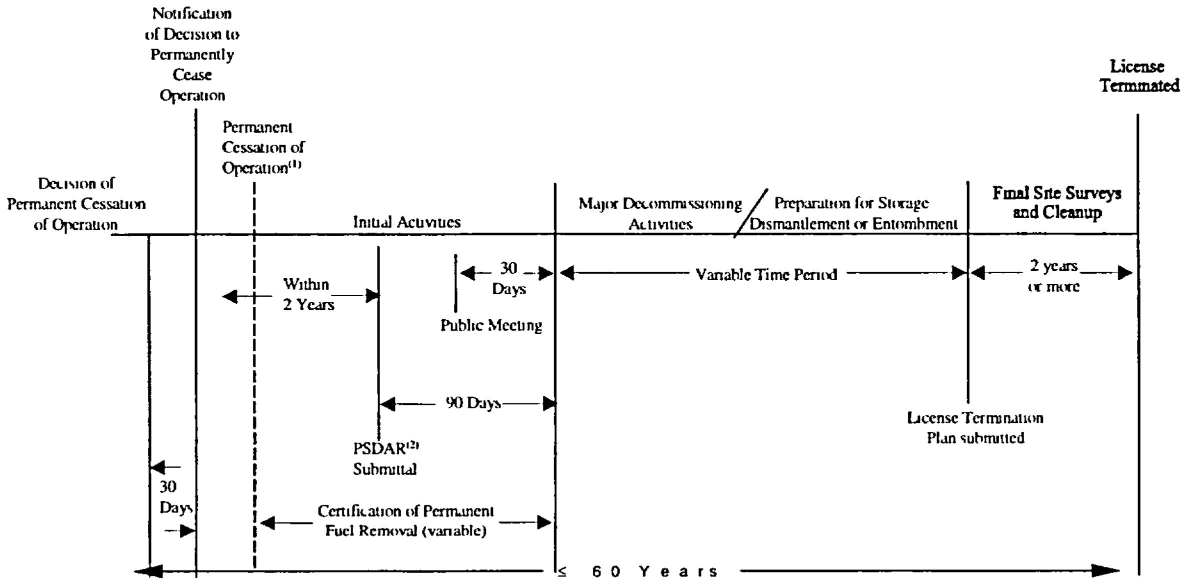

Figure 1-1.
Decommissioning Timeline

(1) The cessation of operations may occur before, concurrent with, or following the certification to permanently cease operations.
(2) The PSDAR may be submitted before permanent cessation of operations.

The licensee may declare or certify the date for permanent cessation of operations prior to the end of the license term and while still operating. In such cases, the decommissioning planning activities prior to shutdown and activities and impacts that occur following the actual shutdown of the facility are within the scope of this Supplement. In some circumstances, the licensee may not operate the facility for a period of many years without certifying that they have permanently ceased power operations. In these cases, the activities occurring before the certification is completed would be considered part of the operational phase of the facility and would be within the scope of the site-specific environmental impact statement (EIS) that covers reactor operations but are outside the scope of this Supplement.

The NRC definition for *decommission* in 10 CFR 50.2 is "to remove a facility or site safely from service and reduce residual radioactivity to a level that permits (1) Release of the property for unrestricted use and termination of the license; or (2) Release of the property under restricted conditions and termination of the license." This Supplement is not limited only to activities directly related to the removal of radioactive material from facilities or that must be performed to facilitate removal of contaminated SSCs. The staff has included activities and impacts related to removing uncontaminated SSCs that were required for reactor operation, such as the intake structure or cooling towers. Including uncontaminated SSCs in this Supplement is consistent with an expectation under NEPA that all impacts associated with an activity and that public concerns about the scope of the review be considered.

Various activities that are performed in conjunction with decommissioning are not considered within the scope of this Supplement, but are reviewed and regulated by the NRC under other licenses. These activities include

- independent spent fuel storage installation (ISFSI) construction, maintenance, and decommissioning – An ISFSI can be operated and decommissioned either under the same license that is used for the operating or decommissioning facility called a general license under 10 CFR Part 50, or under a specific license under 10 CFR Part 72. If a licensee chose to operate the ISFSI under a Part 50 license, it could choose to continue to maintain their Part 50 license, or seek a site -specific 10 CFR Part 72 license for the ISFSI, thus allowing termination of the Part 50 license and the end of the reactor decommissioning process. The NRC staff would also be required to conduct an environmental assessment of the licensee's request for a site-specific 10 CFR Part 72 license.

- spent fuel storage and maintenance – The Commission has independently, in a separate proceeding (the Waste Confidence Proceeding), made a finding that there is

  > reasonable assurance that, if necessary, spent fuel generated in any reactor can be stored safely and without significant environmental impacts for at least 30 years beyond the licensed life for operation (which may include the term of a revised license) of that reactor at its spent fuel storage basin, or at either onsite or offsite independent spent fuel storage installations. (54 FR 39767)

The Commission has committed to review this finding at least every 10 years. In its most recent review, the Commission concluded that experience and developments since 1990 were not such that a comprehensive review of the Waste Confidence Decision was necessary at that time (64 FR 68005). Accordingly, the Commission reaffirmed its findings of insignificant environmental impacts cited above. This finding is codified in the Commission's regulations at 10 CFR 51.23(a). The staff relies on the Waste Confidence Rule, but has elected to include in this Supplement information related to the storage and maintenance of fuel in a spent fuel pool for completeness.

Table 1-1. Activities and Impacts Within or Outside the Scope of This Supplement

In Scope
• Activities performed to remove the facility from service from the time that the licensee certifies that the facility has permanently ceased operations
• Activities (and the resulting impacts) performed in support of radiological decommissioning, including decontamination and dismantlement of radioactive structures and any activities required to support the decontamination and dismantlement process
• Activities performed in support of dismantlement of nonradiological structures, systems, and components (SSCs) required for the operation of the reactor, such as diesel generator buildings and cooling towers
• Activities performed up to license termination and their resulting impacts as provided in the definition of decommissioning Nonradiological impacts occurring after license termination from activities conducted during decommissioning
• Activities related to release of the facility
• Human health impacts from radiological and nonradiological decommissioning activities
• Activities related to preparing the facility for entombment
Out of Scope[a]
• Activities and the resulting impacts (other than planning activities) that are performed before permanent cessation of operation is certified
• Radiological impacts following license termination
• Activities (and the resulting impacts) performed to dismantle structures on the site that are not radiologically contaminated and were not required for operation of the reactor (e.g., training building and administration building)
• Activities performed to support installation of alternate energy-generating facilities during or following the decommissioning process
• Site restoration activities performed during or after the decommissioning process
• Activities (and their impacts) performed after license termination, such as - any additional non-NRC required monitoring to evaluate radiological impacts - site restoration - continued use of site for power production or other activities
• Activities performed at facilities that are separately licensed or regulated - independent spent fuel storage installation (ISFSI) construction, maintenance, or decommissioning - interim storage of Greater-than-Class-C Waste - spent fuel storage,[b] maintenance, and disposal on or away from a reactor location - low-level waste (LLW) disposal at a licensed LLW site or treatment at compactor facilities
• Activities to install engineered barriers and institutional controls for restricted release
• Public perceptions and psychological impacts
• Activities at facilities that have been permanently shut down by a major accident
• Issues related to the ENTOMB option after the facility begins the entombment period

(a) A detailed discussion of the reasons for determining that activities are out of scope can be found in Appendix D.

(b) As discussed in the text, the staff relies on the Waste Confidence Decision Review (54 FR 39767 and 64 FR 68005) but has chosen to include information related to the storage and maintenance of fuel in a spent fuel pool for completeness in this Supplement.

- spent fuel transport and disposal away from the reactor location – Transportation of spent fuel and other high-level nuclear wastes is governed by regulations in 10 CFR Part 71, "Packaging and Transportation of Radioactive Material." Disposal of spent fuel and high-level wastes are governed by the Nuclear Waste Policy Act (NWPA) of 1982, as amended, which defined the goals and structure of a program for permanent, deep geologic repositories for the disposal of high-level radioactive waste and nonreprocessed spent fuel. Under this Act, the U.S. Department of Energy (DOE) is responsible for developing permanent disposal capacity for spent fuel and other high-level nuclear wastes. Title 10 CFR Part 60 contains rules governing the licensing to receive and possess source, special nuclear, and by-product material at a geological repository operations area that is sited, constructed, or operated in accordance with the NWPA. However, the Commission issued the final rule to supercede the generic criteria in 10 CFR Part 60 for disposal at a geological repository with specific criteria in 10 CFR Part 63, issued on November 2, 2001 (66 FR 55732).

- LLW disposal at a licensed LLW site or treatment of LLW at compactor facilities – Regulations related to LLW disposal are in 10 CFR Part 61 and 10 CFR Part 20, Subpart K. A final GEIS supporting the regulations in 10 CFR Part 61, "Final Generic Environmental Impact Statement for 10 CFR Part 61" was published as NUREG-0945 (NRC 1982).

A further description of these activities and the basis for not including them in the scope of this supplement is in Appendix D.

The decommissioning process continues until the licensee requests termination of the license and demonstrates that radioactive material has been removed to levels that permit termination of the NRC license. Once the NRC determines that the decommissioning is completed, the license is terminated. At that point, the NRC no longer has regulatory authority over the site, and the owner of the site is no longer subject to NRC regulations. As a result, activities performed after license termination and the resulting impacts are outside the scope of this Supplement. These activities may include any non-NRC required monitoring, site restoration (grading, planting of vegetation, etc.), continued dismantlement or continued use of the site for activities such as power production using natural gas, oil, or coal.

Any potential radiological impacts following license termination that are related to activities performed during decommissioning are not considered in this Supplement. Such impacts are covered by the Generic Environmental Impact Statement in Support of Rulemaking on Radiological Criteria for License Termination of NRC-Licensed Nuclear Facilities, NUREG-1496 (NRC 1997).

Any potential nonradiological impacts resulting from decommissioning and occurring after termination of the license are considered within the scope of this Supplement. Onsite disposal has been proposed by the industry as a method to dispose of slightly radiologically contaminated building rubble provided that the waste is buried onsite below grade, for example, in existing underground portions of the dismantled plant in such a manner as to meet the site release criteria of 10 CFR Part 20, Subpart E. This concept has been referred to as "Rubblization" (the disposal onsite of slightly contaminated material in a manner to meet the 10 CFR Part 20 release criteria).[a] On February 14, 2000, the staff informed the Commission of licensee interest in this method and the staff's intent to address Rubblization in this Supplement (NRC 2000). The staff has determined that the long-term radiological aspects of Rubblization, or onsite disposal of slightly contaminated material, would require a site-specific analysis and would be addressed at the time the LTP is submitted. The nonradiological impacts, occurring both during the decommissioning period (e.g., noise, dust, land disturbance), and the long-term impacts occurring after the decommissioning activities are completed (e.g., concrete leaching into the groundwater) can be evaluated generically and are included in the evaluation of each of the applicable environmental issues in Chapter 4 of this document.

Public perceptions and psychological impacts related to the risk of a radiological accident during decommissioning are not addressed in the 1988 GEIS and are not addressed in this Supplement. The U.S. Supreme Court stated in *Metropolitan Edison Co. v. People Against Nuclear Energy*, 460 U.S. 766, at 774-775, that such psychological effects or impacts raised policy questions that fell outside of NEPA. This court case involved an organization of residents living in the area of Three Mile Island, People Against Nuclear Energy (PANE), that claimed the NRC should consider, as part of an EIS, the severe psychological stress caused to its members by the restart of Three Mile Island, Unit 1, after the accident at Three Mile Island, Unit 2. However, in *Metropolitan Edison Co., et al. v. People Against Nuclear Energy* (1983), the Supreme Court read NEPA to require

> a reasonably close causal relationship between a change in the physical environment and the effect at issue .... a <u>risk</u> of an accident is not an effect on the physical environment .... We believe that the element of risk lengthens the causal chain beyond the reach of NEPA.

(a) The term "rubblization" is frequently used to describe the crushing of structural material (e g., concrete) to facilitate disposal. The material may be concrete that is uncontaminated or contaminated with radiological material. The staff used the term Rubblization to describe the process of onsite disposal of slightly contaminated material in a manner to meet the site release criteria. For this report, in order to avoid confusion, the staff chose to use the term "demolition" instead of rubblization as the verb to describe the process of crushing structural material to allow for easy burial or disposal.

The decommissioning activities following shutdown of a facility after a major accident resulting in significant contamination of the site are outside the scope of this Supplement. For most types of accidents, decommissioning would be treated on a site-specific basis and, therefore, cannot be considered in a generic sense.

1.4 Categories for Environmental Impacts and Extent of Issues

In the analysis of potential issues in decommissioning activities, two areas in particular were found to benefit from categorization: (a) ranking the significance and severity of potential environmental impacts for proposed decommissioning activities and (b) sorting potential issues as either generic or site-specific.

1.4.1 Levels of Significance of Environmental Impacts

For decommissioning, the staff is using a standard of significance derived from the CEQ terminology for "significantly" (40 CFR 1508.27, which considers "context" and "intensity"). The NRC has defined three significance levels: SMALL, MODERATE, and LARGE.

SMALL – Environmental impacts are not detectable or are so minor that they will neither destabilize nor noticeably alter any important attribute of the resource. For the purposes of assessing radiological impacts in this Supplement, the NRC has concluded that those impacts that do not exceed permissible levels in the Commission's regulations are considered small.

MODERATE – Environmental impacts are sufficient to alter noticeably, but not to destabilize, important attributes of the resource.

LARGE – Environmental impacts are clearly noticeable and are sufficient to destabilize important attributes of the resource.

The discussion of each environmental issue in this Supplement includes an explanation of how the significance level was determined. In determining the significance level, the NRC staff assumed that ongoing mitigation measures would continue (including those mitigation measures implemented during plant construction and/or operation) during decommissioning, as appropriate. Benefits of additional mitigation measures during or after decommissioning are not considered in determining significance levels.

1.4.2 Regulatory Distinction of Generic and Site-Specific Approaches

In addition to determining the significance of environmental impacts, this Supplement includes a determination of whether the analysis of the environmental issue could be applied to all plants, and whether additional mitigation measures would be warranted. An environmental issue may be assigned to one of two categories (generic or site-specific) described below.

- Generic – For each environmental issue, the analysis reported in this Supplement shows the following:

  (1) Environmental impacts associated with the issue have been determined to apply either to all plants, or for some issues to plants having a specific size, specific location, or having a specific type of cooling system or other site characteristics, and

  (2) A single significance level (i.e., SMALL, MODERATE, or LARGE) has been assigned to the impacts, and

  (3) Mitigation of adverse impacts associated with the issue has been considered in the analysis, and it has been determined that additional plant-specific mitigation measures are not likely to be sufficiently beneficial to warrant implementation.

- Site-specific – For each environmental issue that was determined to be site-specific, the analysis reported in this Supplement has shown that one or more of the generic criteria was not met. Therefore, additional plant-specific review is required.

1.5 Uses of This Supplement

This Supplement can be used by the public to understand the decommissioning process, the activities performed during decommissioning, and the potential environmental impacts resulting from these activities. The Supplement does not (1) establish or revise regulations, (2) impose requirements, (3) provide relief from requirements, or (4) provide guidance on the decommissioning process.

This Supplement identifies activities that can be bounded by a generic evaluation. It also identifies the decommissioning activities and associated environmental issues that will likely require site-specific analysis before performing a decommissioning activity.

Licensees can rely on the information in this Supplement as a basis for meeting the requirements in 10 CFR 50.82(a)(6)(ii). This requirement states that the licensee must not perform any decommissioning activity that causes any significant environmental impact not previously reviewed. Prior to conducting a decommissioning activity, the licensee must make a determination that the resulting environmental impacts fall within the bounds of this Supplement or of another EIS related to its facility. When finalized, licensees are expected to reflect the environmental impacts described in this Supplement rather than those in the 1988 GEIS. For any decommissioning activity that does not meet these conditions, the regulations prohibit the licensee from undertaking the activity until it performs a site-specific analysis of the activity. Depending on the results of the site-specific evaluation, the staff may determine that it is appropriate to consult with another agency about the potential impacts. Such agencies could include the U.S. Fish and Wildlife Service or a State Historic Preservation Office. If the activity would result in an impact that is outside the bounds of the GEIS or other environmental assessments, the licensee would be required to submit a license-amendment request. The NRC staff periodically inspects the licensee's procedures and documentation to ensure that a proper environmental review is part of the screening criteria used for proposed changes to the facility.

In addition to the NRC staff's review of the licensee's procedures and documentation, there are two points during the decommissioning process when the licensee performs an evaluation of environmental impacts. The first evaluation occurs when the licensee must submit a PSDAR to the NRC (within two years following permanent cessation of operation). The PSDAR must include a discussion that provides the reasons for concluding that the environmental impacts associated with the licensee's planned site-specific decommissioning activities will be bounded by an appropriate previously issued environmental assessments, including this Supplement. If the licensee identifies environmental impacts that are not bounded by a previous NRC environmental assessment, the licensee must address the impacts in a request for a license amendment regarding the activities. The licensee must also submit a supplement to its environmental report (ER) that describes and evaluates the additional impacts. The NRC will review the supplement to the ER in conjunction with its review of the license-amendment request.

The second evaluation is near the end of decommissioning at the time when the licensee submits an application for license termination. In accordance with 10 CFR 50.82(a)(9), a licensee must submit its LTP at least 2 years before the anticipated termination date of the license. The LTP must be a supplement to the Final Safety Analysis Report or its equivalent for the facility and is submitted as a license amendment. The NRC requires an environmental review as part of the review of the license-amendment request. Thus, the LTP must include a supplement to the ER that describes any new information or significant environmental change associated with the licensee's proposed termination activities. The NRC staff will also rely upon this supplement as a basis for determining if anticipated decommissioning impacts require an additional review.

1.6 Development of This Supplement

The requirements in 10 CFR Part 51 were followed for the development of this Supplement. This included conducting scoping meetings and obtaining public comments (see Appendix N). From these meetings and meetings with other appropriate government agencies, the staff defined the scope of this Supplement (see Sections 1.2 and 1.3). During the scoping process, the staff developed an evaluation process for determining the environmental impacts from decommissioning. Section 4.2 provides additional discussion of the process and Appendix E provides a detailed description of the analysis used to identify the environmental impacts from decommissioning. The evaluation process involved determining the specific activities that occur during decommissioning and obtaining data from site visits and from an information request to decommissioning plants that was related to the impact of these activities at currently decommissioning facilities. The data obtained from the decommissioning sites were analyzed and then evaluated against a list of variables that defined the parameters for plants that are currently operating but which will one day be decommissioned. This evaluation resulted in a range of impacts for each environmental issue that may be used for comparison by licensees that are or will be decommissioning their facilities.

1.7 Parts of This Supplement

Chapter 2 provides background, describing the basis for the current regulations and summarizing the regulations. Chapter 3 describes the types of plants covered by this Supplement, which includes permanently shutdown reactor facilities as well as operating facilities that will eventually cease power operations. Chapter 3 also describes the location and types of buildings on the sites, the systems that may still be active after permanent shutdown, and changes in effluents after permanent shutdown. Chapter 4 describes activities conducted during the decommissioning process and impacts that could arise from these activities. The analysis of the impacts is based on variables such as the option of decommissioning, location of plant, type of plant, and timing of the activity. Chapter 5 discusses the "No Action" alternative to decommissioning, which is the abandonment of the facility after the cessation of operations. Chapter 6 contains the summary of findings and conclusions.

1.8 References

10 CFR 20. Code of Federal Regulations, Title 10, *Energy*, Part 20, "Standards for protection against radiation."

10 CFR 50. Code of Federal Regulations, Title 10, *Energy*, Part 50, "Domestic licensing of production and utilization facilities."

10 CFR 51. Code of Federal Regulations, Title 10, *Energy*, Part 51, "Environmental protection regulations for domestic licensing and related regulatory functions."

10 CFR 60. Code of Federal Regulations, Title 10, *Energy*, Part 60, "Disposal of high-level radioactive wastes in geologic repositories."

10 CFR 61. Code of Federal Regulations, Title 10, *Energy*, Part 61, "Licensing requirements for land disposal of radioactive waste.

10 CFR 63. Code of Federal Regulations, Title 10, *Energy*, Part 63, "Disposal of high-level radioactive wastes in a geologic repository at Yucca Mountain, Nevada."

10 CFR 71. Code of Federal Regulations, Title 10, *Energy*, Part 71, "Packaging and transportation of radioactive material."

10 CFR 72. Code of Federal Regulations, Title 10, *Energy*, Part 72, "Licensing requirements for the independent storage of spent nuclear fuel, high-level radioactive waste, and reactor-related greater-than-Class-C waste."

40 CFR 1508. Code of Federal Regulations, Title 40, *Protection of the Environment*, Part 1508, "Terminology and Index."

54 FR 39767. "10 CFR Part 51 Waste Confidence Decision Review." *Federal Register.* September 28, 1989.

64 FR 68005. "Waste Confidence Decision Review." *Federal Register.* December 6, 1999.

66 FR 55732. "Disposal of High-Level Radioactive Wastes in a Proposed Geologic Repository at Yucca Mountain, Nevada." *Federal Register.* November 2, 2001.

Metropolitan Edison Co., et al v. People Against Nuclear Energy, 460 U.S. 766, at 774-775. 1983.

National Environmental Policy Act (NEPA) of 1969, as amended, 42 USC 4321 et seq.

Nuclear Waste Policy Act of 1982, as amended, 42 USC 10.101 et seq.

U.S. Nuclear Regulatory Commission (NRC). 1982. *Final Generic Environmental Impact Statement for 10 CFR Part 61.* NUREG-0945, NRC, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 1988. *Final Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities.* NUREG-0586, NRC, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 1997. *Final Generic Environmental Impact Statement in Support of Rulemaking on Radiological Criteria for License Termination of NRC-Licensed Nuclear Facilities.* NUREG-1496, Vol. 1, NRC, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 2000. "SECY-00-0041 Use of Rubblized Concrete Dismantlement to Address 10 CFR Part 20, Subpart E, Radiological Criteria for License Termination." NRC, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 2001. Letter from U.S. NRC to Distribution: "Subject: Issuance of a scoping summary report of comments received related to the intent to develop a Supplement to NUREG-0586." Dated April 17, 2001.

2.0 Background Information Related to Decommissioning Regulations

This section provides background information that will assist the reader in understanding the requirements for decommissioning and license termination. The basis for the current decommissioning regulations and a summary of the current regulations are provided below. This chapter and Chapter 3, "Description of NRC Licensed Reactor Facilities and the Decommissioning Process," will give the reader a basic understanding of the overall reactor decommissioning process and environmental impact assessments used during the process.

2.1 Basis for Current Regulations

In the mid-1990s, the Commission initiated an effort to significantly change the regulations for decommissioning power reactor facilities. The new regulations were intended to make the decommissioning process more current, efficient, and uniform. On July 29, 1996, a final rule revising 10 CFR 50.82, "Decommissioning of Nuclear Power Reactors," was published in the Federal Register (61 FR 39278). This rule redefined the decommissioning process and modified the regulations written in 1988, which had required submittal of a detailed decommissioning plan before the start of decommissioning.

The regulations were revised based on experience gained from reactor decommissionings that had occurred during the 1980s and early 1990s. Review of the activities that occur during decommissioning showed that they are similar to the activities that occur during the construction, operation, maintenance, and refueling outages of a power reactor (e.g., decontamination, steam generator replacement, and pipe removal). However, the magnitude of some activities during decommissioning (e.g., removal of piping) is considerably greater than during operations. Activities associated with the decommissioning of facilities had resulted in impacts consistent with or less than those evaluated in the 1988 *Final Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities* (GEIS), NUREG-0586 (NRC 1988). Based on the above reasons, the Commission determined that review and approval by the U.S. Nuclear Regulatory Commission (NRC) staff of a detailed decommissioning plan was not necessary.

2.2 Summary of Current Regulations

2.2.1 Regulations for Decommissioning Activities

The current regulations (10 CFR 50.82) specify the regulatory actions that both the NRC and the licensee must take to decommission a nuclear power facility. Once the licensee decides to permanently cease operations, it must submit, within 30 days, a written certification to the NRC.

The notification must contain the date on which the power-generating operations ceased or will cease. The licensee must permanently remove all fuel from the reactor and submit a written certification to the NRC confirming the completion of fuel removal. Once this certification has been submitted, the licensee is no longer permitted to operate the reactor, or to put fuel back into the reactor vessel. After certification that the fuel is removed, the annual license fee to the NRC is reduced as well as the licensee's obligation to adhere to certain requirements that are needed only during reactor operations.

In addition to the certifications, the licensee must submit a post-shutdown decommissioning activities report (PSDAR) to the NRC and any affected States no later than 2 years after the date of permanent cessation of operations. Section 10 CFR 50.82 requires that the PSDAR include

- a description of the licensee's planned major decommissioning activities
- a schedule for completing these activities
- an estimate of the expected decommissioning costs
- a discussion that provides the reasons for concluding that the environmental impacts associated with site-specific decommissioning activities will be bounded by an appropriate previously issued environmental impact statement (EIS).

After receiving a PSDAR, the NRC publishes a notice of receipt in the Federal Register, makes the PSDAR available for public review and comment, and holds a public meeting in the vicinity of the facility to discuss the licensee's plans. The NRC will examine the PSDAR to determine if the required information is included and will inform the licensee in writing if there are deficiencies that must be addressed before the licensee initiates any major decommissioning activities. The regulations require a 90-day waiting period after submittal of the PSDAR before the licensee may commence major decommissioning activities.

The purpose of the PSDAR is to provide the NRC and the public with a general overview of the licensee's proposed decommissioning activities. The PSDAR serves to inform the NRC staff of the licensee's expected activities and schedule, which facilitates planning for inspections and decisions regarding NRC oversight activities. The PSDAR is also a mechanism for informing the public of the proposed decommissioning activities before those activities are conducted.

Prior to submission of the PSDAR, the licensee can conduct a variety of activities at the site including activities to ensure the safe shutdown of the facility. Systems can be drained, components removed, and certain structures demolished. However, the licensee is prohibited from undertaking any major decommissioning activity as defined in 10 CFR 50.2.

Once the PSDAR has been submitted and the 90-day period has been completed, the licensee may begin major decommissioning activities, which may include the following:

- permanent removal of major radioactive components, such as the reactor vessel, steam generators, or other components that are comparably radioactive
- permanent changes to the containment structure
- dismantling of components containing Greater-than-Class-C (GTCC) Waste.[a]

In accordance with 10 CFR 50.82(a)(6)(ii), licensees shall not perform any decommissioning activities "that result in significant environmental impacts not previously reviewed." If any decommissioning activity does not meet this requirement, the licensee must submit a license-amendment request before conducting the activity. The licensee also must submit a supplement to its environmental report (ER) that relates to the additional impacts. The NRC will review the ER Supplement, and prepare an environmental assessment (EA) or EIS, and amendment to the license in conjunction with its review.

The licensee can choose (1) to immediately decontaminate and dismantle the facility (DECON), or (2) to place the facility in long-term storage (SAFSTOR) followed by subsequent decontamination and dismantlement, or (3) to perform some incremental decontamination and dismantlement activities before or during the storage period of SAFSTOR. Under the current regulations, unless the licensee receives permission to the contrary, the site must be decommissioned within 60 years. Chapter 3 describes in more detail the decommissioning

(a) The NRC has adopted a waste classification system for low-level radioactive waste based on its potential hazards, and has specified disposal and waste form requirements for each of the general classes of waste: A, B, and C. The classifications are based on the key radionuclides present in the waste and their half-lives. Tables defining these three classes are contained in 10 CFR 61.55. In general, requirements for waste form, stability, and disposal methods become more stringent when going from Class A to Class C. GTCC waste exceeds the concentration limits in 10 CFR 61.55 and is generally unsuitable for near-surface disposal as low-level waste (LLW), even though it is legally defined as LLW. The NRC's regulations in 10 CFR 61.55(a)(2)(iv) require that this type of waste must be disposed of in a geologic repository unless approved for an alternative disposal method on a case-specific basis by the NRC. 10 CFR Part 72 allows for interim storage of GTCC from a commercial power reactor.

options available to the licensee. In this Supplement, the staff also evaluates another option called ENTOMB, which encases the radioactive contaminants in a structurally long-lived material.

2.2.2 Regulations for License Termination

In order to terminate the license and allow release of the site, the licensee must submit a license termination plan (LTP). In accordance with 10 CFR 50.82(a)(9), an application for license termination must be accompanied or preceded by an LTP, which is subject to NRC review and approval. The licensee must submit the LTP at least 2 years before the date of license termination. The LTP approval process is by license amendment. By regulation, the LTP must include the following:

- a site characterization
- identification of remaining dismantlement activities
- plans for site remediation
- detailed plans for the final survey of residual contamination
- a description of the end-use of the site (if restricted use is proposed)
- an updated site-specific estimate of remaining decommissioning costs
- a supplement to the ER.

The licensee must submit the LTP as a supplement to its Final Safety Analysis Report or as an equivalent document, thus formalizing the steps necessary to revise the document.

After receiving the LTP, the NRC will place a notice of receipt of the plan in the Federal Register and will make the plan available to the public for comment. The NRC will schedule a public meeting near the facility to discuss the plan's contents and the staff's process for reviewing the submittal. The NRC will also offer an opportunity for a public hearing on the license-amendment request associated with the LTP. At this stage, a site-specific EA is required. Depending on the circumstances, the EA evaluation can result in the development of a full EIS. If the LTP demonstrates that the remainder of decommissioning activities will be performed in accordance with NRC regulations, are not detrimental to the health and safety of the public, and will not have a significant adverse effect on the quality of the environment, the

Commission will approve the plan by a license amendment (subject to whatever conditions and limitations the Commission deems appropriate and necessary).

After the approval of the LTP, the NRC will continue its inspection of the site. These inspections will include validation of commitments made in the LTP. Inspections may also include confirmatory surveys to verify that areas of the site have been decontaminated to the limits established in the LTP.

On July 21, 1997, the NRC published (also in the Federal Register) a final rule entitled, "Radiological Criteria for License Termination" (64 FR 39058) prescribing specific radiological criteria for license termination. At the end of the LTP process, if the NRC determines that the remaining dismantlement has been performed in accordance with the approved LTP, and if the final radiation survey and associated documentation demonstrate that the facility and site are suitable for release, then the Commission will terminate the license.

The radiological criteria for license termination are given in 10 CFR Part 20, Subpart E. There are two broad categories of uses for the facility after the license termination: unrestricted use and restricted use.

Unrestricted use means that there are no NRC-imposed restrictions on how the site may be used. State and local jurisdictions may, and have, imposed additional restrictions or requirements on licensees. The licensee is free to continue to dismantle any remaining buildings or structures and to use or sell the land for any type of application. The Commission has established a 0.25 mSv/yr (25 mrem/yr) total effective dose equivalent (TEDE) to an average member of the critical group[a] as an acceptable criterion for release of any site for unrestricted

(a) The "critical group" is that group of individuals reasonably expected to receive the highest exposure to residual radioactivity within the assumptions of a particular scenario. The average dose to a member of the critical group is represented by the average of the doses for all members of the critical group, which in turn is assumed to represent the most likely exposure situation. For example, when considering whether it is appropriate to "release" a building that has been decontaminated (allow people to work in the building without restrictions), the critical group would be the group of employees that would regularly work in the building. If radiation in the soil is the concern, then the scenario used to represent the maximally exposed individual is that of a resident farmer. The assumptions used for this scenario are prudently conservative and tend to overestimate the potential doses. The added "sensitivity" of certain members of the population, such as pregnant women, infants, children, and any others who may be at higher risk from radiation exposures, are accounted for in the analysis. However, the most sensitive member may not always be the member of the population that receives the highest dose. This is especially true if the most sensitive member (e.g., an infant) does not participate in activities that provide the greatest dose or if they do not eat specific foods that cause the greatest dose.

use. The licensee will be required to show that the site can meet this criterion before the license will be terminated for unrestricted use. In addition, the licensee will need to show that the amounts of residual radioactivity have been reduced to levels that are as low as reasonably achievable (ALARA).[a] For sites that have been determined to be acceptable for unrestricted use, there are no requirements for further measurement of radiation levels. It is not expected that these radiation levels would change (other than to be reduced over time through radioactive decay), and there would be no mechanism for further contamination or radiological releases.

Restricted use means that there are restrictions on the facility use after license termination. A site would be considered acceptable for license termination under restricted conditions if the licensee can demonstrate that further reductions in residual radioactivity necessary to meet the requirements for unrestricted use would result in net public or environmental harm, or were not being made because the residual levels were ALARA. In addition, the licensee must have made provisions for legally enforceable institutional controls (e.g., use restrictions placed in the deed for the property) that provide reasonable assurance that the radiological criteria set by the NRC (0.25 mSv/yr [25 mrem/yr] TEDE to an average member of the critical group) will not be exceeded. The licensee must also have provided sufficient financial assurance to an amenable independent third party to assume and carry out responsibilities for any necessary control and maintenance of the site. There are also regulations relating to the documentation of how the advice of individuals and institutions in the community who may be affected by decommissioning has been sought and incorporated in the LTP if the license is to be terminated under restricted conditions.

Residual radioactivity at the site must be reduced so that if the institutional controls were no longer in effect, there would be reasonable assurance that the TEDE from residual radioactivity distinguishable from background to the average member of the critical group would be ALARA and would not exceed either 1 mSv/yr (100 mrem/yr) or 5 mSv/yr (500 mrem/yr). In the latter case, the licensee must (1) demonstrate that further reductions in residual radioactivity necessary to comply with the 1 mSv/yr (100 mrem/yr) value are not technically achievable, would be prohibitively expensive, or would result in net public or environmental harm, (2) make provisions for durable institutional controls, and (3) provide sufficient financial assurance to enable a responsible government entity or independent third party to carry out periodic checks of the facility no less frequently than every 5 years to ensure that the institutional controls remain in place.

(a) The ALARA concept means that all doses are to be reduced below required levels to the lowest reasonably achievable level considering economic and societal factors. Determination of levels that are ALARA must consider any detriments, such as deaths from transportation accidents, that are expected to potentially result from disposal of radioactive waste.

Alternate release criteria may be used in specific cases. The use of alternate criteria to terminate a license requires the approval of the Commission after consideration of the NRC staff's recommendations that address comments provided by the U.S. Environmental Protection Agency and any public comments submitted pursuant to 10 CFR 20.1405. These alternate criteria are expected to be used only in very rare cases.

To date, the three NRC-licensed facilities (Shoreham, Fort St. Vrain, and Pathfinder) that have completed the decommissioning process have had their licenses terminated, allowing unrestricted use of the sites. License termination plans have been submitted for three other facilities. The LTPs describe plans for unrestricted use of the sites following license termination. No nuclear power licensees have indicated that they plan for restricted use of the site after license termination.

A proposed rule was issued on September 4, 2001 (66 FR 46230) for partial site release prior to license termination. Partial site release means release of part of a nuclear power reactor facility or site for unrestricted use prior to NRC approval of the LTP. The NRC proposes to add a new section to 10 CFR Part 50, separate from the existing rules for decommissioning and radiological criteria for license termination, that identifies the requirements and criteria necessary for partial site release. The proposed rule includes associated amendments to 10 CFR Part 2 and 10 CFR Part 20. The purpose of this rulemaking is to ensure that any remaining residual radioactive material from licensed activities on a portion the site released for unrestricted use will meet the radiological criteria for license termination.

Licensees will be required to submit information necessary to demonstrate the following:

- The release of radiologically impacted property complies with the radiological criteria for unrestricted use in 10 CFR 20.1402 (0.25 mSv/yr [25 mrem/yr] to the average member of the critical group and ALARA).

- The licensee will continue to comply with all other applicable regulatory requirements that may be affected by the release of property and changes to the site boundary. This would include, for example, requirements in 10 CFR Parts 20, 50, 72, and 100.

- Records of property-line changes and the radiological conditions of partial site releases are being maintained to ensure that the dose from residual material associated with these releases can be accounted for at the time of any subsequent partial releases and at the time of license termination.

The proposed rule provides additional flexibility to licensees who are releasing property that has never been radiologically impacted. While an amendment of the Part 50 operating license is required to release radiologically impacted property, the proposed rule offers the opportunity for a letter submittal for partial releases if the licensee can demonstrate that there is no reasonable potential for residual radioactivity from license activities.

2.3 References

10 CFR 2. Code of Federal Regulations, Title 10, *Energy*, Part 2, "Rules of practice for domestic licensing proceedings and issuance of orders."

10 CFR 20. Code of Federal Regulations, Title 10, *Energy*, Part 20, "Standards for protection against radiation."

10 CFR 50. Code of Federal Regulations, Title 10, *Energy*, Part 50, "Domestic licensing of production and utilization facilities."

10 CFR 61. Code of Federal Regulations, Title 10, *Energy*, Part 61, "Licensing requirements for land disposal of radioactive waste."

10 CFR 72. Code of Federal Regulations, Title 10, *Energy*, Part 72, "Licensing requirements for the independent storage of spent nuclear fuel high-level radioactive waste and reactor-related greater-than-Class-C waste."

10 CFR 100. Code of Federal Regulations, Title 10, *Energy*, Part 100, "Reactor site criteria."

61 FR 39278. "Decommissioning of Nuclear Power Reactors. Final Rule." *Federal Register*. July 29, 1996.

64 FR 39058. "Radiological Criteria for License Termination. Final Rule." *Federal Register*. July 21, 1997.

66 FR 46230. "Releasing Part of a Power Reactor Site or Facility for Unrestricted Use Before the NRC Approves the License Termination Plan. Proposed Rule." *Federal Register*. September 4, 2001.

U.S. Nuclear Regulatory Commission (NRC). 1988. *Final Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities*. NUREG-0586, NRC, Washington, D.C.

3.0 Description of NRC Licensed Reactor Facilities and the Decommissioning Process

This chapter provides information on both the operating nuclear power plants and those being decommissioned. First, a general description of the nuclear power plants and sites is provided in Section 3.1 to help the reader understand the types of reactor facilities that will be decommissioned, the location of the radioactive material in these facilities, and the structures, systems, and components (SSCs) that will be referred to later in this document and that are important in the decommissioning process. Next, the methods that are commonly used during decommissioning are described in Section 3.2. Section 3.3 addresses the decommissioning experience of the currently decommissioning plant sites, their chosen method for decommissioning, and the activities that are being used to decommission the facilities.

There are currently 22 nuclear power reactors at 21 sites that are permanently shut down: 19 of these reactors are in various stages of decommissioning, and reactors at 3 sites have finished decommissioning and no longer maintain a license. The decommissioning efforts at these 22 plants equates to over 200 equivalent years of experience decommissioning commercial power reactors since the 1988 *Final Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities*, NUREG-0586 (1988 GEIS; NRC 1988) was published. There are also currently 104 nuclear plants that have a license and are either operating or have not yet certified that they have permanently ceased power operations. Between 2006 and 2035, these 104 plants will either permanently cease operations or renew their licenses. Ultimately, they will all permanently cease operations and be decommissioned.

3.1 Plants, Sites, and Reactor Systems[a]

Between 1957 and 1996, the U.S. Nuclear Regulatory Commission (NRC) issued 126 operating licenses for commercial power reactor operation at 80 sites. The history of and experience with the 22 reactors that are being decommissioned currently or have completed decommissioning are addressed in Section 3.3. Because each of the remaining 104 operating plants will eventually enter the decommissioning process, their attributes and characteristics are included in this section to ensure that this Supplement is appropriate for future decommissioning plants. The material presented in this section is also provided as background information for the reader.

(a) Much of the information in this section was taken from NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants* (NRC 1996) and from NUREG-1628, *Staff Responses to Frequently Asked Questions Concerning Decommissioning of Nuclear Power Reactors* (NRC 2000a). This information has been supplemented and updated as appropriate to include all operating and currently decommissioning nuclear plants.

Nuclear power reactor facilities are located in 35 of the contiguous States, with none in Alaska or Hawaii. Thirty-nine sites contain two or three nuclear power reactors (units) per site. Of the 126 plants, 98 are located east of the Mississippi River with most of the nuclear capacity located in the northeast (New England States, New York, and Pennsylvania), the midwest (Illinois, Michigan, and Wisconsin) and the southeast (Virginia, North and South Carolina, Georgia, Florida, and Alabama).

Typically, nuclear power plants are sited in flat or rolling countryside, in wooded or agricultural areas away from urban areas. Most are located on or near rivers or lakes. Several plants are located in arid regions, and 19 plants are located along the seacoast on bays or inlets. More than 50 percent of the sites have 80-km (50-mile) population densities of less than 77 persons/km^2 (200 persons/mi^2) and over 80 percent have 80-km (50-mile) densities of less than 193 persons/km^2 (500 persons/mi^2). The most notable exception is the Indian Point Station, located within 80 km (50 mi) of New York City, which has a projected 1999 population density within 80 km (50 mi) of more than 770 persons/km^2 (2000 persons/mi^2). Indian Point has one permanently shutdown reactor and two operating reactors.

Site areas range from a minimum of 34 ha (84 ac) for the San Onofre Nuclear Generating Station, (a three unit site, with one permanently shutdown reactor) in California to 9700 ha (24,000 ac) for the Turkey Point Plant in Florida (two operating units). Almost 60 percent of plant sites cover from 200 to 800 ha (500 to 2000 ac). Larger land-use areas are associated with plant cooling systems that include reservoirs, artificial lakes, and buffer areas.

Appendix F contains summary tables for both permanently shutdown and currently operating nuclear power facilities showing location, reactor type, thermal power, site area, cooling system and cooling water source, and licensing dates.

3.1.1 Types of Nuclear Power Reactor Facilities

In the United States, nearly all reactors used for commercial power generation have been conventional (thermal) light water reactors (LWRs) that use water as a moderator and coolant. The two types of LWRs are pressurized water reactors (PWRs) and boiling water reactors (BWRs). Of the 123 LWRs, 80 are PWRs and 43 are BWRs. The three plants that are not LWRs are Fermi, Unit 1, which is a permanently shutdown fast breeder reactor (FBR), and Peach Bottom, Unit 1, and Fort St. Vrain, which are permanently shutdown high-temperature gas-cooled reactors (HTGRs). Fermi, Unit 1, is currently performing the decontamination and dismantlement phase of SAFSTOR (see Section 3.2). Peach Bottom, Unit 1, is in long-term storage. Fort St. Vrain has had its license terminated following completion of decommissioning activities.

Brief descriptions of these different types of reactors are given below as background.

3.1.1.1 Pressurized Water Reactors

In PWRs, water is heated to a high temperature under pressure inside the reactor. The water is then pumped in the primary circulation loop to the steam generator. Within the steam generator, water in the secondary circulation loop is converted to steam that drives the turbines. The turbines turn the generator to produce electricity. The steam leaving the turbines is condensed by water in the tertiary loop and returned to the steam generator. The tertiary loop water flows either to cooling towers, where it is cooled by evaporation or discharged to a body of water such as a river, lake, or other heat sink. The tertiary loop is open to the atmosphere, but the primary and secondary cooling loops are not (see Figure 3-1).

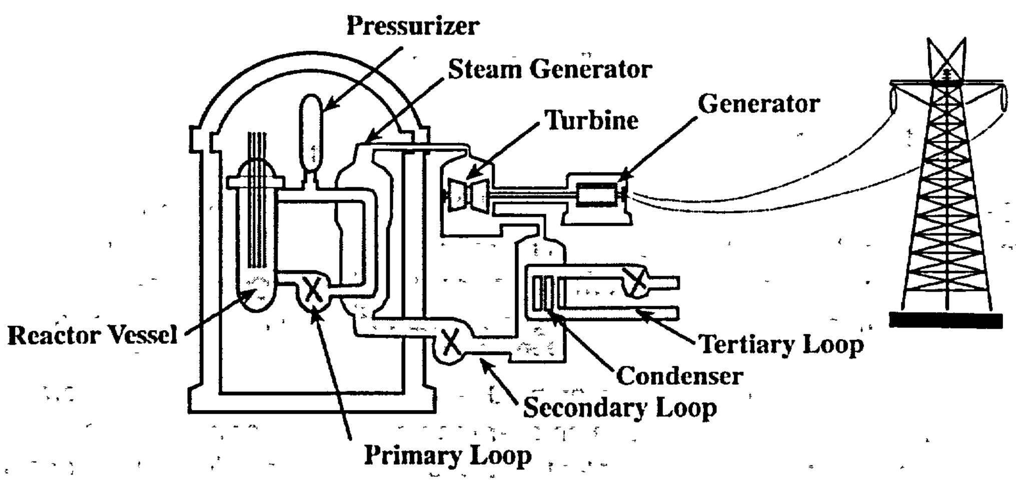

Figure 3-1. Pressurized Water Reactor

3.1.1.2 Boiling Water Reactors

The BWRs generate steam directly within the reactor vessel. The steam passes through moisture separators and steam dryers and then flows to the turbine. By generating steam directly in the reactor vessel, the power generation system contains only two heat transfer loops. The primary loop transports the steam from the reactor vessel directly to the turbine, which generates electricity. The secondary coolant loop removes excess heat from the primary loop in the condenser. From the condenser the primary condensate proceeds into the feedwater stage and the secondary coolant loop removes the excess heat to the environment (see Figure 3-2).

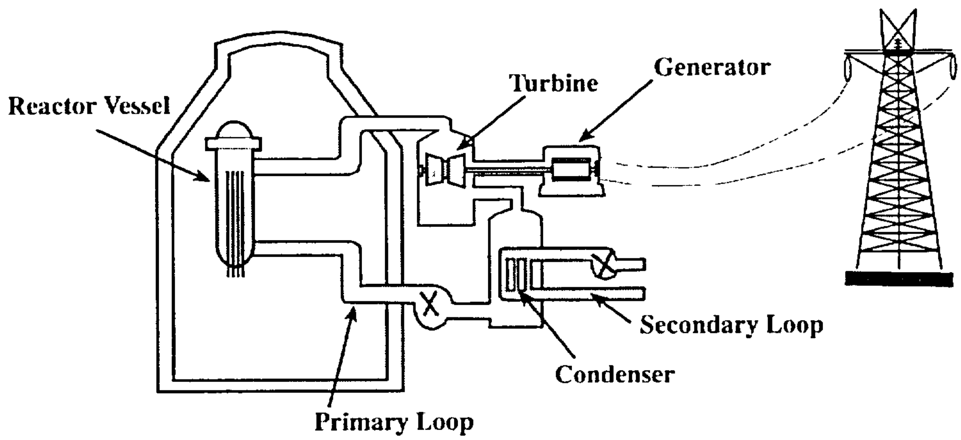

Figure 3-2. Boiling Water Reactor

3.1.1.3 Fast Breeder Reactors

In the FBR, such as Fermi, Unit 1, liquid sodium is used as the reactor coolant instead of water. The Fermi, Unit 1, FBR used the fissile isotope of uranium as fuel. During the chain reaction, while some neutrons are fissioning plutonium atoms and releasing heat energy, others are captured by uranium atoms, which are then converted into more plutonium atoms. Depending on design, a fast breeder can produce 1.4 new plutonium atoms for every one fissioned–enough to refuel another reactor in 10 years. Fast breeders also generally have a higher power density in the core (thus, a smaller reactor) and better heat transfer characteristics, which improves power-plant efficiency. The Fermi, Unit 1, reactor also utilized a steam cycle to generate electricity, similar to a PWR. However, the Fermi, Unit 1, reactor had two sodium loops. Primary-loop liquid sodium was circulated through the reactor core, where it absorbed the heat generated by the reactor, and then through a heat exchanger, where its heat was transferred to the second (intermediate) sodium loop. The intermediate-loop liquid sodium was then circulated through a steam generator. The steam produced in the steam generators was then circulated to the turbine generators to produce electricity.

At this time, there are no commercial FBRs operating or under construction in the United States. Fermi, Unit 1, is currently in SAFSTOR. The environmental impacts described in this Supplement for FBRs are applicable to Fermi, Unit 1.

3.1.1.4 High-Temperature Gas-Cooled Reactors

Commercial HTGRs, operated in the United States at Peach Bottom, Unit 1, and Fort St. Vrain, use helium gas instead of water (as in LWRs) to transfer the heat from the reactor core to produce steam. In HTGRs, the entire primary coolant system, including the reactor, the steam generators, and the helium circulators, is housed within a prestressed concrete or steel reactor vessel. The helium circulators pump the pressurized coolant through the core, where it absorbs the heat from the fission process. The helium then enters the steam generators, which transfer the heat to the secondary system. The secondary system is a steam cycle similar to that found in any modern fossil-fuel facility. Superheated steam is produced in the steam generators and routed to the turbine generator, which generates the electricity (Fuller 1988).

At this time, there are no HTGRs operating or under construction in the United States. Decommissioning at Fort St. Vrain is complete and the license is terminated, and Peach Bottom, Unit 1, is currently in SAFSTOR. The environmental impacts described in this Supplement for HTGRs are applicable to Peach Bottom, Unit 1.

3.1.2 Types of Structures Located at a Nuclear Power Facility

As discussed in Chapter 1, the definition of decommissioning includes the reduction of residual radioactivity to a level that permits release of the property and termination of the license. As a result, the decontamination and/or dismantlement of those SSCs that are radioactive are, by definition, included within the scope of this Supplement as part of decommissioning. If the structures must be decontaminated or parts of the structures removed to meet the requirements for the termination of the NRC license, those activities are also considered within scope as part of the decommissioning process. This includes removing nonradiological structures necessary to decontaminate another structure. Additionally, the impacts of dismantling all SSCs that were built or installed at the site to support power production are considered in this Supplement. This section discusses all the structures that will be referred to later in the document as background information for the reader.

Nuclear power plants generally contain similar facilities. They all contain a nuclear steam supply system, as described in Section 3.1.1 above. Additionally, there are a number of common SSCs necessary for plant operation. However, the layout of buildings and structures varies considerably among the sites. For example, control rooms may be located in the auxiliary building, in a separate control building, or in a radwaste and control building. Thus, the following list describes typical structures located on most sites.

- <u>Containment or reactor building</u>: The containment or reactor building in a PWR is a massive concrete or steel structure that houses the reactor vessel, reactor coolant piping and pumps, steam generators, pressurizer, pumps, and associated piping. The reactor building structure of a BWR generally includes a containment structure and a shield building. The containment is a massive concrete or steel structure that houses the reactor vessel, the reactor coolant piping and pumps, and the suppression pool. It is located inside a somewhat less substantive structure called the shield building. The shield building for a BWR also generally contains the spent fuel pool and the new fuel pool.

  The reactor building for both PWRs and BWRs is designed to withstand such disasters as hurricanes and earthquakes. The containment's ability to withstand such disasters and to contain the effects of accidents initiated by system failures are the principal protections against releasing radioactive material to the environment.

  The containment building for the FBR is a steel-domed structure that contains the upper end of the reactor vessel and the fuel-handling equipment. Below ground there is considerable concrete shielding.

  The HTGRs have two containment structures. Peach Bottom's inner containment structure is made of a steel pressure vessel and Fort St. Vrain's was made of prestressed concrete. This inner vessel houses the entire primary coolant system, the interconnecting ducts and plenums, the reactor core assembly, and the steam generator. The inner vessel is housed inside a second containment structure, which is designed to contain the entire primary coolant system helium under conditions postulated for the design basis accident.

- <u>Fuel building</u>: For PWRs, the fuel building has a fuel pool that is used for the storage and servicing of spent fuel and the preparation of new fuel for insertion into the reactor. This building is connected to the reactor building by a transfer tube or channel that is used to move new fuel into the reactor and to move spent fuel out of the reactor for storage.

- <u>Turbine building</u>: The turbine building houses the turbine generators, condenser, feedwater heaters, condensate and feedwater pumps, waste-heat rejection system, pumps, and equipment that supports those systems. Primary coolant is circulated through these systems in BWRs, thereby causing them to become slightly contaminated. Primary coolant is not circulated through the turbine building systems in PWRs. However, it is not unusual for portions of the turbine building to become mildly contaminated during power generation at PWRs.

- Auxiliary buildings: Auxiliary buildings house such support systems as the ventilation system, the emergency core cooling system, the laundry facilities, water treatment system, and waste treatment system. The auxiliary building may also contain the emergency diesel generators and, in some PWRs, the fuel storage facility. Often, the facility's control room is also located in the auxiliary building.

- Diesel generator building: Often, there is a separate building for housing the emergency diesel generators if they are not located in the auxiliary building. The emergency diesel generators do not become contaminated or activated.

- Pumphouses: Various pumphouses may be present onsite for circulating water, standby service water, or makeup water. Pumphouses that carry clean water do not require radiological decommissioning.

- Cooling towers: Cooling towers are structures that are designed to remove excess heat from the condenser without dumping the heat directly into water bodies, such as lakes or rivers. There are two principal types of cooling towers: mechanical draft towers and natural draft towers. Most nuclear plants that have once-through cooling do not have cooling towers associated with them (see the descriptions in Section 3.1.3). However, five facilities with once-through cooling also have cooling towers.

- Radwaste facilities: If the radwaste facilities are not contained in the auxiliary building, they may be located in a separate solid radwaste building. An interim radwaste storage facility may also be used.

- Ventilation stack: Many older nuclear power plants, particularly BWRs, have ventilation stacks to discharge gaseous waste effluents and ventilation air. These stacks can be 90 m (300 ft) tall or more and contain monitoring systems to ensure that radioactive gaseous discharges are below fixed release limits. Radioactive gaseous effluents are treated and processed prior to discharge out the stack.

The following structures may also be part of the nuclear reactor facility but are not evaluated in this Supplement.

- Independent spent fuel storage installations (ISFSI): An ISFSI is designed and constructed for the interim storage of spent nuclear fuel and other radioactive materials associated with spent fuel storage. ISFSIs may be located at the site of a nuclear power plant or at another location. The most common design for an ISFSI, at this time, is a concrete pad with dry casks containing spent fuel bundles. ISFSIs are used by operating plants that require increased spent fuel storage capability because their spent fuel pools have reached capacity. Decommissioning facilities also use ISFSIs. The first dry-storage installation was licensed by the NRC in 1986. As of August 21, 2002, there were 23 nuclear power facilities licensed to use dry storage: Surry, Oconee, H.B. Robinson, Calvert Cliffs, Fort St. Vrain, Palisades, Point Beach, Prairie Island, Davis-Besse, Susquehanna, Arkansas Nuclear One, North Anna, Trojan, Dresden, Hatch, McGuire, Oyster Creek, Peach Bottom, Yankee Rowe, Fitzpatrick, Rancho Seco, Maine Yankee, and U.S. Department of Energy (DOE [TMI-2 fuel debris]) at Idaho National Engineering and Environmental Laboratory.

An ISFSI can be constructed and operated and decommissioned either under the same license that is used for the operating or decommissioning facility called a general license under 10 CFR Part 50 or a specific license under 10 CFR Part 72 license. If a licensee chose to operate the ISFSI under a Part 50 license, it could, seek a site-specific 10 CFR Part 72 license for the ISFSI, thus allowing termination of the Part 50 license at the end of the decommissioning process. The NRC staff would also be required to conduct an environmental assessment of the licensee's request for a site-specific 10 CFR Part 72 license.

- Switchyard: A plant site also contains a large switchyard, where the electric voltage is stepped up and fed into the regional power distribution system. The switchyard is an integral part of the electric power transmission grid, and may remain on the site even after termination of the license.

- Administrative, training, and security buildings: Normally, the administrative, training, and security buildings are located outside the radiation protection zones, and no radiological hazards are present.

3.1.3 Description of Systems

After permanent cessation of operations and transfer of the fuel from the reactor vessel, licensees begin to shut down systems that are no longer operated in a decommissioning plant. However, specific systems will continue to be used during the different phases of the decommissioning process although in some cases in reduced roles. This section provides background information related to the systems, explains the differences between the systems' use during operations and during the decommissioning process, and explains how their continued operation could impact the environment during the decommissioning process. Lobner et al. (1990) provides more comprehensive descriptions of these systems in U.S. commercial LWRs. The systems described below are typical and may differ at specific facilities.

- Cooling and auxiliary water systems: The predominant water use at an operating nuclear power plant is for removing excess heat generated in the reactor by the condenser cooling system. The quantity of water that is used for condenser cooling in an operating plant is a function of several factors, including the capacity rating of the plant and the increase in cooling water temperature from the discharge to the intake. The cooling water system for the reactor is not operated after the facility has permanently ceased power operations and the fuel has been removed from the reactor vessel. Therefore, water use is greatly reduced when operations cease. However, systems are not immediately drained upon cessation of operation and are frequently left in place for a period of time to provide shielding to the workers.

  There are two major types of cooling systems for operating plants: once-through cooling and closed-cycle cooling.

  In a once-through cooling system, circulating water for condenser cooling is obtained from an adjacent body of water, such as a lake or river, passed through the condenser tubes, and returned at a higher temperature to the adjacent body of water. Flow through the condenser for a 1000-MW plant during operations is typically 45 to 65 m^3/s (700,000 to 1,000,000 gpm) (NRC 1996). The waste heat is dissipated to the atmosphere mainly by evaporation from the water body and, to a much smaller extent, by conduction, convection, and thermal radiation loss.

  In a closed-cycle system at an operating plant, the cooling water is recirculated through the condenser after the waste heat is removed by dissipation to the atmosphere, usually by circulating the water through large cooling towers constructed for that purpose. The average for makeup water withdrawals for a 1000-MW plant during operations is typically about 0.9 to 1.1 m^3/s (14,000 to 18,000 gpm). Recirculating cooling systems consist of either natural draft or mechanical draft cooling towers, cooling ponds, lakes, or canals. Because the predominant cooling mechanism associated with closed-cycle systems is evaporation, most of the water used for cooling is consumed and is not returned to the water source.

  In addition to removing heat from the reactor of an operating facility, cooling water is also provided to the service water system and to the auxiliary water system. These systems account for 1 to 15 percent of the water needed for the condenser cooling. The auxiliary water systems include emergency core cooling systems, the containment spray and cooling system, the emergency feedwater system, the component cooling water system, and the spent fuel pool water systems. Most of these systems would not be needed following permanent cessation of operations. However, some, such as the systems for the spent fuel pool cooling, will be used after the plant has shut down.

- Waste systems (gaseous, liquid, solid, and nonradioactive): The gaseous waste management system in an operating nuclear facility collects fission products, mainly noble gases, that accumulate in the primary coolant. It is designed to reduce the radioactive material in gaseous waste before discharge to meet the dose design objectives in 10 CFR Part 50, Appendix I. During decommissioning, the gaseous waste management system is used during the decontamination and dismantlement of certain tanks or pipes. It is also used during dismantlement to assist in the control of radioactive dust or loose contamination. In addition, high-efficiency particulate air (HEPA) filters are used to remove radioactive material on a localized basis. For example, when removing concrete with a power hammer or drill in the containment building, a temporary plastic tent equipped with a HEPA filter, prevents contaminated dust particles from entering the building. A second set of HEPA filters is located on the exhaust vent pathway for the building. The quantities of gaseous effluents released from operating plants and those in the decommissioning process are controlled by the administrative limits that are defined in the Offsite Dose Calculation Manual (ODCM) or similar document, which is specific for each plant. The limits in the ODCM are designed to provide reasonable assurance that radioactive material discharged in gaseous effluents are not in excess of the limits specified in 10 CFR Part 20, Appendix B, thereby limiting the exposure of a member of the public in an unrestricted area.

  The liquid radioactive waste system in operating nuclear power plants is used to collect and process liquid wastes collected from equipment leaks, valve and pump seal leaks, laundry wastes, personnel and equipment wastes, and steam generator blowdown (for PWRs), as well as building, laboratory, and floor drains. Each of these sources of liquid wastes receives varying degrees and types of treatment before storage, reuse, or discharge to the environment. During decommissioning, any radioactive liquids from operation of decommissioning activities in the facility will be processed and disposed of, thus necessitating the use of the liquid radioactive waste system. Some systems such as the laundry will likely still operate for a period of time, but others like the steam generator blowdown will not. Controls for limiting the release of radiological liquid effluents are described in the facility's ODCM. Controls are based on (1) concentrations of radioactive materials in liquid effluents and projected dose or (2) dose commitments to a member of the public. Concentrations of radioactive material that may be released in liquid effluents to unrestricted areas are limited to the concentration specified in 10 CFR Part 20, Appendix B, Table 2.

  Solid low-level waste (LLW) from nuclear power plants is generated by removal of radionuclides from liquid waste streams, filtration of airborne gaseous emissions, and removal of contaminated material. The major source of solid LLW during decommissioning is the decommissioning process itself. Removal of contamination involves the use of protective clothing and cleaning rags. Dismantlement results in concrete or metal that has low levels of contamination or activation products. While the amount of liquid and gaseous radioactive waste generated is usually lower for decommissioning plants than for operating plants, the quantity of solid LLW being generated is significantly higher during decommissioning.

Solid waste is packaged in containers to meet the applicable requirements of 49 CFR Parts 171 through 177. Disposal and transportation are performed in accordance with the applicable requirements of 10 CFR Part 61 and 10 CFR Part 71, respectively.

Solid radioactive waste generated during either decommissioning or operations is usually shipped to a LLW processor or, in some cases, directly to a LLW disposal site. Volume reduction may occur both onsite and offsite. The most common onsite volume reduction techniques are high-pressure compacting in waste drums, dewatering and evaporating wet wastes, monitoring waste streams to segregate wastes, and sorting. Offsite waste management vendors compact wastes at ultra-high pressures, incinerate dry active waste, separate and incinerate oily and organic wastes, and asphalt-solidify resins and sludges before the waste is sent to the LLW site.

Nonradioactive wastes, including storm water system and sewage waste, are also generated during the decommissioning process. For example, use of hazardous oils or other chemicals in solvent cleaning and repair of equipment produces some nonradioactive wastes. Also, during decommissioning, additional quantities of nonradioactive waste (paint, asbestos) are generated or removed. Disposal of essentially all of the hazardous chemicals used at nuclear power plants is regulated by the Resource Conservation and Recovery Act (RCRA) of 1976 or by National Pollutant Discharge Elimination System (NPDES) permits, which are regulated by the U.S. Environmental Protection Agency (EPA) and administered by EPA, or if authorized, by the States to control the amount and types of pollutants that may be discharged from the plant.

Mixed waste is regulated under RCRA, the Atomic Energy Act, and NRC and is sent to a facility that is licensed to handle mixed waste.

- Miscellaneous mechanical systems: A variety of existing plant mechanical systems may continue to be used during plant decommissioning, including

  - the fire protection system

  - the heating, ventilation, and air conditioning (HVAC) system

- the fuel-handling system
- various cranes and hoists.

The use of these systems generally does not have a direct impact on the environment. For example, the HVAC system that is used inside a contaminated area would be exhausted to the gaseous waste management system.

- Instrumentation and control systems: While most instrumentation and control systems in the plant can be deactivated after permanent shutdown and defueling of the reactor, a few may continue to be used to support decommissioning operations, including:

  - the radiation monitoring system, which detects, measures, and records radiation levels during decommissioning operations and alerts plant staff of off-normal readings, and
  - the security system, which monitors the plant protected area to prevent uncontrolled access.

  In most cases, these systems are altered or reduced during the decommissioning process. The use of these systems during the decommissioning process does not impact the environment.

- Electrical systems: Numerous electrical systems may continue to be used during decommissioning operations. These include systems needed to provide uninterrupted power, lighting, and communication. In some cases, licensees have installed a new power distribution system, re-energizing only those loads that are necessary for continued use during decommissioning. In many facilities, the circuits that are being used are color-coded so that workers can easily identify the live circuits. Both of these practices are intended to prevent workers from cutting into a live wire during the decommissioning process.

- Spent fuel storage systems: Before beginning the decommissioning process, the licensee must certify to the NRC that it has permanently removed the fuel from the reactor vessel. The fuel is first moved into the spent fuel pool, which is a specially designed water-filled basin. Even after the nuclear reactor is shut down, the fuel continues to generate decay heat from the radioactive decay of fission products. The rate at which the decay heat is generated decreases the longer the reactor has been shut down. Therefore, the longer the time from last criticality, the less heat the spent fuel gives off. Storing the spent fuel in a pool of water provides an adequate heat sink for the removal of heat from the irradiated fuel. In addition, the fuel is located far enough under water that the radiation emanating from the fuel is shielded by the water, thus protecting workers from the radiation. After the fuel has cooled adequately, it can be stored in an ISFSI in air-cooled dry casks. Typically, transfer of spent fuel to an ISFSI occurs after the fuel has cooled for 5 years.

After removal of the fuel to the spent fuel pool, it is common for the licensee to reduce the security area at the facility to a "nuclear island" that focuses primarily on the storage area for the spent fuel. This allows the spent fuel to be protected and the security system to cover only the storage location for the spent fuel.

At this time, there are no facilities for permanent disposal of high-level radioactive wastes (HLW). The Nuclear Waste Policy Act of 1982 defined the goals and structure of a program for permanent, deep geologic repositories for HLW and unreprocessed spent fuel. Under this Act, the DOE is responsible for developing permanent disposal capacity for the spent fuel and other high-level nuclear wastes. At the present time, DOE, as directed by Congress, is investigating a site in Yucca Mountain, Nevada, for a possible disposal facility. A HLW repository would be built and operated by DOE and licensed by the NRC.

The Commission believes (10 CFR 51.23(a)) there is reasonable assurance that at least one mined geological repository will be available in the first quarter of the 21st Century and that, within 30 years beyond the licensed life of operation for any reactor, sufficient repository capacity will be available to dispose of the reactor's HLW and spent fuel generated up to that time.

Until a HLW repository is available or some interim central waste storage facility is approved and licensed, licensees generally store the fuel onsite, either in dry storage (ISFSI) or in wet storage in a spent fuel pool. Licensees are prohibited from shipping spent fuel from one reactor spent fuel pool to another without NRC approval by license amendment.

The Commission has independently, in a separate proceeding (the Waste Confidence Proceeding), made a finding that there is

> reasonable assurance that, if necessary, spent fuel generated in any reactor can be stored safely and without significant environmental impacts for at least 30 years beyond the licensed life for operation (which may include the term of a revised license) of that reactor at its spent fuel storage basin, or at either onsite or offsite independent spent fuel storage installations (54 FR 39767).

The Commission has committed to review this finding at least every 10 years. In its most recent review, the Commission concluded that experience and developments since 1990 were not such that a comprehensive review of the Waste Confidence Decision was necessary at this time (64 FR 68005). Accordingly, the Commission reaffirmed its findings of insignificant environmental impacts cited above. This finding is codified in the Commission's regulations at 10 CFR 51.23(a). The staff relies on the Waste Confidence Rule, but for completeness has elected to include in this Supplement information related to the storage and maintenance of fuel in a spent fuel pool.

- Transportation systems: There are four broad classes of shipments to and from operating nuclear power plants: (1) routinely generated LLW transported from plants to disposal facilities, (2) routine LLW shipped to offsite facilities for volume reduction, (3) nuclear fuel shipments from fuel-fabrication facilities to plants for loading into reactors, and (4) spent fuel shipments to other nuclear power plants with available storage space (an infrequent occurrence that is usually limited to plants owned by the same utility).

  The transportation of radioactive materials is regulated jointly at the Federal level by the U.S. Department of Transportation (DOT) and the NRC. The responsibilities of the two agencies are delineated in a Memorandum of Understanding (see 44 FR 38690). Most LLW is shipped in packages authorized by the DOT. Some packages for larger quantities of LLW require NRC certification. The LLW packages can be loaded onto trucks, trains, barges, or other ships for shipment to the LLW disposal site. In general, the areas regulated by the agencies are as follows:

  - DOT – Regulates shippers and carriers of radioactive material and the conditions of transport, including routing, tiedowns, radiological controls, vehicle requirements, hazard communication, handling, storage, emergency response information, and employee training. DOT regulations are located in the Code of Federal Regulations, Title 49, "Transportation."

  - NRC – Regulates users of radioactive material and the design, construction, use, and maintenance of shipping containers used for larger quantities of radioactive material and fissile material such as uranium. NRC regulations are located in 10 CFR Part 71, "Packaging and Transportation of Radioactive Material."

  Title 10 CFR 71.47 states that under normal transportation conditions, each package of radioactive materials must be designed and prepared for shipment such that the radiation level does not exceed 2 mSv/h (200 mrem/h) at any point on the external surface of the package and 0.1 mSv/h (10 mrem/h) at any point 1 m (3.3 ft) from the packaging surface. This type of shipment is called a nonexclusive use shipment. If the package exceeds the limits specified for nonexclusive use shipments, it must be transported by exclusive use shipment only. The radiation limits for exclusive use packages are the following:

- At any point on the package surface: 2 mSv/h (200 mrem/h). For closed transport vehicle only: 10 mSv/h (1000 mrem/h)
- At 2 m (6.6 ft) from lateral surfaces of vehicle: 0.1 mSv/h (10 mrem/h)
- At all external surfaces of the vehicle: 2 mSv/h (200 mrem/h)
- In the occupied area of the vehicle: 0.02 mSv/h (2 mrem/h), with certain exceptions.

For more information regarding waste packaging and radioactive transportation regulations, see 10 CFR Part 71.

The frequency of waste shipments increases sharply during the decommissioning period. In some cases, such as the shipment of large components (e.g., steam generators, reactor vessels, or pressurizers), the waste packaging is unique compared to most shipments during operations. However, the licensee is still required to meet the regulations discussed above, unless the NRC approves an exemption after a thorough analysis of the licensee's proposal.

3.1.4 Formation and Location of Radioactive Contamination and Activation in an Operating Plant

During reactor operation, a large inventory of radioactive fission products builds up within the fuel. Virtually all of the fission products are contained within the fuel pellets. The fuel pellets are enclosed in hollow metal rods, which are hermetically sealed to prevent further release of fission products. Occasionally fuel rods develop small leaks, allowing a small fraction of the fission products to contaminate the reactor coolant. The radioactive contamination in the reactor coolant is the source of gaseous, liquid, and solid radioactive wastes generated at LWRs during operation. Most of the contamination in the reactor coolant system is from the activation of corrosion products and not from leaking fuel.

There are two sources of radioactive material: contamination and activation. Contaminated materials are unintentionally transported through the facility by workers, equipment, and, to some degree, air movement. Although many precautions are taken to prevent the movement of contaminated material in a nuclear facility and to clean up any contaminated materials that may be found, it is likely that contamination will occur in the reactor building, around the spent fuel pool, and around specific SSCs in the auxiliary building and other buildings and equipment in the area near the reactor. The areas known to contain contamination are labeled by the licensee, who routinely checks for contamination and removes as much as possible during operations. Radioactive contamination may be deposited from the air or dissolved in water and subsequently deposited onto material such as concrete. Radioactive contamination is generally located on or near the surface of materials such as metals, high-density concrete, or painted walls. It can travel farther into unpainted surfaces or lower-density concrete. Radioactive contamination can usually be removed from surface areas by washing, scrubbing, spraying, or, in extreme cases, by physically removing the outer layers of the surface material.

Activation products are also formed during reactor operation. Activation products are radioactive materials created when stable substances are bombarded by neutrons. Concrete and steel surrounding the core of the reactor are the most common types of activated products. Activation products cannot be removed by the processes used to remove contamination. Activation products are incorporated into the molecular structure of the material and cannot be wiped off or removed. The entire structure (or portions) that have been activated must be removed and treated as radioactive waste. Activated metal and concrete contain the single largest inventory of radionuclides with the exception of the spent fuel, in facilities that are being decommissioned. The radioactive decay of activation products, both of structures as well as corrosion products, is the main source of radiation exposure to plant personnel.

The spent fuel contains the largest amount of radioactive material at a permanently shutdown facility followed by the reactor vessel, internals, and bioshield. Systems containing smaller amounts of radioactive material include the steam generator, pressurizer, piping of the primary system and other systems, piping, as well as the radwaste systems. Minor contamination is found in the secondary systems and miscellaneous piping.

3.2 Decommissioning Options

This Supplement evaluates the environmental impacts of three decommissioning options or combinations of the options. These options, first identified in the 1988 Generic Environmental Impact Statement (GEIS) using the acronyms DECON, SAFSTOR, and ENTOMB, are defined as follows:

DECON: The equipment, structures, and portions of the facility and site that contain radioactive contaminants are promptly removed or decontaminated to a level that permits termination of the license shortly after cessation of operations.

SAFSTOR: The facility is placed in a safe, stable condition and maintained in that state (safe storage) until it is subsequently decontaminated and dismantled to levels that permit license termination. The determination of SAFSTOR includes those activities necessary for the final decontamination and dismantlement of the facility. During SAFSTOR, a facility is left intact, but the fuel has been removed from the reactor vessel, and radioactive liquids have been drained from systems and components and then processed. Radioactive decay occurs during the SAFSTOR period, thus reducing the quantity of contaminated and radioactive material that must be disposed of during decontamination and dismantlement. The definition of SAFSTOR also includes the decontamination and dismantlement of the facility at the end of the storage period.

ENTOMB: Radioactive SSCs are encased in a structurally long-lived substance, such as concrete. The entombed structure is appropriately maintained, and continued surveillance is carried out until the radioactivity decays to a level that permits termination of the license.

The choice of decommissioning option is left entirely to the licensee, provided that it can be performed according to the NRC's regulations. This choice is communicated to the NRC and the public in the post-shutdown decommissioning activities report (PSDAR). In addition, the licensee may choose to combine the DECON and SAFSTOR options. For example, after power operations cease at a facility, a licensee could use a short storage period for planning purposes, followed by removal of large components (such as the steam generators, pressurizer, and reactor vessel internals), place the facility in storage for 30 years, and eventually finish the decontamination and dismantlement process.

Although the selection of the decommissioning option is up to the licensee, the NRC requires the licensee to re-evaluate its selection if the option (1) could not be completed as described, (2) could not be completed within 60 years of the permanent cessation of plant operations, (3) included activities that would endanger the health and safety of the public by being outside of the NRC's health and safety regulations, or (4) would result in a significant impact to the environment.

To date, most utilities have used DECON or SAFSTOR to decommission reactors. Several sites have performed some incremental decontamination and dismantlement during the storage period of SAFSTOR, a combination of SAFSTOR and DECON. A site using DECON may have a short period of time (1 to 4 years) when the facility is in SAFSTOR. Several licensees continue to conduct limited decommissioning activities during a SAFSTOR period as personnel, money, or other factors become available. This process of occasionally conducting active decontamination and dismantlement is referred to as incremental DECON. No utilities have used the ENTOMB option for a commercial nuclear power reactor.

The following sections provide a general overview of each decommissioning option.

3.2.1 DECON

The DECON decommissioning option involves removing or decontaminating equipment, structures, and portions of the facility and site that contain radioactive contaminants to a level that permits termination of the license, as defined in Regulatory Guide 1.184 (NRC 2000a).

There are several advantages to using the DECON option of decommissioning. One is that the facility license is quickly terminated so that the facility and site become available for other purposes. By beginning the decontamination and dismantlement process soon after permanent cessation of operation, the available work force can be maintained and is highly knowledgeable about the facility. The availability of facilities willing to accept LLW may also be a factor in the licensee's decision to pursue the DECON option. Currently, the estimated cost of decommissioning a site using DECON is less than SAFSTOR due primarily to price escalation in the disposal of LLW. Because most activities that occur during DECON also occur during SAFSTOR, the price for decommissioning at a later date is greater because of the cost of storage and inflation (NRC 2000c). DECON also eliminates the need for long-term security, maintenance, and surveillance of the facility (excluding the onsite storage of spent fuel), which is required for the other decommissioning options.

The major disadvantages of DECON are the higher worker dose and significant initial expenditures. Also, compared to SAFSTOR, DECON requires a larger potential commitment of disposal site space (NRC 2000c).

The general activities that may occur during DECON are listed below (NRC 2000d):

- draining (and potentially flushing) of some contaminated systems and removal of resins from ion exchangers
- setup activities such as establishing monitoring stations or designing and fabricating special shielding and contamination-control envelopes to facilitate decommissioning activities
- reduction of site-security area (setup of new security monitoring stations)
- modification of the control room or establishing an alternate control room
- site surveys
- decontamination of radioactive components, including use of chemical decontamination techniques

- removal of reactor vessel and internals
- removal of other large components, including major radioactive components
- removal of the balance of the primary system (charging system, boron control system, etc.)
- general activities related to removing other significant radioactive components
- decontamination and/or dismantlement of structures or buildings
- temporary onsite storage of components
- shipment and processing of LLW, including compaction or incineration of the waste
- removal of the spent fuel and Greater-than-Class-C (GTCC) Waste to an ISFSI
- removal of hazardous radioactive (mixed) wastes
- changes in management and staffing.

3.2.2 SAFSTOR

The SAFSTOR decommissioning option involves placing the facility in a safe, stable condition and maintaining that state for a period of time, followed by subsequent decontamination and dismantlement to levels that permit license termination. During the storage period of SAFSTOR, the facility is left intact. The fuel has been removed from the reactor vessel and radioactive liquids have been drained from systems and components and processed. Radioactive decay occurs during the storage period, reducing the quantity of contaminated and radioactive material that must be disposed of during decontamination and dismantlement.

There are several advantages to using the SAFSTOR option of decommissioning. A substantial reduction in radioactive material as a result of radioactive decay during the storage period reduces worker and public doses below those of the DECON alternative. Since there is potentially less radioactive waste, less waste-disposal space is required. Moreover, the costs immediately following permanent cessation of operations are lower than costs during the first years of DECON because of reduced amounts of activity and a smaller work force (NRC 2000c).

However, because of the time gap between cessation of operations and decommissioning activities, SAFSTOR can result in a shortage of personnel familiar with the facility at the time of dismantlement and decontamination. During the prolonged period of storage, the plant requires continued maintenance, security, and surveillance. Also, uncertainties regarding the availability and cost of LLW sites in the future could mean higher costs for decontamination and dismantlement (NRC 2000c).

Activities that typically occur during the preparation and storage stages of the SAFSTOR process are described below (NRC 2000d).

<u>During preparation</u>:

- draining (and potential flushing) of some systems and removal of resins from ion exchangers
- spent fuel pool cooling systems reconfiguration
- decontamination of highly contaminated and high dose areas as necessary
- performance of a radiological assessment as a baseline before storage
- removal of LLW that is ready to be shipped
- shipment and processing or storage of the fuel and GTCC waste
- de-energizing or deactivating systems and equipment
- reconfiguration of ventilation systems, fire protection systems, and spent fuel pool cooling system for use during storage
- establishment of inspection and monitoring plans for use during storage
- maintenance of any systems critical to final dismantlement during storage
- changes in management and staffing.

<u>During storage</u>:

- performance of preventative and corrective maintenance on plant systems that will be operating and/or functional during storage

- maintenance to preserve structural integrity
- maintenance of security systems
- maintenance of radiation effluent and environmental monitoring programs
- processing of any radwaste generated (usually small amounts).

Following the storage period, the facility is decontaminated and dismantled to radiological levels that allow termination of the license. Activities during this period of time will be the same activities that occur for DECON.

3.2.3 ENTOMB

The ENTOMB decommissioning method was defined in the Supplementary Information to the 1988 Decommissioning Rule (53 FR 24018) as the option in which radioactive contaminants are encased in a structurally long-lived material, such as concrete. The entombed structure is appropriately maintained and surveillance is continued until the radioactivity decays to a level permitting unrestricted release of the property (NRC 1988).

Currently, 10 CFR 50.82 (a)(3) requires that decommissioning be completed within 60 years of permanent cessation of operations, and completion of decommissioning beyond 60 years be approved by the NRC only when necessary to protect public health and safety. The factors that could be considered by the Commission in evaluating an option that provides for the completion of decommissioning beyond 60 years of permanent cessation of operation include unavailability of waste disposal capacity and site-specific factors affecting the licensee's capability to carry out decommissioning, including the presence of other nuclear facilities at the site.

The current regulations, pertaining to the decommissioning of nuclear reactors promulgated in 1988, are also structured to favor decommissioning options that result in unrestricted release of the site. As noted in the supplementary information for the June 27, 1988, final rule, the ENTOMB option was not specifically precluded because it was recognized that it might be an allowable option for protecting public health and safety.

The 1997 Rule for Radiological Criteria for License Termination (64 FR 39058) established criteria (10 CFR Part 20, Subpart E) that allow for both restricted and unrestricted release of property. Under a restricted release, the dose to the average member of the critical group must not exceed 0.25 mSv/yr (25 mrem/yr) total effective dose equivalent (TEDE) and must be as low as reasonably achievable (ALARA) with the restrictions in place. If the restrictions were no longer in effect, the dose due to residual radioactivity could not exceed 1 mSv/yr (100 mrem/yr) (or 5 mSv/yr [500 rem/yr], if additional conditions are met) TEDE and must be ALARA. These caps were chosen to provide a safety net in the highly unlikely event that the restrictions failed.

In the Staff Requirements Memorandum on the ENTOMB option, dated July 20, 2000 (NRC 2000b), the Commission directed that

> [T]he staff closely coordinate this rulemaking effort for this rulemaking with the ongoing efforts to update the generic environmental impact statement for the decommissioning of power reactors. The staff should include the entombment option in the GEIS recognizing that not all entombment proposals can be forecast but that the GEIS would provide a bounding analysis. The staff should also address the issue of entombing Greater Than Class C waste for this category of waste.

On September 18, 2001, the Commission approved the staff's rulemaking plan (see Section 2.2.2) for potential development of a rule to allow entombment as a decommissioning option for power reactors. NRC published an Advance Notice of Proposed Rulemaking (ANPR) on October 16, 2001 (66 FR 52551) seeking stakeholder input on three proposed regulatory options and whether entombment was a viable decommissioning alternative. The ANPR comment period closed on December 31, 2001. NRC received 19 comments from: six States; eight licensees; the Nuclear Energy Institute (NEI); the U.S. Environmental Protection Agency (EPA); the Conference of Radiation Control Program Directors' E-24 Committee on Decommissioning and Decontamination (CRCPD E-24 Committee); the Southeast Compact Commission (SCC); and a private individual.

Generally, the eight utilities and NEI stated that they would have entombment available as a decommissioning option; however, none unequivocally committed to using entombment for their decommissioning process. Some Agreement State commenters endorsed the 10 CFR Part 20 dose limits, with one State adding that a time limit to reach the dose rates should be considered. Although one State advocated extending the decommissioning period beyond 60 years, most were silent on the decommissioning regulations in 10 CFR Part 50. The staff notes that there was no consensus on a preferred option. NRC staff has considered the comments received and has prepared a paper transmitting the staff's recommendations to the Commission. As of the date of this publication the Commission has not acted on the staff's recommendations.

| The assessment of impacts associated with the ENTOMB option presented in this GEIS is independent of a prospective rulemaking before the Commission. The staff is making the assumption that environmental issues arising from any rulemaking effort will be addressed in the rulemaking and its supporting environmental documentation. These issues may include: (1) the long-term onsite retention of radioactive materials, including those that may be classified

as GTCC, (2) issues related to long-term NRC oversight and monitoring requirements, (3) durability of institutional controls and site-engineered barriers, and (4) site-specific requirements.

The purpose of the entombment process is to isolate the entombed radioactive waste so that the reactor facility can be released and the license terminated. Therefore, prior to entombment, (1) an accurate characterization of the radioactive materials that are to remain is needed, and (2) the adequacy of the entombment configuration to isolate the entombed radioactive waste must be determined. Because of the requirement in the regulation to complete decommissioning within 60 years, no licensee has proposed the use of ENTOMB as the preferred decommissioning option for any of the nuclear power reactors currently undergoing decommissioning. The staff can envision a large number of entombment scenarios arranged along a continuum, differing primarily on the amount of decontamination and dismantlement done prior to the actual entombment.

The staff evaluated the impacts associated with the entombment options by developing two scenarios that have been designated ENTOMB1 and ENTOMB2. These two scenarios were developed specifically to envelope a wide range of potential options by describing two possible extreme cases of entombment. ENTOMB1 assumes significant decontamination and dismantlement and removal of all contamination and activation involving long-lived radioactive isotopes prior to entombment. ENTOMB2 assumes significantly less decontamination and dismantlement, significantly more engineered barriers, and the retention onsite of long-lived radioactive isotopes. Both options assume that the spent fuel would be removed from the facility and either transported to a permanent HLW repository or placed in an onsite ISFSI. Licensees choosing ENTOMB will adapt the entombment option to fit their specific site requirements.

ENTOMB1 is envisioned by the staff to begin the decommissioning process in a manner similar to the DECON option. The reactor would be defueled and the fuel initially placed into the spent fuel pool for some period prior to disposal at a licensed HLW repository or placed in an onsite ISFSI. Any decommissioning activity would be preceded by an accurate radiological characterization of SSCs throughout the facility. Active decommissioning would begin with draining and decontamination of SSCs throughout the facility with the goal of isolating and fixing contamination. SSCs would either be decontaminated or removed and either shipped to a LLW burial site or placed inside the reactor containment building. Offsite disposal of resins and considerable amounts of contaminated material would occur. There would likely be a chemical decontamination of the primary system. The reactor pressure vessel (RPV) and reactor internals would be removed, either intact or after sectioning, and disposed of offsite.

Any other SSCs that have long-lived activation products would be removed. Interim dry storage of the vessel, vessel internals, and any other SSCs containing long-lived activation products could occur onsite until a final disposal site for this waste (predominately GTCC waste) is identified. Steam generators and the pressurizer, depending on whether or not the components are contaminated with long-lived radioisotopes, would either be removed and disposed of offsite or retained inside the reactor containment. The spent fuel pool would be drained and decontaminated. The reactor building or containment would then be filled with SSCs

contaminated with relatively short-lived isotopes from the balance of the facility. Material would be placed in the building in a manner that would minimize the spread of any contamination (i.e., dry, contamination fixed, isolated). Engineered barriers would be put in place to deny access and eliminate the possibility of the release of any contamination to the environment. The reactor building or containment would be sealed and made weather tight.

The license termination monitoring program would be submitted and the site would be characterized. A partial site release would be completed for almost all of the site and the balance of the plant. The staff makes no assumptions as to when the license would be terminated and whether it would be terminated under the restricted or unrestricted provisions of 10 CFR Part 20, Subpart E. These decisions would likely be addressed as part of the staff's rulemaking effort related to entombment, explained above. The staff does assume that there would be a monitoring program period as long as 20 to 30 years to demonstrate that there was isolation of the contamination and adequate permanence of the structure.

The general activities that would occur during ENTOMB1 are listed below:

- planning and preparation activities
- draining (and potentially flushing) of contaminated systems and removal of resins from ion exchangers
- reduction of site-security area (optional)
- deactivation of support systems
- decontamination of radioactive components, including use of chemical decontamination techniques
- removal of the reactor vessel and internals
- removal of other large components, including major radioactive components

- removal of fuel from the spent fuel pool to an ISFSI
- dismantlement of remaining radioactively contaminated structures and placement of the dismantled structures in the reactor building
- installation of engineered barriers and other controls to prevent inadvertent intrusion and dispersion of contamination outside of the entombed structure
- filling of the void spaces in the previous reactor building structure with grout (concrete).

ENTOMB2 is also envisioned by the staff to begin the decommissioning process in a manner similar to the DECON option. The reactor would be defueled and the fuel initially placed into the spent fuel pool for some period prior to disposal at a licensed HLW repository or placed in an onsite ISFSI. Any decommissioning activity would be preceded by an accurate radiological characterization of SSCs throughout the facility. Active decommissioning would begin with the draining and decontamination of SSCs throughout the facility with the goal of isolating and fixing contamination. The spent fuel pool would be drained and decontaminated. SSCs would either be decontaminated or removed and either shipped to a LLW burial site or placed inside the reactor containment building (PWR) or the reactor building (BWR). Disposal offsite of resins would occur. The primary system would be drained, the RPV filled with contaminated material, all penetrations sealed, the RPV head reinstalled, and the reactor vessel filled with low-density concrete. Reactor internals would remain in place. Emphasis would be placed on draining and drying all systems and components and fixing contamination to prevent movement, either by air or liquid means. The steam generators and pressurizer would be laid up dry and remain in place. The reactor building or containment would then be filled with contaminated SSCs from the balance of the facility. Material would be placed in the building in a manner that would minimize the spread of any contamination (i.e., dry, contamination fixed, isolated).

Engineered barriers would be put in place to deny access and eliminate the possibility of the release of any contamination to the environment. The ceiling of the containment or reactor building, in the case of BWRs, may be lowered to near the refueling floor and to the top of the pressurizer for PWRs. The cavity of the remaining structure would be filled with a low-density concrete. The resulting structure would be sealed and made weather tight and covered with an engineered cap designed to deny access, and prevent the intrusion of water or the release of radioactive contamination to the environment.

The license termination monitoring program would be submitted and the site would be characterized. A partial site release would be completed for almost all of the site and the balance of the plant. The license would be likely terminated under the restricted release provisions of 10 CFR Part 20, Subpart E, after a site-monitoring program that demonstrates the isolation of the contamination and the permanence of the structure. Monitoring could be as long as 100 years.

The general activities that would occur during ENTOMB2 are listed below:

- planning and preparation activities
- draining (and potentially flushing) of contaminated systems and removal of resins from ion exchangers
- deactivation of support systems
- removal of fuel from the spent fuel pool to an ISFSI
- dismantlement of all radioactively contaminated structures (other than the reactor building) and placement of the dismantled structures in the reactor building
- potentially lowering of the ceiling of the reactor building to near the refueling floor (in BWRs) or near the top of the pressurizer (in PWRs)
- installation of engineered barriers and other controls to prevent inadvertent intrusion and dispersion of contamination outside of the entombed structure
- filling of the cavity of the reactor building structure with low-density concrete
- placement of an engineered cap over the entombed structure to further isolate the structure from the environment.

The advantages of both ENTOMB options are reduced public exposure to radiation due to significantly less transportation of radioactive waste to an LLW disposal site and corresponding reduced cost of LLW disposal. An additional advantage of ENTOMB2 is related to the significant reduction in the amount of work activity, and thus a significant reduction in occupational exposures, as compared to the DECON or SAFSTOR decommissioning options.

3.3 Summary of Plants That Have Permanently Ceased Operations

Twenty-two of the commercial nuclear reactors licensed by the NRC have permanently shut down and have had their licenses terminated or are currently being decommissioned. This section presents the significant characteristics of these plants, the decommissioning options being used by each plant, and each plant's decommissioning activities.

3.3.1 Plant Sites

An overview of the shutdown plants can be found in Table 3-1, which includes 22 units shut down between 1963 and 1997. Table 3-2 summarizes important characteristics of the shutdown plants. The thermal power capabilities of the reactors ranged from 23 to 3411 MW(t). The reactors operated from just a few days (Shoreham) to 33 years (Big Rock Point). Since 1987, an average of one plant per year has been shut down.

Three of the 22 plants (Fort St. Vrain, Shoreham, and Pathfinder) have completed decommissioning and have had their 10 CFR Part 50 licenses terminated. Two of these three (Fort St. Vrain and Shoreham) used the DECON process for decommissioning. One facility, Shoreham, operated less than three full power days before being shut down and decommissioned so there was relatively little contamination. Another facility, Pathfinder, was placed in SAFSTOR and subsequently decommissioned. Eleven of the plants shut down prematurely. Three Mile Island, Unit 2, ceased power operations as a result of a severe accident. Three Mile Island, Unit 2, has been placed in a monitored storage mode until Unit 1 permanently ceases operation, at which time both units are to be decommissioned.

Eleven of the permanently shutdown plants were part of the U.S. Atomic Energy Commission's (AEC's) Demonstrations Program, including Big Rock Point; Dresden, Unit 1; Fermi, Unit 1; GE-VBWR; Humboldt Bay, Unit 3; Indian Point, Unit 1; La Crosse; Pathfinder; Peach Bottom, Unit 1; Yankee Rowe; and Saxton. These plants were prototype designs that were jointly funded by the AEC and commercial utilities. One of the plants, Pathfinder, has completed decommissioning and had its license terminated.

The most recent of the Demonstration Program reactors to shut down was Big Rock Point, which operated for 33 years and permanently shut down in 1997.

Table 3-1. Summary of Shutdown Plant Information

Types and Number of Shutdown Reactors	
BWR	8
PWR	11
HTGR	2
FBR	1
Decommissioning Option	
SAFSTOR	14
DECON	7
Accident cleanup followed by storage	1
Fuel Location	
Fuel onsite in pool	13
No fuel onsite[a]	8
Fuel onsite in ISFSI	1
Plan to move fuel to an ISFSI between 2000 and 2005	9

(a) Includes Three Mile Island, Unit 2, which has approximately 900 kg of fuel remaining onsite due to the accident.

Eight of the decommissioned or decommissioning plants are located in the northeast (or mid-Atlantic states), six in the west, six in the midwest, and one in the east. The majority of the shutdown plants (13) are situated on freshwater or impoundments, five others are in coastal or estuarine environments, and three others are on the Great Lakes.

3.3.2 Description of Decommissioning Options Selected

Seven decommissioned units are located on multi-unit sites in which the remaining units continue to operate and one multi-unit site shut down both units permanently. All eight of these licensees chose SAFSTOR as the decommissioning option. In most cases, SAFSTOR was chosen so that all units on a site could be decommissioned simultaneously. For various reasons, however, most shutdown units have done some decontamination and dismantlement.

The reasons cited by licensees for choosing DECON have included the availability of LLW capacity, availability of staff familiar with the plant, available funding, the licensee's intent to use the land for other purposes, influence by State or local government to complete decommissioning, or a combination of other reasons.

A number of the plants have combined the DECON and SAFSTOR process by either entering shorter SAFSTOR periods or by doing an incremental DECON, allowing the plant to use resources and "decommission as they go." Sites have combined the options, usually to achieve economic advantages. For example, one site decided to shorten the SAFSTOR period and begin incremental dismantlement out of concern over future availability of a waste site and future costs of disposal. One site that prematurely shut down had a short SAFSTOR period to allow short-lived radioactive materials to decay and to conduct more detailed planning. Safety is another reason for combining the two options. Because of seismic safety concerns, one site undertook a major dismantling project to remove a 76-m (250-ft) concrete vent stack after it had been in SAFSTOR for 10 years.

The licensee determines the physical condition of the site after the decommissioning process. Some licensees intend to restore the site to "greenfield" status at the end of decommissioning, while others may install a non-nuclear facility. The NRC's regulatory authority is only over that portion of the facility that is contaminated. Some licensees will leave structures standing at the time of license termination, and others will not. While undergoing the decommissioning process, some licensees have opted for partial site release to decrease the size of the site area.

3.3.3 Decommissioning Process

The processes of decommissioning a power reactor facility for the SAFSTOR and DECON options can be divided into four stages, as shown in Figure 3-3. Figure 3-4 identifies the comparable stages that could be postulated for the two ENTOMB options. The order of each step and the duration of each stage vary, depending on plant-specific characteristics, such as location, operating history, reactor vendor, and licensee. The staff considered the differences in timing and choice of activities in evaluating the environmental impacts of decommissioning based on the experiences of currently decommissioning facilities.

Stage 1 in Figures 3-3 and 3-4 includes the licensee's initial preparations to shut down the plant and begin decommissioning. This stage is primarily administrative. Stage 1 typically lasts 1½ to 2½ years, regardless of the decommissioning option chosen. The main activities during the planning and preparation stage are determining the decommissioning option, making changes to the organization structure (layoffs, hiring experienced decommissioning contractors, etc.), and initiating licensing-basis changes.

The planning and preparation activities of Stage 1 vary, depending on when the licensee decides to cease operation. If the end of service is planned, the licensee may make plans for the decommissioning process and may even submit the PSDAR in advance of shutdown. This allows the plant to start major decommissioning activities immediately following the certification of permanent shutdown and the removal of the fuel (see Chapter 2, "Background Information

Related to Decommissioning Regulations," for a discussion of major decommissioning activities). If the end of service is unplanned, the licensee will probably not be ready to start decommissioning activities immediately following the certification of permanent shutdown and removal of fuel. Therefore, the order and duration of the activities in Stage 1 might vary compared to a planned shutdown. For most plants, the organizational changes will include a reduction in the number of staff as well as implementation of an employee-retention program to encourage the needed staff to stay on. However, one site actually had to increase staffing levels at the time of the permanent cessation of operation to start the DECON process. Initial plant characterization will be made during the planning activities and will continue throughout the decommissioning process. Because these activities are mostly planning, administrative, and organizational in nature, there is little potential for onsite or offsite impacts from these activities and only small amounts of decommissioning-related LLW generated.

Stage 2 in Figures 3-3 and 3-4 involves the transition of the plant from reactor operation to decommissioning. Stage 2 will last from about ½ to 1½ years for plants in SAFSTOR, DECON, and ENTOMB. All plants will have to transfer fuel out of the reactor and into the spent fuel pool. Isolation and stabilization of all unnecessary SSCs are also conducted during this stage.

Licensing-basis changes will continue during this stage, and the licensee may request an exemption from offsite emergency preparedness requirements.

For DECON and SAFSTOR, there are a number of activities during Stage 2 that the plant can either choose not to perform or can perform at a later date. Chemical decontamination of the primary system and creation of a nuclear island are the two main activities that several decommissioning sites have undertaken. Chemical decontamination is optional for ENTOMB1 and would not likely occur for ENTOMB2. Support systems no longer necessary to reactor operation may also be removed for all four options. Likewise, additional support systems needed for decommissioning activities may be installed at this stage for DECON, SAFSTOR, and ENTOMB1. Changes to electrical systems are common during Stage 2.

Chemical decontamination of the primary system has been performed at several facilities, resulting in a reduction of total person-rem during decommissioning activities. One facility evaluated conducted a system decontamination, aiming at significant reduced dose to workers and reduced cost, by reducing both the amount and level of contamination from disposal of contaminated piping. This chemical decontamination was performed following the removal of the steam generators, pressurizer, and reactor coolant pump motors, as well as most of the

Table 3-2. Permanently Shutdown Plants

Nuclear Plant	Reactor Type	Thermal Power	Shutdown Date [a]	Decommissioning Option[b]	Location	Fuel Status and License Termination Date
Plants Currently in Decommissioning Process						
Big Rock Point	BWR	240 MW	08/30/97	DECON	Michigan	Fuel in pool
Dresden, Unit 1	BWR	700 MW	10/31/78	SAFSTOR	Illinois	Fuel in ISFSI
Fermi, Unit 1	FBR	200 MW	09/22/72	SAFSTOR[c]	Michigan	No fuel onsite
GE-VBWR	BWR	50 MW	12/09/63	SAFSTOR	California	No fuel onsite
Haddam Neck	PWR	1825 MW	07/22/96	DECON	Connecticut	Fuel in pool
Humboldt Bay, Unit 3	BWR	200 MW	07/02/76	SAFSTOR[c]	California	Fuel in pool
Indian Point, Unit 1	PWR	615 MW	10/31/74	SAFSTOR	New York	Fuel in pool
La Crosse	BWR	165 MW	04/30/87	SAFSTOR	Wisconsin	Fuel in pool
Maine Yankee	PWR	2700 MW	12/06/96	DECON	Maine	Fuel in pool[d]
Millstone, Unit 1	BWR	2011 MW	11/04/95	SAFSTOR	Connecticut	Fuel in pool
Peach Bottom, Unit 1	HTGR	115 MW	10/31/74	SAFSTOR	Pennsylvania	No fuel onsite
Rancho Seco	PWR	2772 MW	06/07/89	SAFSTOR[c]	California	Fuel in ISFSI/Partial DECON proposed in 1997
San Onofre, Unit 1	PWR	1347 MW	11/30/92	SAFSTOR[c]	California	Fuel in pool
Saxton	PWR	28 MW	05/01/72	SAFSTOR[c]	Pennsylvania	No fuel onsite/Currently in DECON
Three Mile Island, Unit 2	PWR	2772 MW	03/28/79	Accident cleanup followed by storage	Pennsylvania	Approx 900 kg fuel onsite/ Post-defueling monitored storage
Trojan	PWR	3411 MW	11/09/92	DECON	Oregon	Fuel in pool
Yankee Rowe	PWR	600 MW	10/01/91	DECON	Massachusetts	Fuel in pool[d]
Zion, Unit 1	PWR	3250 MW	02/21/97	SAFSTOR	Illinois	Fuel in pool
Zion, Unit 2	PWR	3250 MW	09/19/96	SAFSTOR	Illinois	Fuel in pool
Terminated Licenses						
Fort St. Vrain	HTGR	842 MW	08/18/89	DECON	Colorado	Fuel in ISFSI/License terminated in 1997
Pathfinder	BWR	190 MW	09/16/67	SAFSTOR	South Dakota	No fuel onsite/License terminated in 1992
Shoreham	BWR	2436 MW	06/28/89	DECON	New York	No fuel onsite/License terminated in 1995

(a) The shutdown date corresponds to the date of the last criticality.
(b) The option shown in the table for each plant is the option that has been officially provided to NRC. Plants in DECON may have had a short (1 to 4 yr) SAFSTOR period. Likewise, plants in SAFSTOR may have performed some DECON activities or may have transitioned from the storage phase into the decontamination and dismantlement phase of SAFSTOR.
(c) These plants have recently performed or are currently performing the decontamination and dismantlement phase of SAFSTOR.
(d) Licensee is in process of transferring fuel to dry storage in onsite ISFSI.

auxiliary piping. At a second facility evaluated, a chemical decontamination was considered necessary to keep doses within previously issued EAs. The chemical decontamination was performed early in the decommissioning process to allow dismantling to proceed unimpeded. Other plants, both operating and permanently shutdown, have also performed chemical decontamination.

Some plants have also created nuclear islands, which reduce the scope of the required safeguards and security systems to only the fuel storage facilities and isolate the spent fuel so decontamination and dismantlement can proceed on the balance of the facility without the potential for affecting the spent fuel. Creating a nuclear island may involve installing an electrical power supply at the spent fuel pool, installing or modifying chemistry controls, designing and constructing a new heat removal system, and moving or installing new security-related equipment. For plants going into SAFSTOR, creation of a nuclear island is primarily a cost savings, but for plants in active decontamination and dismantlement, work activities may be done more conveniently when workers are not constrained by security requirements. ENTOMB2 would not benefit from the "nuclear island" concept.

Environmental impacts may vary at each site, depending on the activities and the timing of the activities performed. Examples of impacts include activities such as chemical decontamination, which result in the use of small quantities of water and produce LLW as well as some liquid effluents that would not be released unless they are below the limits allowed by the regulations in 10 CFR Part 20. Smaller amounts of waste will likely be generated during the creation of a nuclear island or the rewiring of a facility.

Stage 3 in Figure 3-3 involves decontamination and dismantlement of the plant for DECON, SAFSTOR, and ENTOMB1. For ENTOMB2, Stage 3 involves dismantlement of all radioactively contaminated SSCs external to the reactor building and placement of these SSCs in the reactor building, followed by lowering the ceiling to the D-rings (PWRs) or refueling floor (BWRs). For both ENTOMB options, it includes installation of concrete and engineered barriers and development of the license termination monitoring program. For those sites that have a SAFSTOR period, Stage 3 includes the storage time. The decontamination and dismantlement activities performed for SAFSTOR can occur before, after, or during the storage period. For the SAFSTOR period, Stage 3 can be from just a few years to about 54 years. For a site going straight through the DECON option, the time for Stage 3 would be expected to take between 3½ and 10 years. For either ENTOMB option Stage 3 would be expected to take 2 to 4 years

The greatest variability in the decommissioning process is seen in Stage 3 and is related to dismantlement. Every plant that has completed decommissioning or has started dismantlement has performed the activities in different ways and at different times during the decommissioning process. Two examples of large-component removal are at Rancho Seco and Trojan. Rancho Seco has started its dismantlement on the secondary side, removing the moisture separators, diesel generators, steam piping, and related components. Dismantlement of the equipment in the auxiliary building was also initiated. Plans for large-component removal are still in process. The primary issues related to decisions on large-component removal are how to transport the components. Because there are no convenient waterways for transport, the large components from Rancho Seco will have to be shipped by both road and rail, which will require segmentation or cutting up the larger components. Trojan took a different approach to dismantlement, based on the ability to ship by barge and the availability of disposal at Hanford. Trojan removed its four steam generators and pressurizer, pumped grout into them, and shipped them by barge for burial at Hanford. Following that activity, the reactor vessel and internals were removed whole, filled with grout, welded closed, and shipped. For Trojan, removing and shipping these large components as whole units saved millions of dollars and significantly reduced dose to workers.

Stage 4 of decommissioning is license termination. Activities for this stage, which are similar for all options, include final site characterization, final radiation survey submission of final license termination plan, and final site survey. The ENTOMB options would include both a partial site release and a site monitoring program.

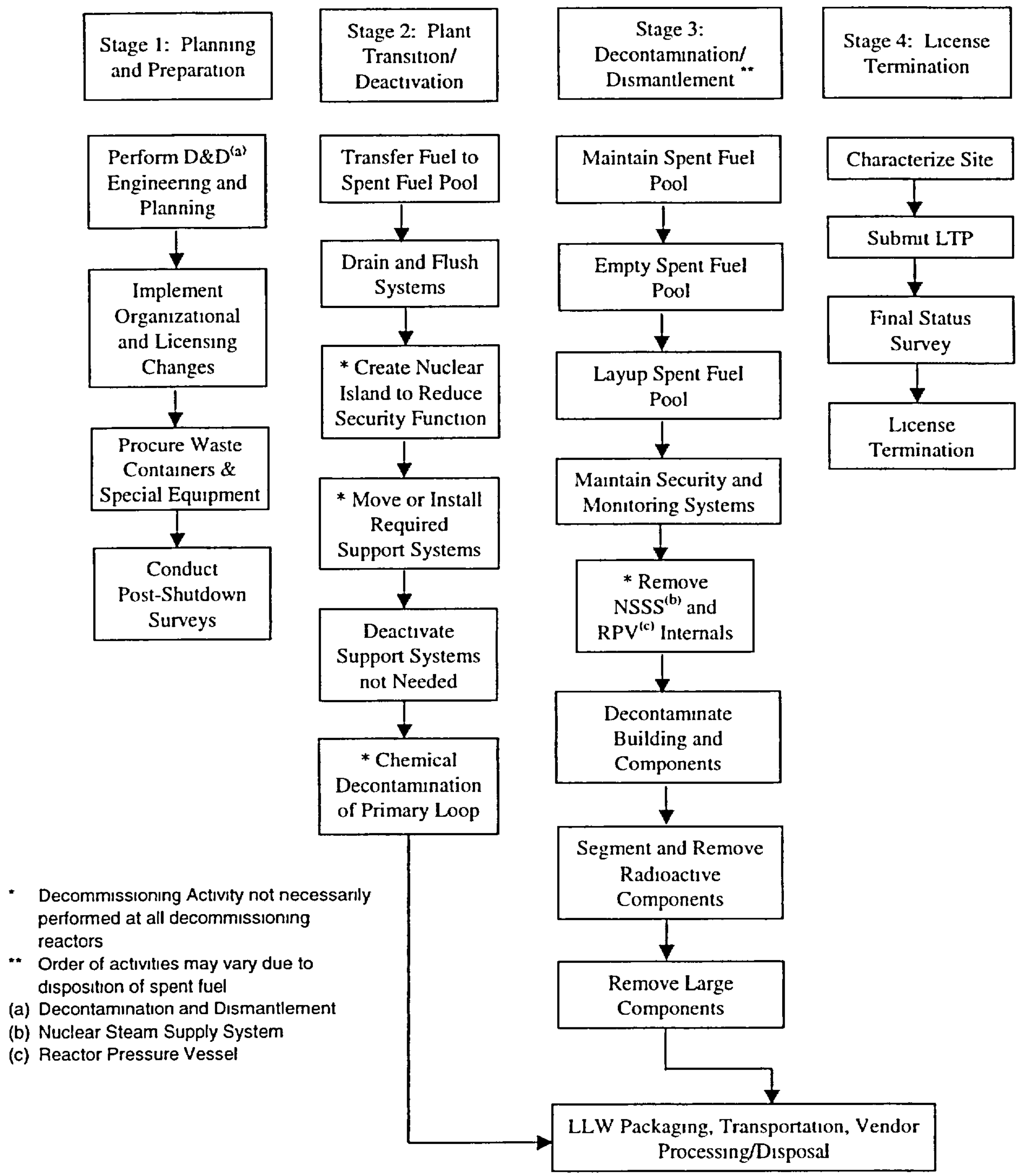

Figure 3-3. Reactor Decommissioning Process - DECON or SAFSTOR

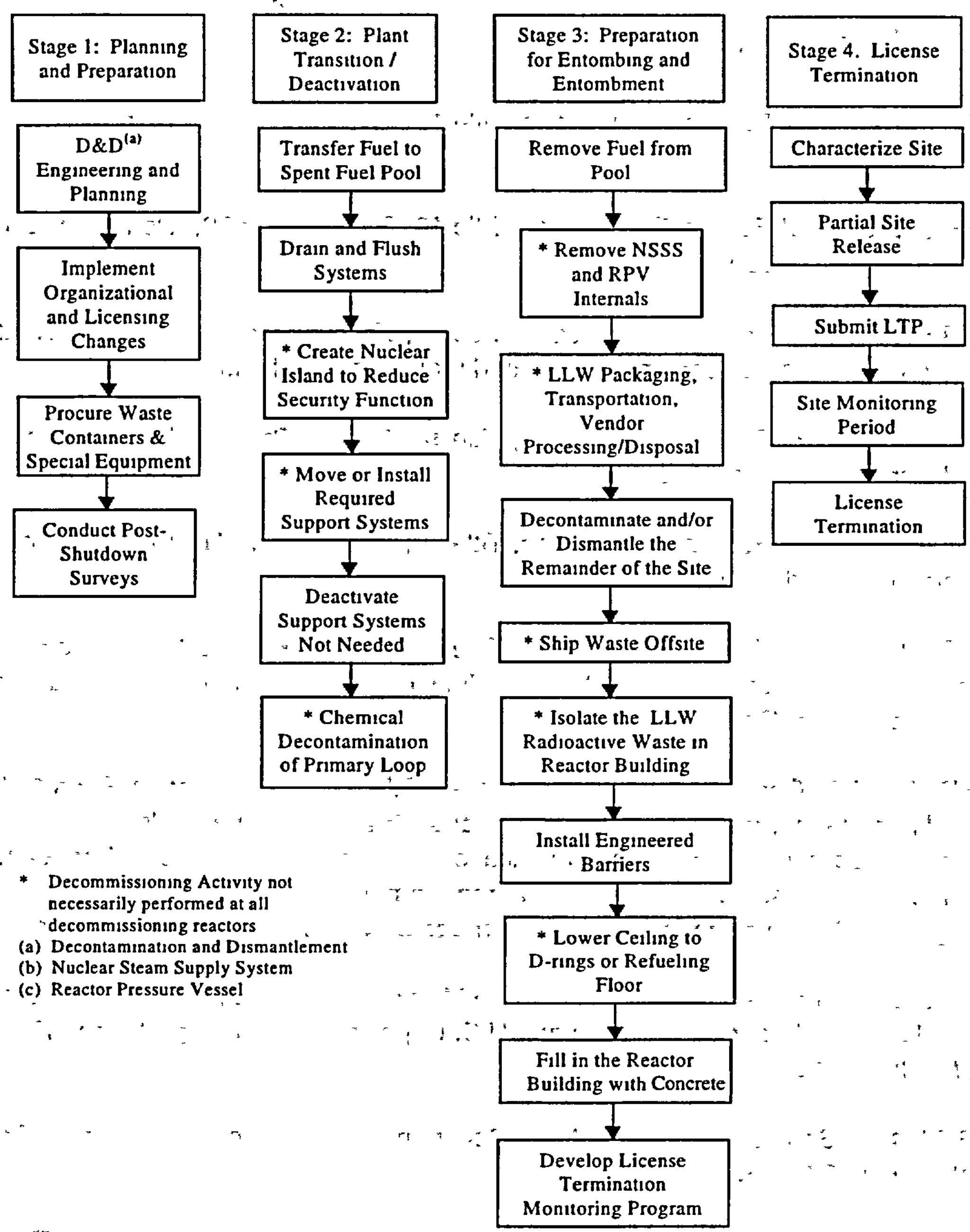

Figure 3-4. Reactor Decommissioning Process - ENTOMB

3.4 References

10 CFR 20. Code of Federal Regulations, Title 10, *Energy*, Part 20, "Standards for protection against radiation."

10 CFR 50. Code of Federal Regulations, Title 10, *Energy*, Part 50, "Domestic licensing of production and utilization facilities."

10 CFR 51. Code of Federal Regulations, Title 10, *Energy*, Part 51, "Environmental protection regulations for domestic licensing and related regulatory functions."

10 CFR 61. Code of Federal Regulations, Title 10, *Energy*, Part 61, "Licensing requirements for land disposal of radioactive waste."

10 CFR 71. Code of Federal Regulations, Title 10, *Energy*, Part 71, "Packaging and transportation of radioactive material."

10 CFR 72. Code of Federal Regulations, Title 10, *Energy*, Part 72, "Licensing requirements for the independent storage of spent nuclear fuel, high-level radioactive waste and reactor-related greater-than-Class-C waste."

49 CFR 171-177. Code of Federal Regulations. Title 49, *Transportation*, Parts 171-177, "General information, regulations, and definitions;" "Hazardous materials table, special provisions, hazardous materials, communications, emergency response information, and training requirements;" "Shippers—general requirements for shipments and packagings;" "Carriage by rail;" "Carriage by aircraft;" "Carriage by vessel;" "Carriage by public highway."

44 FR 38690. "Transportation of Radioactive Materials. Memorandum of Understanding." U.S. Nuclear Regulatory Commission and U.S. Department of Transportation. *Federal Register*. July 2, 1979.

53 FR 24018. "General Requirements for Decommissioning Nuclear Facilities." *Federal Register*. June 27, 1988.

54 FR 39767. "10 CFR Part 51 Waste Confidence Decision Review." *Federal Register*. September 28, 1989.

64 FR 39058. "Radiological Criteria for License Termination." *Federal Register*. July 21, 1997.

64 FR 68005. "Waste Confidence Decision Review." *Federal Register.* December 6, 1999.

66 FR 52551. "Entombment Options for Power Reactors." *Federal Register.* October 16, 2001.

Fuller, C. H. 1988. "Fort St. Vrain Operational Experience." In *Technical Committee Meeting on Design Requirements, Operation, and Maintenance of Gas-Cooled Reactors.* San Diego, California. September 21-23, 1988, pp. 55-61. International Atomic Energy Agency, International Working Group on Gas-Cooled Reactors, IWGCCR-19, Vienna. Available: org/inis/aws/htgr/fulltext/iwggcr19_9.pdf.

Lobner, P, C. Donahoe, and C. Cavallin. 1990. *Overview and Comparison of U.S. Commercial Nuclear Power Plants.* NUREG/CR-5640, NRC, Washington, D.C.

Resource Conservation and Recovery Act (RCRA) of 1976, as amended by the Hazardous and Solid Waste Amendments Act of 1984, 42 USC 6901 et seq.

U.S. Nuclear Regulatory Commission (NRC). 1988. *Final Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities.* NUREG-0586, NRC, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 1996. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants.* NUREG-1437, NRC, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 2000a. *Decommissioning of Nuclear Power Reactors.* Regulatory Guide 1.184, NRC, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 2000b. "Staff Requirements SECY-00-0129 Workshop Findings in the Entombment Options for Decommissioning Power Reactors and Staff Recommendations on Further Activities." Staff Requirements Memorandum, NRC, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 2000c. *Staff Responses to Frequently Asked Questions Concerning Decommissioning of Nuclear Power Reactors.* NUREG-1628, NRC, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 2000d. *Standard Format and Content for Post-Shutdown Decommissioning Activities Report.* Regulatory Guide 1.185, NRC, Washington, D.C.

4.0 Environmental Impacts of Decommissioning Permanently Shutdown Nuclear Power Reactors

This section discusses the environmental impacts of decommissioning permanently shutdown nuclear power reactor facilities. Section 4.1 defines the terms used to describe environmental impacts of decommissioning activities. Section 4.2 briefly describes the process that was used to identify the environmental impacts of the decommissioning activities. The environmental impacts, including the staff's conclusions, are discussed in Section 4.3.

4.1 Definition of Environmental Impact Standards

This Supplement provides a measure of (1) the significance and severity of potential environmental impacts and (2) the applicability of these decommissioning impacts to a variety of facilities, both permanently shutdown and operating. The significance of each environmental impact is described as SMALL, MODERATE, or LARGE. The applicability of these impacts to a class of plants or site characteristics is categorized as either generic or site-specific. The following sections define the significance and applicability terms used in the Chapter 4 analyses.

4.1.1 Terms of Significance of Impacts

For decommissioning, the staff is using a standard of significance derived from the Council on Environmental Quality (CEQ) terminology for "significantly"[(a)] (40 CFR 1508.27, which considers "context" and "intensity"). The NRC has defined three significance levels: SMALL, MODERATE, and LARGE.

SMALL – Environmental impacts are not detectable or are so minor that they will neither destabilize nor noticeably alter any important attribute of the resource. For the purposes of assessing radiological impacts in this Supplement, the NRC has concluded that those impacts that do not exceed permissible levels in the Commission's regulations are considered small.

(a) The National Environmental Policy Act of 1969 (NEPA) requires consideration of both *context* and *intensity* when determining the significance of an environmental impact. **Context** means that the significance of an action must be analyzed in several contexts, such as society as a whole (human, national), the affected region, the affected interests, and the locality. Significance varies with the setting of the proposed action. **Intensity** refers to the severity of the impact and depends on many different factors, such as the unique characteristics of the site and the degree to which the proposed action affects public health or safety or may establish a precedent.

MODERATE – Environmental impacts are sufficient to alter noticeably, but not to destabilize, important attributes of the resource.

LARGE – Environmental impacts are clearly noticeable and are sufficient to destabilize important attributes of the resource.

The discussion of each environmental issue in this Supplement includes an explanation of how the significance level was determined. In determining the significance level, the staff assumed that ongoing mitigation measures would continue (including those mitigation measures implemented during plant construction and/or operation) during decommissioning, as appropriate. Additionally, the staff has assumed that a licensee will obtain all relevant permits and appropriate consultations, will continue to comply with the conditions of those permits or consultations, and will use appropriate best management practices (BMPs) to minimize impacts of decommissioning activities. Benefits of additional mitigation measures during or after decommissioning are not considered in determining significance levels.

The cumulative impacts of all activities were assessed. Cumulative impacts are incremental impacts of the decommissioning activity when added to other past, present, and reasonably foreseeable future actions at the licensed site.

4.1.2 Terms of Applicability of Impacts

In addition to determining the significance of environmental impacts, this Supplement includes a discussion of whether the analysis of the environmental issue could be applied to all plants and whether additional mitigation measures would be warranted. Each environmental issue is assigned to one of two categories:

- Generic – For the issue, the analysis reported in this Supplement presents the following:

  (a) Environmental impacts associated with the issue have been determined to apply either to all plants or, for some issues to plants of a specific size, a specific location, or having a specific type of cooling system or site characteristics, and

  (b) A single significance level (i.e., SMALL, MODERATE, or LARGE) has been assigned to the impacts, and

  (c) Mitigation of adverse impacts associated with the issue has been considered in the analysis, and it has been determined that additional plant-specific mitigation measures are likely not to be sufficiently beneficial to warrant implementation.

- Site-specific – For the issue, the analysis reported in this Supplement has shown that one or more of the generic criteria was not met. Therefore, additional plant-specific review is required. An example of a site-specific issue is threatened and endangered species.

For many issues, similar activities may be performed either on the plant site or offsite. In several cases, the conclusions as to generic or site-specific are different for these locations. In this Supplement, the term "operational areas" are the areas within the protected area fences, the intake and discharge structures, the cooling system, and other site structures, and the associated paved, graveled, and maintained landscaped areas. The operational area is defined as the portion of the plant site where most or all of the site activities occur, such as reactor operation, materials and equipment storage, parking, substation operation, facility service and maintenance, etc.

4.2 Evaluation Process

This section briefly describes the process that the staff used to determine the environmental impacts from decommissioning nuclear power facilities. For a detailed description of this process, see Appendix E, "Evaluation Process for Identifying the Environmental Impacts of Decommissioning Activities." Figure 4-1 is a flowchart showing the evaluation process. Figure 4-1 identifies activities that occur during decommissioning and shows whether the activities affect any of the identified environmental issues. The environmental issues analyzed by the staff are the following: onsite/offsite land use, water use, water quality, air quality, aquatic ecology, terrestrial ecology, threatened and endangered species, radiological, radiological accidents, occupational issues, cost, socioeconomics, environmental justice, cultural impacts, aesthetic issues, noise, transportation, and irretrievable resources. To analyze each issue, the staff used the data obtained from previous studies and environmental reviews, information obtained during site visits and provided by the plants undergoing decommissioning, and information from currently operating nuclear power facilities. The staff's assessment includes an assessment of cumulative impacts. For discussions of cumulative impacts, the NRC used the terminology defined in 40 CFR 1508.7. "Cumulative impact is the impact on the environment, which results from the incremental impact of the action (in the case of this Supplement, that is decommissioning activities) when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time." The staff examined the cumulative impacts of decommissioning activities and other past, present, and reasonably foreseeable future activities at the licensed sites.

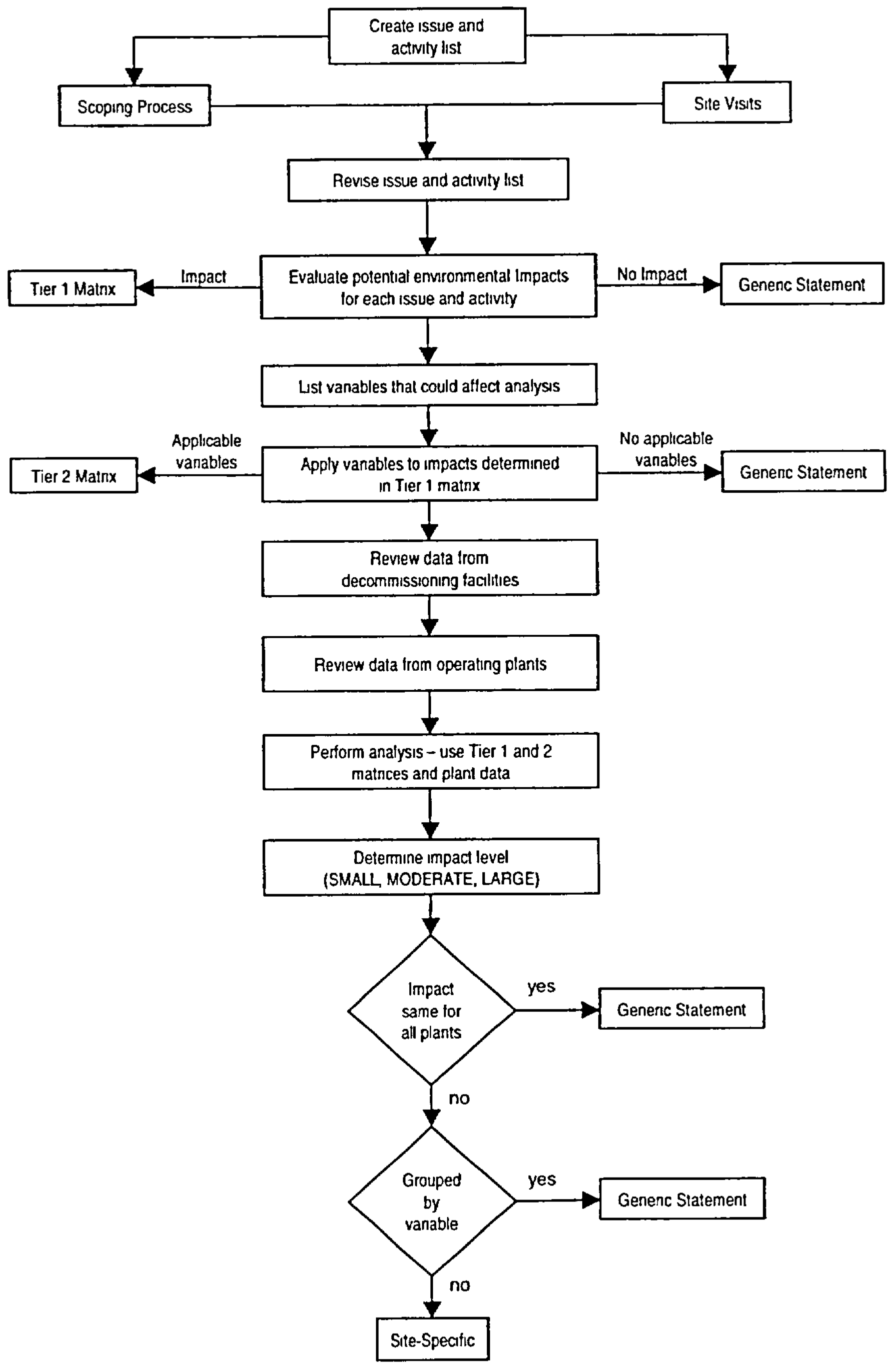

Figure 4-1. Environmental Impact Evaluation Process

Previous or anticipated decommissioning activities at the fast breeder reactor (FBR) or high-temperature gas-cooled reactor (HTGR) have not and are not expected to result in impacts that are different from those found at other nuclear reactor facilities.

After analyzing each issue, the staff determined the nature of the impact (site-specific or generic) and the significance level of the environmental impact (SMALL, MODERATE, or LARGE). This evaluation resulted in a range of impacts for each issue that may be used for comparison by licensees that are or will be decommissioning their facilities.

4.3 Environmental Impacts from Nuclear Power Facility Decommissioning

The following sections are organized by issue and discuss environmental impacts. Each section has four parts:

(1) Regulations – Identifies statutes, regulations, or limits relevant to the issue.

(2) Potential impacts from decommissioning activities - Discusses possible impacts related to the issue and defines, where appropriate, the terms detectable and destabilizing for the issue.

(3) Evaluation – Describes analysis and professional judgement used to estimate whether an activity or group of activities is likely to make a noticeable impact on the environment, considering the available data. If an impact is likely, existing and additional mitigation measures that can be taken to avoid the impact are evaluated. If an impact cannot be avoided, a determination is made as to whether the impact is likely to destabilize the resource.

(4) Conclusion – Provides the staff's conclusion on significance (SMALL, MODERATE, LARGE) and applicability (generic or site-specific) of impacts to the issue.

The conclusions from this chapter are summarized in two tables in Appendix H. Table H-1 provides a list of decommissioning activities that have been determined to have no environmental impacts. These activities can be performed by licensees without further analysis. Table H-2 provides a comprehensive summary of the decommissioning activities and associated environmental issues that have been determined by the staff to have potential environmental impacts. Providing they fall within the range of the impacts identified, these activities can be performed with no further analysis by the licensee.

4.3.1 Onsite/Offsite Land Use

Nuclear power facilities are large physical entities, of which 20 to 40 ha (50 to 100 ac) may actually be disturbed during plant construction. Other land commitments can amount to many thousands of hectares for transmission line rights-of-way (ROWs) and cooling lakes. Farming and other types of agricultural land use occur on some nuclear reactor facility sites. Some utilities have designated portions of their sites for land uses such as recreation, management of natural areas, and wildlife conservation.

4.3.1.1 Regulations

Nuclear power facilities that began initial operation after the promulgation of the National Environmental Policy Act of 1969 (NEPA; 42 USC 4321 to 4347) or the Endangered Species Act of 1973 (ESA; 16 USC 1531 to 1544) were sited and are operated in compliance with these statutes. Any modifications to the facilities after the effective dates of these acts and others (see Appendix L-2) must be in compliance with the requirements of these statutes. The ESA applies to both terrestrial and aquatic biota. The individual States may also have requirements regarding threatened and endangered species; the State-listed species may vary from those on the Federal lists. In addition, activities such as decommissioning must take into account and avoid disturbance of historic and archeological sites, and American Indian grave sites. (Native American Graves Protection and Repatriation Act of 1990; 25 USC 3001 et seq.)

4.3.1.2 Potential Impacts of Decommissioning Activities on Land Use

Temporary changes in onsite land use could occur at a nuclear reactor facility site during decommissioning. Temporary changes may include addition or expansion of staging and laydown areas or construction of temporary buildings and parking areas. These temporary changes in onsite land use do not change the fundamental purpose or use of the reactor site. The major activities that may influence onsite land use are removal of large components, such as the reactor vessel and steam generators, structure dismantlement, and low-level waste (LLW) packaging and storage. Table E-3 in Appendix E describes the activities that occur during decommissioning that influence offsite and onsite land use.

The need for land during decommissioning is affected by the site layout. Most sites have sufficient area existing within the previously disturbed area (whether during construction or operation of the site) and, therefore, no additional land needs to be disturbed. The major activities projected to occur for decommissioning that are expected to temporarily require land include activities such as staging of equipment and removal of large components. In addition, the large number of temporary workers needed to accomplish the major decommissioning activities may require that temporary facilities be installed for onsite parking, training, site security access, office space, change areas, fabrication shops, mockups, and related needs.

Some activities, such as widening and rebuilding access roads or creating or expanding gravel pits for building roads, may occur offsite. The experience of plants that are being decommissioned has not included any needs for additional land offsite.

Changes to land use are considered detectable if changes in the area's general land-use pattern result. The change would be destabilizing if large-scale new development and major changes in the land-use pattern occur. For example, a new local access route through rural land to the plant would represent a detectable, but not destabilizing, change in many localities.

4.3.1.3 Evaluation

Nuclear power facility site areas range from 34 ha (84 ac) for the San Onofre Nuclear Generating Station in California to 9,700 ha (24,000 ac) for the Turkey Point Plant in Florida. According to NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants* (NRC 1996), of the operating reactors, 29 site areas range from 200 to 400 ha (500 to 1000 ac), with an additional 13 sites ranging from 400 to 800 ha (1000 to 2000 ac). Thus, almost 60 percent of the plant sites encompass 200 to 800 ha (500 to 2000 ac). Larger land-use areas are associated with plant cooling systems that include reservoirs, artificial lakes, and buffer areas.

The nuclear reactor facilities being decommissioned are predominantly on the smaller sites, primarily because the older, smaller reactors have already permanently ceased operation. Only 6 out of 21 sites (29 percent) were between 400 and 800 ha (100 to 2000 ac); 6 (29 percent) were larger than 800 ha (2000 ac); and the rest (43 percent) were smaller than 400 ha (1000 ac) (see also Appendix F).

Almost all of the sites undergoing active decommissioning are utilizing areas used during construction. Land requirements for decommissioning activities appear to be well within the range of land requirements for activities during major outages that occur in the course of normal operations. There does not appear to be any significant differences in land use between plants using SAFSTOR or DECON options. There is no experience with either ENTOMB option with commercial power reactors in the United States, although there is some entombment experience with former U.S. Department of Energy (DOE) scientific and nuclear materials production reactors. Because of the potential need for large amounts of concrete and aggregate for ENTOMB2, it is possible that a concrete batch plant might be set up onsite. There might not be adequate room within the operational area at some of the sites for such a facility, but it is likely that the impact of such a disturbance would be temporary and minor. Smaller amounts of concrete and aggregate would likely be required for the ENTOMB1 option.

Many of the facilities currently being decommissioned are relatively small reactors and located on small areas of land. However, a comparison of the land-use needs shows that many activities require the same amount of land for reactors whether the reactor size is small or large. It does not appear that land use will be significantly greater for future decommissioning at remaining sites. Previous or anticipated decommissioning activities at the FBR or HTGR have not and are not expected to result in onsite or offsite land-use impacts that are different from those found at other nuclear reactor facilities. There has been limited experience with multi-unit sites. Multiple-plant sites that are being decommissioned may be able to economize on space by reusing laydown areas.

Large-component removal is similar in its land requirements to major component replacement activities, such as steam generator replacement and refurbishment activities. Based on previous experience with steam generator replacement at a pressurized water reactor (PWR), it was estimated in NUREG-1437 that ~1 to 4 ha (~2.5 to 10 ac) of land may be needed to accommodate laydown, staging, handling, temporary storage, personnel processing, mockup and training, and related needs (NRC 1996). The impacts of steam generator or other major component removal during decommissioning should be similar or less. Generally, this land has been previously disturbed during the construction of the facility. Once the major decommissioning activities are completed, this land could be returned to its previous uses.

Based on current information collected at sites using the DECON and SAFSTOR options, decommissioning activities that affect offsite land use are not expected unless major upgrades to transportation links are required. It may be necessary to establish or re-establish road, rail, or water transportation links into the site for the purpose of bringing in equipment (especially large equipment), removing large components, and shipping offsite certain chemicals, waste concrete and metal, or other materials created, contaminated, or used in the decontamination and dismantlement processes. In such cases, offsite land-use impacts may be detectable or destabilizing. Additional attention to transportation routing and to the organization of activities to minimize the need for transportation re-establishment or upgrade may be able to reduce the impacts to undetectable levels. The ENTOMB options may require additional land offsite for a concrete batch plant, but in most cases the land use for this activity will be temporary, though detectable.

4.3.1.4 Conclusions

The staff has considered available information on the potential impacts of decommissioning on land use, including comments received on the draft of Supplement 1 of NUREG-0586. For facilities having only onsite land-use changes as a result of large component removal, structure dismantlement, and LLW packaging and storage, the impacts on land use are not detectable or destabilizing. Therefore, the staff makes a generic conclusion that the potential impacts to land use onsite are SMALL. The staff has considered mitigation and concludes that no additional measures are likely to be sufficiently beneficial to be warranted.

If changes in land use beyond the site boundary are anticipated, the impacts may or may not be detectable or destabilizing, depending on the site-specific conditions, and cannot be predicted generically. Therefore, the staff has concluded that if new land uses beyond the site boundary are anticipated, the magnitude of the potential impact may be SMALL, MODERATE, or LARGE, depending on the nature, size, and permanence of the disturbance to existing land use and must be determined through a site-specific analysis.

4.3.2 Water Use

Nuclear reactor facilities are usually located near or adjacent to significant water bodies (aquifers, rivers, lakes, etc.) that are important to the region. Operating nuclear reactor facilities use water from multiple sources. For example, water from an adjacent lake might provide cooling water, whereas potable water may come from groundwater wells located onsite. Reactor cooling is the greatest use of water at an operating reactor. Other uses include waste treatment, potable water, process water, and site maintenance.

4.3.2.1 Regulations

Water use at nuclear reactor facilities is regulated by State- and locally-issued permits. Most States require permits for surface water or groundwater withdrawals.

4.3.2.2 Potential Impacts of Decommissioning Activities on Water Use

Cessation of plant operations will result in a significant decrease in water consumption because reactor cooling is no longer required. Although water will still be required for spent fuel cooling, this demand will decrease as the fuel ages. Dewatering systems may remain active during decommissioning of a nuclear facility to control the water pathway for the release of radioactive material. Table E-3 in Appendix E lists decommissioning activities that may influence water use. These activities include fuel removal, staffing changes, large component removal, decontamination and dismantlement (using high-pressure water sprays), structure dismantlement, and entombment.

Impacts to water resources of decommissioning activities would be considered detectable if such activities result in a significant change in water supply reliability. The reliability of water supplies is impacted by a variety of factors, such as natural climatic variability and the reliability of the regional and local water-supply infrastructures. For example, an additional incremental drawdown attributable to a groundwater well at a decommissioning site may be measurable at an offsite well. However, this does not necessarily constitute a detectable change in the reliability of the water supply. It would be detectable if the offsite well is unable to withdraw its permitted volumes as a result of this increased drawdown. The impacts of decommissioning activities are considered destabilizing if they result in a permanent and/or significant loss of water supply reliability. For instance, heavy pumping of an aquifer that results in subsidence may cause a permanent loss of aquifer capacity. Another example of a destabilizing impact is a change in site drainage or stream-channel changes that would result in a detectable and significant change in the probability of flooding.

4.3.2.3 Evaluation

In general, the impact of nuclear reactor facilities on water resources dramatically decreases after plants cease operation. The flow through the condenser of an operating plant can range from 3 to 78 m^3/s (49,000 to 1,200,000 gpm) (NRC 1996), depending upon the size of plant. This operational demand for cooling and makeup water is largely eliminated after the facility permanently ceases operation. As the plant staff decreases, the demand for potable water also generally decreases. However, in a few cases staffing levels have temporarily increased above levels that were common for routine operations. For these short periods of time, commonly during the early stages of decontamination and dismantlement activities, there may be a slight increase in demand for potable water.

Most of the impacts to water resources likely to occur during decommissioning of a nuclear facility are also typical of the impacts that would occur during decommissioning or construction of any large industrial facility. For example, providing water for dust abatement is a concern for any large construction project, as is potable water usage. However, the quantities of water required are trivial compared to the quantity used during operations. There are some activities affecting water resources and decommissioning nuclear facilities that are different from other industrial non-nuclear activities. The demand for water for spent fuel maintenance (approximately 200 to 2000 L [50 to 500 gal.] of water per day, depending on the size and location of the pool) and wet decontamination methods (such as a full flush of the primary system or hydrolasing embedded piping in place), although not large, are unique to nuclear facilities. One facility reported using approximately 9500 to 11,000 L (2500 to 3000 gal.) of water per day for spent fuel pool spray-cooling during the summer months. Additionally, water in some of the systems or piping may continue to be used during decontamination and dismantlement to provide shielding from radiation for workers who are dismantling structures, systems, and components (SSCs) in the vicinity. For example, 912,000 L (240,000 gal.) of water was used at one site to fill the reactor cavity in preparation for the segmentation of the reactor vessel.

Common engineering practices, such as water reuse, are used to limit water use impacts at most construction or industrial sites. However, use of some of these practices may be limited by radiological exposure considerations at decommissioning sites.

Water use at decommissioning nuclear reactor facilities is significantly smaller than water use during operation. The water use will be greater in facilities that are undergoing decontamination and dismantlement than those that are in the storage phase. During ENTOMB, water will be required as the concrete for entombment is mixed. Greater amounts of water will be needed for the ENTOMB2 option than for ENTOMB1. However, in both cases, this process would be of short duration and would not consume quantities of water in excess of those used in the construction of large buildings.

Previous or anticipated decommissioning activities at the FBR or HTGR have not and are not expected to result in water use impact that is different from those found at other nuclear reactor facilities.

4.3.2.4 Conclusions

The staff considered available information on the potential impacts of decommissioning on water use, including information received on the draft of Supplement 1 of NUREG-0586. This information indicates that the impacts of decommissioning on water use are neither detectable nor destabilizing. Therefore, the staff makes a generic conclusion that the potential impacts to water use are SMALL. The staff has considered mitigation and concludes that no additional measures are likely to be sufficiently beneficial to be warranted.

4.3.3 Water Quality

There are quality standards for drinking water, protection of aquatic and terrestrial habitats, and release of potential pollutants to surface and groundwater environs. Nuclear reactor facilities are usually located above aquifers or adjacent to important sources of water. Intended and accidental releases of potential pollutants may impact the quality of these waters. This section considers water quality impacts of nonradioactive material for both surface water and groundwater during the decommissioning process. Impacts from releases of radioactive material in liquid effluents are discussed in Section 4.3.8, "Radiological."

4.3.3.1 Regulations

Intentional releases of nonradioactive discharges to surface waters are regulated through the National Pollutant Discharge Elimination System (NPDES; Section 402 of the Federal Water Pollution Control Act, commonly referred to as the Clean Water Act [CWA] [33 USC 1251 to 1387]) to protect water quality. Congress has delegated the responsibility for NPDES implementation to the U.S. Environmental Protection Agency (EPA). When the EPA determines that State programs are equivalent to the Federal NPDES program, the NPDES permitting process is delegated to the State. Generally, discharge limits specified by the NPDES permit are revisited every 5 years. Ongoing monitoring programs may be required as part of an NPDES permit.

The Resource Conservation and Recovery Act of 1976 (RCRA; 42 USC 6901 et seq.) addresses the need to investigate and clean up contamination in the event of the release of nonradioactive hazardous material not covered within the limits of the NPDES permit. As with the NPDES permitting process, Congress has delegated the responsibility for RCRA implementation to the EPA. Because NPDES permits regulate only intentional discharges to surface water, any accidental releases of nonradioactive hazardous materials that may impair water quality (surface water or groundwater) are regulated through the RCRA process. RCRA requires responsible parties to clean up environmental contaminants regardless of the time of their release. The degree of investigation and subsequent corrective action necessary to protect human health and the environment vary significantly among facilities. When the EPA determines that State programs are equivalent to the Federal RCRA program, the corrective action program is delegated to the State.

Based on an October 1978 decision by the Atomic Safety and Licensing Board, (TVA 1978a, TVA 1978b), NRC authority does not extend to matters within the jurisdiction of the EPA. More specifically, the NRC authority is limited for those matters expressly assigned to the EPA by the Federal Water Pollution Control Act Amendments of 1972. This decision would also apply to decommissioning nuclear reactor facilities.

4.3.3.2 Potential Impacts of Decommissioning Activities on Water Quality

Table E-3 in Appendix E shows the activities during decommissioning that may affect water quality. These major activities include fuel removal, stabilization, decontamination and dismantlement, and structure dismantlement. Separate assessments of potential impacts were performed for surface water and groundwater. Surface waters are most likely to be impacted either by stormwater runoff or by releases of substances during decommissioning activities.

Because water quality and water supply are interdependent, changes in water quality must be considered simultaneously with changes in water supply. For example, reduced groundwater pumping may result in a rise in the water table, providing a new pathway for contaminants currently in the subsurface. Changes in the landscape (terrain and vegetation) during decommissioning can alter the hydrologic pattern of recharge and surface-water runoff. The convergence of surface water over unvegetated soils may result in accelerated erosion and the delivery of sediment to important downstream habitat.

Impacts to water quality of decommissioning activities would be considered detectable if such activities result in a significant change in water-supply reliability. For example, stormwater erosion at a facility undergoing decommissioning may result in a measurable increase in suspended sediment in an adjacent stream or disposal of concrete onsite could alter local water chemistry of the groundwater. However, this does not constitute a detectable change in the reliability of the water supply unless the incremental change in sediment concentration precludes permitted or environmental uses. The impacts of decommissioning activities would be considered to be destabilizing on water quality if they result in a permanent or significant loss of water-supply reliability. For instance, significant increases in erosion might result in a permanent loss of benthic habitat for certain fish species.

4.3.3.3 Evaluation

Both the decommissioning activities themselves and the order in which the activities are performed control the impacts to water quality. The same activities performed in a different order can have a significantly different impact on water quality. The time between activities may also be important in assessing impacts. Delaying activities during SAFSTOR may exacerbate water-quality issues. For example, the aging of structures may create new pathways for groundwater to enter contaminated subgrade structures. This would be less of an issue for entombment of a facility, where the plant's contaminated SSCs are encased in concrete and maintained as a solid structure isolated from the environment.

Stormwater runoff and erosion control are issues faced at many industrial sites, and it is expected that after application of common BMPs, any changes in surface-water quality will be nondetectable and nondestabilizing.

All commercial nuclear power facilities have NPDES permits that regulate intentional releases of hazardous materials. Historically, unintentional releases of hazardous substances have been an infrequent occurrence at decommissioning facilities. Because the focus of decommissioning is the ultimate cleanup of the facility, considerable attention is placed on minimizing spills. Except for a few substances such as hydrocarbons (diesel fuel), such hazardous spills are localized, quickly detected, and relatively easy to remediate. Relevant regulations are listed in Appendix L. Some of the groundwater parameters measured in the license termination plan (LTP) might also be indicators of a heretofore undetected nonradiological subsurface plume. If such indications were observed, further characterization and corrective actions would be dictated by the relevant regulations discussed in Appendix L and permits, if appropriate.

Certain decommissioning activities or options may result in changes in local water chemistry. For example, if licensees dismantle structures by demolition and disposal of the concrete rubble on the site, then there is a potential that the hydration of concrete could cause an increase in alkalinity of groundwater. The pH of interstitial (pore) water very close to the concrete rubble would remain above 10.5 for several hundred thousand years (Krupa and Serne 1988). However, as the leachate migrates away from the demolition debris, it is reasonable to expect the leachate pH to be rapidly reduced (within meters) to natural conditions due to the large buffering capacity of soils. While the leachate's pH may not be a water-quality concern, such leachate may affect the transport properties of radioactive and nonradioactive chemicals (notably metals) in the subsurface although this transport would not be detectable offsite. Surface spreading of the demolition debris over large areas may provide adequate opportunity for soils to buffer the pH to background. Because the nonradiological impacts would be nondetectable, they are considered to be generic for all sites. However, concentrated disposal of demolition debris, either within or outside of existing below-grade structures, would require below-grade compliance with RCRA guidelines. The radiological aspects of onsite disposal of slightly contaminated material would require a site-specific analysis and would be addressed at the time the LTP is submitted.

Current or anticipated decommissioning activities at the FBR or HTGR have not and are not expected to result in water-quality impacts that are different from those found at other nuclear reactor facilities.

4.3.3.4 Conclusions

The staff considered available information on the potential impacts of decommissioning on nonradioactive aspects of water quality for both surface water and groundwater, including comments received on the draft of Supplement 1 of NUREG-0586. This information indicates that for all facilities the impacts of decommissioning on water quality will be neither detectable nor destabilizing. Therefore, the staff makes a generic conclusion that for all facilities, the impacts on nonradioactive aspects of water quality are SMALL. The staff has considered mitigation and concludes that no additional measures are likely to be sufficiently beneficial to be warranted.

4.3.4 Air Quality

Decommissioning activities have the potential to adversely impact air quality. The activities may be direct, such as demolition of buildings, or indirect, such as transportation of decommissioning workers to and from the site. This section discusses the nonradiological impacts of decommissioning on air quality. Radiological impacts on air quality are addressed in Section 4.3.8, "Radiological."

4.3.4.1 Regulations

The purpose of the Clean Air Act (CAA) as amended (42 USC 7401 et seq.) is to "protect and enhance the quality of the Nation's air resources so as to promote the public health and welfare and the productive capacity of its population." Section 118 of the CAA, as amended, requires that each Federal agency, such as NRC, with jurisdiction over any property or facility that might result in the discharge of air pollutants, comply with "all Federal, state, interstate, and local requirements" with regard to the control and abatement of air pollution. Pursuant to the Act, the EPA established National Ambient Air Quality Standards to protect public health, with an adequate margin of safety, from known or anticipated adverse effects of regulated pollutants (42 USC 7409). Hazardous air pollutants and radionuclides are regulated separately (42 USC 7412).

EPA's regulations are found in Title 40 of the Code of Federal Regulations. The National Primary and Secondary Ambient Air Quality Standards are found in 40 CFR Part 50. The standards related to particulate matter (40 CFR 51.06 and 40 CFR 51.07) are particularly relevant to decommissioning activities. Other regulations that may cover decommissioning activities are found in 40 CFR Part 61, which deals with hazardous air pollutants such as asbestos, chlorofluorocarbons, and radionuclides; 40 CFR Part 81, which deals with designation of areas for air-quality planning purposes; and 40 CFR Part 82, which deals with protection of stratospheric ozone.

In addition, State and local agencies have developed and enforce a variety of air-quality regulations. These regulations require permits for emission sources, limit emission rates, and set maximum atmospheric concentrations for pollutants. Finally, different regulations apply to indoor air quality and worker safety.

4.3.4.2 Potential Impacts of Decommissioning Activities on Air Quality

Table E-3 in Appendix E shows activities that may have an effect on air quality. These include organizational changes, stabilization, storage preparation for SAFSTOR, decontamination and dismantlement, structural dismantlement, entombment, and transportation. The potentially adverse impacts identified include (1) degradation of air quality caused by emissions (e.g., NO_x, CO, and hydrocarbons) from internal combustion engines, (2) increased particle loading of the atmosphere caused by the movement of vehicles and equipment, demolition of structures, dismantlement of systems, and operation of concrete batch plants, and (3) alteration of other characteristics of the atmosphere (e.g., the ozone layer) by releases of gases used in plant systems (e.g., in fire suppression or refrigeration).

Air-quality impacts of emissions from internal combustion engines and changes in atmospheric particle loading can be assessed by comparison with standards set in air-quality regulations. These potential impacts are considered detectable if a decommissioning activity is likely to cause a measurable increase in the concentration of one or more regulated air pollutants that can be directly attributed to the activity. The impact is considered to be destabilizing if the impact is detectable and causes a change in the attainment status of the region. Air-quality impacts of the releases of other gases can be assessed by comparison with the magnitude of potential releases during decommissioning with the magnitude of releases of the same or similar gases from other sources.

4.3.4.3 Evaluation

Decommissioning activities that have the potential to have a nonradiological impact on air quality include:

- worker transportation to and from the site
- dismantling of systems and removing of equipment
- movement and open storage of material onsite
- demolition of buildings and structures
- shipment of material and debris to offsite locations, and
- operation of concrete batch plants.

These activities typically take place over a period of years from the time the facility ceases operation until the decommissioning is complete and the license is terminated. The magnitude and the timing of the potential impacts of each activity will vary from plant to plant, depending on the decommissioning options selected by the licensee and the status of facilities and structures at the time of license termination.

Worker transportation: Air-quality impacts of transportation of workers to and from the site are caused by emissions from the vehicles and by fugitive dust from traffic on paved and unpaved roads. Consequently, the impacts can be estimated directly from the size of the work force. Experience with decommissioning indicates that for most sites the onsite work force tends to decrease from the time that plants cease operation until decommissioning is complete. There are occasional increases during specific decontamination and dismantlement activities. However, the work force during decommissioning is smaller than the construction work force and the work force during refueling outages, and almost always smaller than the work force during facility operation.

Assuming that neither the mix of vehicles used for worker transportation nor the vehicle occupancy is different during decommissioning than during plant construction or operation, emissions from vehicles and fugitive dust associated with traffic is expected to decrease during the decommissioning period. These decreases are expected to improve air quality rather than degrade it. Consequently, the change in air quality associated with changes in worker transportation during decommissioning should not be detectable or destabilizing at any site.

Dismantling systems and removing equipment: Air-quality impacts of dismantling systems and removing equipment may be caused by the generation and release of particulate matter associated with the physical activities of dismantling and by the release of gases from the systems (for example, refrigeration systems and fire-protection systems).

The predominant potential effluent from system dismantling and removal of equipment will be particulate matter and fugitive dust. This material will generally be released in and remain within buildings and other structures because most decommissioning activities associated with dismantling systems and removing equipment will be conducted inside the containment, auxiliary, and fuel-handling buildings. These buildings have systems to minimize airborne contamination, such as whole-building air filtration. Filtration systems control the release of particulate matter to the environment. These systems, which are typically maintained and periodically operated during decommissioning, reduce the impact of airborne particulate material. Where filtration systems are not in place to control particulate releases, temporary systems can be established, as needed. Special air-ventilation pathways may be established before the start of a SAFSTOR period to ensure that air ventilates from the building through high efficiency particulate air (HEPA) filters. It is unlikely that particulate matter released to the environment as a result of system dismantlement and equipment removal will be sufficient to be detectable offsite. Special precautions are required for worker protection where hazardous materials such as asbestos may become airborne, as discussed in Section 4.3.10, "Occupational Issues."

Various systems associated with reactors contain gases that are of environmental concern. For example, some gases used in refrigeration systems and fire-suppression systems have been identified as ozone-depleting compounds. Venting of these gases to the atmosphere is prohibited by law. Standard methods exist to purge systems with these gases and limit releases to the environment to insignificant quantities. Other fire suppression and refrigeration systems may contain greenhouse gases. The quantities of these gases at a nuclear plant are generally small in comparison with the quantities of greenhouse gases released hourly by a fossil-fuel combustion plant used for heating or power generation. The impacts of ozone-depleting and greenhouse gases are global rather than local. Therefore, it is unlikely that releases of ozone-depleting or greenhouse gases during decommissioning of any nuclear power plant will be detectable or destabilize the environment.

Movement and open storage of material onsite: Movement of equipment and open storage of materials onsite during decommissioning are similar to activities during construction or demolition of an industrial facility. The air-quality impacts of the movement of equipment and open storage of materials onsite are primarily associated with fugitive dust. Movement of equipment outside of the buildings may generate fugitive dust. Movement of equipment may also alter the size distribution of particles on the ground, making the particles more susceptible to suspension by the wind. Mitigation measures will be taken to minimize dust to comply with local air-quality regulations. Common mitigation measures include watering and other soil stabilization measures, such as spraying sealants on the area and seeding. Therefore, it is unlikely that the movement of equipment and open storage of materials will be detectable or destabilize regional air quality.

Demolition of buildings and structures: Once decontamination has been completed, the demolition of buildings and other structures at a nuclear power plant is similar to demolition of buildings and structures at industrial facilities. Demolition of buildings and major structures may cause a temporary increase in fugitive dust from the site. Fugitive dust from demolition of buildings and structures will involve large particles that will settle to the ground quickly. Demolition will generally be limited to a small number of short-duration events. Mitigation measures will be used to minimize dust. Therefore, it is unlikely that the fugitive dust from demolition of buildings and structures will be detectable or destabilize air quality.

If residual contamination is present at the time of demolition, then the demolition of buildings and structures must be conducted using techniques that keep releases of contaminated material within regulatory limits. For purposes of assessing radiological impacts, impacts are of small significance if doses and releases do not exceed limits established by the Commission's regulations.

Shipment of material and debris to offsite locations: Dismantled equipment, material, and debris from decommissioning are typically removed from the site as decommissioning progresses. The number of shipments required during the decommissioning period depends on the method of transportation and the decommissioning option chosen. Although the number of shipments may be relatively large, the decommissioning period extends over several years. As a result, the number of shipments per day is small. Current experience is that there is an average of less than one shipment per day of LLW from the plant (see Section 4.3.17, "Transportation"). Therefore, it is unlikely that the emissions from a shipment or a small number of shipments per day would be detectable or destabilize local or regional air quality at any nuclear power plant undergoing decommissioning.

Operation of a concrete batch plant: The ENTOMB options will require a large amount of concrete and aggregate. Unloading, movement, and dispensing of the materials that make concrete result in fugitive dust in the vicinity of concrete batch plants. Most of the dust is associated with unloading dry cement at the concrete batch plant and loading mixers or trucks. This dust tends to consist of large particles that settle out of the air quickly. As a result, dust associated with concrete batch plant operations is likely to be localized near the concrete batch plant. There will also be emissions from heavy equipment at concrete batch plants and vehicles used to transport concrete from the concrete batch plant to the entombment site. The likely impacts of these emissions will be smaller than those from dust.

There are a number of mitigation measures that can be used to control dust. Dust control measures commonly used at concrete batch plants include enclosure of dumping and unloading areas and conveyors, use of filters, and use of water sprays. There would be no significant difference between a concrete batch plant used in the ENTOMB option and a batch plant used for any other major construction activity. Therefore, the staff considers it unlikely that the environmental impacts of operation of a concrete batch plant for a plant undergoing entombment would be detectable or destabilize air quality.

In summary, the most likely impact of decommissioning on air quality is degradation of air quality by fugitive dust. Fugitive dust during decommissioning should be less than during plant construction because the size of the disturbed areas is smaller, the period of activity is shorter, and paved roadways may exist. Use of BMP, such as seeding and wetting, can be used to minimize fugitive dust. During demolition activities, some particulate matter in the form of fugitive dust may be released into the atmosphere, but much of this fugitive dust consists of large particles that settle quickly. To date, licensees decommissioning nuclear reactor facilities have taken appropriate and reasonable control measures to minimize fugitive dust. No anticipated new methods of conducting decommissioning and no peculiarities of operating plant sites are anticipated to affect this pattern.

The selection of the decommissioning option (DECON, SAFSTOR, ENTOMB1, or ENTOMB2) is more likely to affect the timing of air-quality impacts than the magnitude of the impacts. Immediate decontamination and dismantlement of the facility (DECON) results in impacts earlier than the SAFSTOR option, in which most decommissioning activities are postponed to permit residual activity in the plant to decay. ENTOMB1 and ENTOMB2 may include the dismantlement of structures outside of containment and, thus, could result in air-quality impacts related to fugitive dust that would be the same as or greater than during DECON.

Previous or anticipated decommissioning activities at the FBR or HTGR have not and are not expected to result in air-quality impacts that are different from those found at other nuclear facilities.

4.3.4.4 Conclusions

The staff has considered available information on the potential impacts of decommissioning on air quality, including comments received on the draft of Supplement 1 of NUREG-0586. This information indicates that the impacts of decommissioning on air quality are neither detectable nor destabilizing. Therefore, the staff makes the generic conclusion that the impacts on air quality are SMALL. The staff has considered mitigation and concludes that current and commonly used measures are sufficient and no additional measures are likely to be sufficiently beneficial to be warranted.

4.3.5 Aquatic Ecology

Aquatic ecology issues incorporate all of the plants, animals, and species assemblages in the rivers, streams, oceans, estuaries, or any other aquatic environments near a nuclear power facility. Aquatic ecology also includes the interaction of those organisms with each other and the environment.

4.3.5.1 Regulations

Federal laws that are included within a NEPA evaluation of aquatic ecology issues include the CWA, the ESA of 1973, the Fish and Wildlife Coordination Act (16 USC 661 to 667c), and NEPA. Although some biota may be affected by a number of decommissioning activities, full consideration is usually reserved for the more important aquatic resources, which may be either individual species or habitat-level resources. Some activities, such as removal of in-stream or shoreline structures, may require permits from other agencies.

4.3.5.2 Potential Impacts of Decommissioning Activities on Aquatic Ecological Resources

Table E-3 in Appendix E identifies decontamination and dismantlement and structural dismantlement as activities that may affect aquatic ecology. Aquatic ecological resources may be impacted during the decommissioning process via either the direct or the indirect disturbance of plant or animal communities near the plant site. Direct impacts can result from activities such as the removal of shoreline or in-water structures (i.e., the intake or discharge facilities), the active dredging of a stream, river, or ocean bottom, or the filling of a stream or bay while indirect impacts may result from effects such as runoff. During decommissioning, aquatic environs at the plant site may be disturbed for the construction of support facilities, such as to build a dock for barges or to bridge a stream or aquatic area. Additionally, aquatic environs away from the plant site may be disturbed to upgrade or install new transportation systems (e.g., a new rail line to support large component removal) or to install or modify transmission lines. In most cases, aquatic disturbances will result in relatively short-term impacts and the aquatic environs will either recover naturally or impacts can be mitigated. Minor impacts to aquatic resources could result from sediment runoff generation due to ground disturbance and surface erosion and runoff. Impacts may occur if shoreline or in-water structures, such as the intake or discharge facilities and pipes, are removed. These impacts will typically be temporary and will not be detectable nor will they destabilize important attributes of the resource. It is important that shoreline or in-water structure removal is managed in a manner that does not result in the establishment of nonindigenous or noxious plants and animals to the exclusion of native species.

If decommissioning does not include removal of shoreline or in-water structures, very little aquatic habitat is expected to be disturbed during decommissioning. Thus, practically all aquatic habitat that was used during regular plant operations or, at a minimum, was not previously disturbed during construction of the site will not be impacted. If all activities are confined to the plant operational areas, impacts are expected to be minor and would primarily result from increased sediment from physical alterations of the site. If no disturbances occur beyond the regular operational areas of the site, it is expected that the impact to aquatic resources will be nondetectable, nondestabilizing, and easily mitigated.

In some cases, the aquatic habitats that were originally disturbed during the construction of the site will continue to be of low habitat quality at the time of site decommissioning, even beyond the normal operations boundaries. However, important resources could either develop on the site or colonize the area disturbed by the construction. If a decommissioning activity results in the "removal" of species from an area (e.g., if a commercial or recreational fishery is no longer possible), this may be detectable. Reworking the ground surface during construction could alter the surface-drainage patterns such that wetlands on the original construction site may no longer support an aquatic community. If this is an important local or regional resource, it may be considered destabilizing.

4.3.5.3 Evaluation

The primary factors that must be considered in evaluating the potential for adverse impacts in areas previously disturbed by construction include the quantity of habitat to be disturbed, the length of time since initial disturbance, and the successional patterns of the aquatic communities (especially nuisance species). Most of the important aquatic ecological resources are not likely to occur on most plant sites. If they do occur, the decommissioning activities can probably be planned to avoid or minimize detectable and destabilizing effects.

Two decommissioning activities may result in impacts to the aquatic environment: removal of structures from the shoreline or in-water environment and removal of contaminated soil from the site (the latter applies only if the soil is in or near an aquatic environment).

Additionally, dredging and modification of barge loading facilities may result in impacts to aquatic ecological resources. Periodic permitted, maintenance dredging of the barge unloading facility is not expected to result in long term detectable or destabilizing impacts to the aquatic environment. Impacts to the aquatic resources would be within the bounds of the generic assessment. However, a significant expansion of the barge unloading facility necessary to accommodate, for example, a large shipping package such as a reactor vessel would require a site specific assessment. The environmental assessment may be performed by the U.S. Corps of Engineers as part of the review to permit the enlargement of the barge unloading facility.

In most cases, the aquatic environment required to support the decommissioning process is relatively small and is normally a very small portion of the overall plant site. Usually, the areas disturbed or utilized to support decommissioning are within the boundaries of the site operational areas and typically are immediately adjacent to the reactor, auxiliary, and control buildings. Discharge permits to the aquatic environment for operation are almost always greater than planned or realized during decommissioning. In almost all cases examined, licensees expect to restrict activities to previously disturbed areas and operate within the limits of operational permits.

The potential for adverse impacts are likely to be nondetectable or nondestabilizing regardless of the decommissioning option selected. The activity most likely to result in impacts to aquatic environments is specific to removal of shoreline or in-water structures. The decision to conduct these activities would not be dependent on the decommissioning option. The only option where shoreline or in-water structure removal appears to be guaranteed is for those plants where return to a "Greenfield" is desired or required.

When there is a decommissioning activity outside the operational area, the significance of the potential impacts are more difficult to define and will depend on site-specific considerations. The primary factors that need to be considered include the total acreage of habitat to be disturbed, and the overall importance of the plant or animal species or communities to be disturbed. If important resources may be affected by the decommissioning activities, the impacts may be detectable and destabilizing.

Current or anticipated decommissioning activities at the FBR or HTGR have not and are not expected to result in aquatic ecology impacts that are different from those found at other nuclear reactor facilities.

4.3.5.4 Conclusion

The staff has considered available information on the potential impacts of removing facility structures or contaminated soil from or near the aquatic environment on the aquatic ecological resources, including comments received on the draft of Supplement 1 of NUREG-0586. For facilities where disturbance of lands beyond the operational areas is not anticipated, the impacts on aquatic ecology are not detectable or destabilizing. The staff believes that activities within operational areas including the removal of shoreline or in-water structures, will have minimal impact on aquatic resources provided all applicable BMPs are employed and required permits are obtained. Therefore, the staff makes a generic conclusion that for such activities, the potential impacts to aquatic ecology are SMALL. The staff has considered mitigation measures and concludes that no additional mitigation measures are likely to be sufficiently beneficial to be warranted.

If disturbance beyond the operational areas is anticipated, the impacts may or may not be detectable or destabilizing, depending on site-specific conditions and cannot be predicted generically. Therefore, the staff concludes that if disturbance beyond the operational areas is anticipated, the potential impacts may be SMALL, MODERATE, or LARGE, and must be determined through site-specific analysis.

4.3.6 Terrestrial Ecology

Terrestrial ecology considers all of the plants, animals, and species assemblages in the vicinity of the nuclear power facility as well as the interaction of those organisms with each other and the environment. Evaluations of impacts to terrestrial ecology are usually directed at important habitats and species, including plants and animals that are important to industry, recreational activities, the area ecosystems, and those protected by endangered species regulations and legislation. Federally listed threatened and endangered species, and designated critical habitat for such species, are addressed in a separate section of this Supplement (Section 4.3.7). There are also many species identified by State agencies as endangered or threatened, and potential impacts to such species should be evaluated and mitigated, as appropriate. Important habitat resources include (but are not limited to) wetlands, riparian areas, resting or nesting areas for large numbers of waterfowl, rookeries, communal roost sites, strutting or breeding grounds for gallinaceous birds, calving grounds, and areas containing rare plant communities. Some States have programs to formally designate priority or rare habitat community types.

4.3.6.1 Regulations

Federal statutes that are directly applicable in a NEPA evaluation of terrestrial ecology issues include the ESA of 1973, the Migratory Bird Treaty Act of 1918 (MBTA) (16 USC 703-712), and portions of other statutes, such as the wetlands provisions of the CWA (see Section 4.3.5.1, "Regulations").

The MBTA was initially enacted in 1918 to implement the 1916 Convention between the United States and Great Britain (for Canada) for the protection of migratory birds. Specifically, the Act established a Federal prohibition, unless otherwise regulated, to pursue, hunt, take, capture, or kill any bird included in the terms of the convention, or any part, nest, or egg of any such bird. The MBTA was amended in 1936 to include species included in a similar convention between the United States and Mexico, in 1974 to include species included in a convention between the United States and Japan, and in 1978 in a treaty between the United States and the Soviet Union. Executive Order 13186 (2001) further defined the responsibilities of Federal agencies, such as the NRC, to ensure the protection of migratory birds and to consider potential impacts to migratory birds during the preparation of NEPA documents.

4.3.6.2 Potential Impacts of Decommissioning Activities on Terrestrial Ecological Resources

Table E-3 in Appendix E identifies stabilization, large-component removal, structure dismantlement, and decontamination and dismantlement as activities that may affect terrestrial ecology. Terrestrial ecological resources may be impacted during the decommissioning process via direct or indirect disturbance of native plant or animal communities in the vicinity of the plant site. Direct impacts can result from activities such as the clearing of native vegetation or filling of a wetland. Indirect impacts may result from effects such as erosional runoff, dust, or noise. During decommissioning, land at the site may be disturbed for the construction of laydown yards, stockpiles, and support facilities. Additionally, land away from the plant site may be disturbed to upgrade or install new transportation or utility systems. For example, building a new rail line may be necessary to support large-component removal. Installing or altering existing transmission lines could also have an effect on the terrestrial environment. In most cases, land disturbances will result in relatively short-term impacts and the land will either recover naturally or will be landscaped appropriately for an alternative use after completion of decommissioning.

Minor impacts to terrestrial resources could result from dust generation due to ground disturbance and traffic, noise from dismantlement of facilities and heavy equipment traffic, surface erosion and runoff, and migratory bird collisions with crane booms or other construction equipment. Most of these minor, indirect impacts are temporary and will not be significant issues after the completion of decommissioning. The effects of such impacts can also be minimized using standard BMPs.

Impacts to terrestrial resources are considered to be detectable if they result in changes to local species populations or plant or animal communities beyond the typical levels of natural variability (i.e., normal year-to-year variations). The impacts are considered to be destabilizing if they result in the extirpation of important species or result in long-term changes in ecological functions (such as flow of energy), species richness, diversity, or proportion of invasive species.

4.3.6.3 Evaluation

At most commercial nuclear facilities, there is a relatively distinct operational area where most or all site activities occur (e.g., materials and equipment storage, parking, substation operation, facility service and maintenance, etc.). This operational area usually includes all areas within the protected area fence, the intake, discharge, cooling, and other associated structures, as well as adjacent paved, graveled, and maintained landscaped areas. The operational area may include the entire area disturbed during facility construction, but is often considerably smaller.

Terrestrial habitats disturbed during the construction of the site will often continue to be of low habitat quality during plant operation and decommissioning. However, sensitive habitats can develop on the site or rare species can colonize the area disturbed during construction. This is especially true if the site has been in SAFSTOR for several decades. For example, reworking the ground surface during construction may have altered the surface-drainage patterns such that wetlands develop on the original construction site. Trees could grow to the point where they become usable as roosting or nesting sites for eagles, osprey, or wading birds. These habitats may be inhabited by sensitive species at the time of decommissioning. Rare species have colonized portions of the site at several operating commercial nuclear power plants.

In most cases, the amount of land required to support the decommissioning process is relatively small and is a small portion of the overall plant site. Usually, the areas disturbed or utilized to support decommissioning are within the operational areas of the site and typically are within the protected area. Usually, there is sufficient room within the operational areas to function as temporary storage, laydown, and staging sites. In most cases, management, engineering, and administrative staff would have been assigned space in existing support or administration buildings. In some cases, the licensees have installed trailers or temporary buildings to house engineering and administrative staff or to otherwise support decommissioning. Most licensees expect to restrict decommissioning activities to highly disturbed operational areas but a few expect to use lands beyond the operational areas, as defined above. The licensees typically anticipate utilizing an area of between 0.4 ha (1 ac) to approximately 10.5 ha (26 ac) to support the decommissioning process. One facility (Big Rock Point) required a new transmission line ROW to provide electrical power to the plant site during decommissioning (this line will also provide power to the onsite independent spent fuel storage installation [ISFSI] after decommissioning is completed). However, construction of a new transmission line ROW is probably an unusual situation. It is expected that some sites will require the reconstruction or installation of new transportation links, such as railroad spurs, road upgrades, or barge slips. Activities conducted within the operational areas are not expected to have a detectable impact on important terrestrial resources. Activities conducted outside the operational areas may have detectable impacts, depending on the magnitude and type of activity and the resources potentially affected.

None of the decommissioning options have a greater likelihood of resulting in detectable or destabilizing impacts to terrestrial resources. The selection of the decommissioning option is more likely to affect the timing of the impact on ecological resources than it is the magnitude of the impacts. DECON may require slightly more land area to support a larger number of simultaneous activities. The ENTOMB2 option would probably have the least likelihood of adverse impacts onsite because some large components may be left in place, reducing the land requirements needed for large construction equipment, waste storage, and barge or rail loading areas. However, impacts of ENTOMB2 could be larger if additional land disturbance is required to install a concrete batch plant and associated material stockpiles. The potential impacts of SAFSTOR may be smaller than DECON, depending on the time over which activities are performed. If decontamination and dismantlement occur slowly over many years (incremental DECON), the same storage and staging areas can be reused for sequential activities. If many activities are performed over a short time period at the end of the SAFSTOR period, the impacts may be as large as those for DECON. The activity of demolition of construction material should not have significant nonradiological impacts beyond other decommissioning activities except for potential short-term noise and dust effects.

Previous or anticipated decommissioning activities at the FBR or HTGR have not and are not expected to result in impacts on terrestrial ecology that are different from those found at other nuclear facilities.

4.3.6.4 Conclusions

The staff has considered available information on the potential impacts of decommissioning activities on terrestrial resources, including comments received on the draft of Supplement 1 of NUREG-0586. For facilities where habitat disturbance is limited to operational areas, the impacts on terrestrial ecology are not detectable or destabilizing. Therefore, the staff makes a generic conclusion that for such facilities the potential impacts to terrestrial ecology are SMALL. The staff has considered mitigation measures and concludes that no additional mitigation measures are likely to be sufficiently beneficial to be warranted.

If habitat disturbance beyond the operational areas is anticipated, the impacts may or may not be detectable or destabilizing, depending on site-specific conditions and cannot be predicted generically. Therefore, the staff concludes that if disturbance beyond the operational areas is anticipated, the potential impacts may be SMALL, MODERATE, or LARGE and must be determined through site-specific analysis.

4.3.7 Threatened and Endangered Species

Plants and animals protected under the ESA of 1973 may be present at or near all commercial nuclear power facilities (Sackschewsky 1997). At operating plants, the most common potential impacts to endangered aquatic species are effects related to the operation of the cooling water system via impingement, entrainment, or occasional temperature or chemical effects. Because the cooling system is not used at a plant undergoing decommissioning, it is anticipated that the potential impacts of decommissioning on threatened or endangered aquatic species will normally be no greater than and likely far less than the potential impacts of plant operations.

For terrestrial species that are threatened or endangered, the most common potential impacts for operating plants are from transmission ROW maintenance activities. Most transmission lines beyond the switchyard are expected to remain energized, even after a commercial nuclear power facility closes operation, and the ROW maintenance activities are expected to continue. Therefore, the potential impacts of decommissioning on terrestrial species will normally be no greater than the potential impacts of plant operations.

4.3.7.1 Regulations

The ESA is the Federal statute that is directly applicable in a NEPA evaluation of threatened and endangered species issues. The ESA is intended to protect plant and animal species that are threatened with extinction and to provide a means to conserve the ecosystems on which they rely. Under the ESA, the U.S. Fish and Wildlife Service (USFWS) is responsible for all terrestrial and freshwater organisms. Marine and anadromous fish species are the responsibility of the National Marine Fisheries Service (NMFS). The ESA prohibits the taking of listed species and the destruction of designated critical habitat for listed species. The term "take" means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect or attempt to engage in such conduct (16 USC 1532). The ESA applies to Federal agencies as well as individuals. However, in general, the prohibitions against take in respect to listed plant species are only applicable to Federal agencies or to individuals on Federal lands.

Section 7 of the ESA provides a means for Federal agencies to consult with USFWS and NMFS concerning impacts to endangered species resulting from Federal actions. Although USFWS and NMFS are the administering agencies, it is the responsibility of the action agency to determine the potential impacts of a proposed action (including licensing actions) on endangered or threatened species via the preparation of a biological assessment. If the consultation process results in a determination that there may be adverse impacts to listed species, Section 10 of the ESA provides a means for permitted takes that are incidental to otherwise legal activities.

4.3.7.2 Potential Impacts of Decommissioning Activities on Threatened and Endangered Species

Table E-3 in Appendix E indicates that stabilization, large-component removal, structural dismantlement, and decontamination and dismantlement are activities that may affect threatened or endangered species. Such species may be impacted during the decommissioning process either through direct take (kill, maim, or unable to reproduce) or via disturbances of native plant or animal communities near the plant site that the species relies on for food or shelter. Additionally, an extended period of SAFSTOR may allow the establishment of onsite populations of protected species that may be adversely affected by facility decontamination and dismantlement at the end of the storage period.

The greatest potential for impact to protected species is associated with physical alteration or dismantlement of the facilities, landscape, or aquatic environment. Impacts can result from activities such as the removal of near-shore or in-water structures (e.g., the intake or discharge facilities); the active dredging of a stream, river, or ocean bottom; the filling of a stream, bay, or wetland; or the clearing of native vegetation. Indirect impacts may result from runoff, sedimentation, dust generation, or noise disturbance. The aquatic environment at a plant site may be disturbed for the construction of support facilities to allow barges to dock or to bridge a stream or other aquatic area. Additionally, terrestrial and aquatic environments away from the plant site may be disturbed to upgrade or install new transportation or utility systems. For example, a new rail line may be necessary to support large component removal. Installing or altering transmission lines could also affect the terrestrial and aquatic environment. In most cases, disturbances will result in relatively short-term impacts and the environment and local populations will either recover naturally or impacts can be mitigated using standard BMPs. An important exception may occur if near-shore or in-water structure removal or land surface disturbances result in the establishment of nonindigenous or noxious plants and animals to the exclusion of threatened or endangered species.

Impacts to endangered or threatened species are considered detectable if there are changes (attributable to the facility) in the species behavior or in the local population size that are greater than normal year-to-year variation. Impacts would be considered destabilizing if they result in direct mortality or major behavior changes (such as abandonment of most suitable habitat areas in the plant vicinity) or if they otherwise jeopardize the local population.

4.3.7.3 Evaluation

Usually, very little land will be disturbed during decommissioning that was not used during regular plant operations or previously disturbed during construction of the facility. If all activities are confined to site operational areas (i.e., within protected area fences, intake, discharge, cooling, and other associated structures, and adjacent paved, graveled, and maintained landscaped areas), the impacts to terrestrial threatened or endangered species are expected to be minor and nondetectable. Any impacts that did occur would primarily result from increased noise and dust generation from physical alterations of the plant site and from increased truck traffic to and from the site. If no disturbances occur beyond the operational areas of the site, it is expected that the impact to threatened or endangered terrestrial species will be relatively small, temporary, and mitigable. The impacts of activities beyond the operational areas would depend on the activity, the species potentially affected, and the mitigation options available.

Unless there are major structural changes in the aquatic environment, the potential for adverse impacts to aquatic threatened or endangered species is expected to be minimal and nondetectable. Impacts to aquatic threatened or endangered species resulting from runoff/ sedimentation or chemical inputs during decommissioning will be significantly less than the potential entrainment and impingement impacts that were present when the plant was operating because of the drastically reduced water use.

The different decommissioning options will probably not differ significantly in potential impacts to threatened or endangered species, except in those cases where the plant is held in SAFSTOR for extended periods. In those cases, there is a greater potential for rare species to colonize areas that may subsequently be disturbed during the decommissioning process.

The likelihood of impacts to threatened and endangered species is related to their presence or absence. This issue requires consultation with appropriate agencies to determine whether threatened or endangered species are present and whether they would be adversely affected. Consultation under Section 7 of the ESA must be initiated to determine if protected species are near the plant. If species are identified, an assessment of the potential impacts of decommissioning must be determined. Previous or anticipated decommissioning activities at the FBR or HTGR have not and are not expected to result in impacts on threatened and endangered species that are different from those found at other nuclear facilities.

4.3.7.4 Conclusions

The staff has considered available information on the potential impacts of decommissioning on threatened and endangered species, including comments received on the draft of Supplement 1 of NUREG-0586. Based on this information, the staff has considered that the adverse impacts and associated significance of the impacts must be determined on a site-specific basis.

The ESA imposes two basic requirements on the NRC. First, the ESA requires the NRC to ensure that any action authorized, funded, or carried out by NRC is not likely to jeopardize the continued existence of any endangered or threatened species, or to result in the destruction or impairment of any critical habitat for such species. Second, the NRC is required to consult with the Secretary of the Interior (for freshwater and terrestrial species through the USFWS) or the Secretary of Commerce (for marine and some anadromous fish through the NMFS) to determine if any listed species may be affected by an action. This consultation may be formal or informal, depending on the nature of the action, the species potentially affected, and the level of impacts to those species.

Acknowledging the site- and species-specific nature of threatened and endangered species and the special obligations imposed on the NRC by the ESA, the staff has concluded that the potential impacts to threatened and endangered species may be SMALL, MODERATE, or LARGE, and is not a generic issue. Informal consultation will be initiated by the NRC staff with the appropriate service after the licensee announces permanent cessation of operations. It is expected that any formal or informal consultation will be completed prior to the licensee beginning major decommissioning activities, which can occur 90 days after the submission of the post-shutdown decommissioning activities report (PSDAR). At that time, it will be determined whether such species could be affected by decommissioning activities and whether formal consultation will be required to address the impacts. Each State should also be consulted about its own procedure for considering impacts to State-listed species.

4.3.8 Radiological

The NRC considers radiological doses to workers and members of the public when evaluating the potential consequences of decommissioning activities. Radioactive materials are present in the reactor and support facilities after operations cease and the fuel has been removed from the reactor core. Exposure to these radioactive materials during decommissioning may have consequences for workers. Members of the public may also potentially be exposed to radioactive materials that are released to the environment during the decommissioning process. All decommissioning activities were assessed to determine their potential for radiation exposures that may result in health effects to workers and the public. This section considers the impacts to workers and the public during decommissioning activities performed up to the time of the termination of the license. Any potential radiological impacts following license termination are not considered in this Supplement. Such impacts are covered by the *Generic Environmental Impact Statement in Support of Rulemaking on Radiological Criteria for License Termination of NRC-Licensed Nuclear Facilities*, NUREG-1496 (NRC 1997).

4.3.8.1 Regulations

Decommissioning reactors in the United States continue to be licensed by the NRC and must comply with NRC regulations and conditions specified in the license. The regulatory standards for radiation exposure to workers and members of the public are found in 10 CFR Part 20 (see detailed discussion in Appendix G). Title 10 CFR Part 20 requires that the sum of the external and internal doses (total effective dose equivalent, or TEDE) for a member of the public may not exceed 1 mSv/yr (0.1 rem/yr). Compliance is demonstrated by measurement or calculation, to show (1) that the highest dose to an individual member of the public from sources under the licensee's control does not exceed the limit or (2) that the annual average concentrations of radioactive material released in gaseous and liquid effluents do not exceed the levels specified in 10 CFR Part 20, Appendix B, Table 2, at the unrestricted area boundary. In addition, the dose from external sources in an unrestricted area should not exceed 0.02 mSv (0.002 rem) in any given hour or 0.5 mSv (0.05 rem) in 1 yr. Occupational doses are limited to a maximum of 0.05 Sv (5 rem) TEDE per year, with separate limits for dose to various tissues and organs.

Potential radiological impacts following license termination are not covered in this Supplement. Specific radiological criteria for license termination were added as Subpart E of 10 CFR Part 20 in 1997, and the basis for public health and safety considerations is discussed in NUREG-1496 (NRC 1997). These criteria limit the dose to members of the public to 0.25 mSv/yr (25 mrem/yr) from all pathways following unrestricted release of a property. In cases where unrestricted release is not feasible, the licensee must provide for institutional controls that would limit the dose to members of the public to 0.25 mSv/yr (25 mrem/yr) during the control period and to 1 mSv/yr (100 mrem/yr) after the end of institutional controls. These criteria will largely determine the types and extent of activities undertaken during the decommissioning process to reduce the radionuclide inventory remaining onsite.

Power reactor licensees are required to meet the requirements in 10 CFR 50.36a for effluent releases after permanent cessation of operations. Licensees are also required to keep releases of radioactive materials to unrestricted areas at levels as low as reasonably achievable (ALARA).

In addition to NRC limits on effluent releases, nuclear power facility releases to the environment must comply with EPA standards in 40 CFR Part 190, "Environmental radiation protection standards for nuclear power operations." These standards specify limits on the annual dose equivalent from normal operations of uranium fuel-cycle facilities (except mining, waste disposal operations, transportation, and reuse of recovered special nuclear and by-product materials). Radon and its decay products are excluded from these standards.

The NRC has not established standards for radiological exposures to biota other than humans on the basis that limits established for the maximally exposed members of the public would provide adequate protection for other species. In contrast to the regulatory approach applied to human exposures, the fate of individual nonhuman organisms is of less concern than the maintenance of the endemic population (NCRP 1991). Because of the relatively lower sensitivity of nonhuman species to radiation, and the lack of evidence that nonhuman populations or ecosystems would experience detrimental effects at radiation levels found in the environment around nuclear power facilities, these effects are not evaluated in detail for the purposes of this Supplement.

4.3.8.2 Potential Radiological Impacts of Decommissioning Activities

As indicated in Table E-3 in Appendix E, all decommissioning activities have potential radiological concerns. Radiological impacts during decommissioning include offsite dose to members of the public and occupational dose to the work force at the facility. For this Supplement, public and occupational radiation exposures from decommissioning activities have been evaluated on the basis of information derived from recent decommissioning experience. Effluent releases anticipated during decommissioning were estimated from experiences in recent decommissioning activities from both PWRs and boiling water reactors (BWRs).

Many activities that take place during decommissioning are generally similar to those that occur during normal operations and maintenance activities. Those activities include decontamination of piping and surfaces in order to reduce the dose to nearby workers. Removal of piping or other components, such as pumps and valves, and even large components, such as heat exchangers, is performed in operating facilities during maintenance outages. However, some of the activities, such as removal of the reactor vessel or demolition of facilities, would be unique to the decommissioning process. Those activities would have the potential to result in exposures to workers who are close to contaminated structures or components, and to provide pathways for release of radioactive materials to the environment that are not present during normal operation.

4.3.8.3 Evaluation

At the cessation of plant operations, there are areas of the plant structures where residual radiation exceeds the radiation standards for license termination set forth in 10 CFR Part 20, Subpart E. One of the goals of decommissioning is to reduce this residual radiation to levels that would permit license termination. Most of the decommissioning activities listed in Table E-3 in Appendix E have the potential for radiological impacts. The staff expects that all of the activities that have potential radiological impacts will be conducted following approved procedures to keep doses ALARA and well within regulatory limits. Radiological impacts are considered to be undetectable and nondestabilizing, in the NEPA sense, if doses remain within regulatory limits.

For this Supplement, information gained from experience in decommissioning facilities has been used to evaluate radiological dose to workers and members of the public. Occupational doses, radionuclide emissions, and doses to members of the public during decommissioning were compared to those experienced during periods of routine operation at the same facilities or at similar facilities. They were also compared to estimates presented in the 1988 GEIS (NUREG-0586 [NRC 1988]). This comparison was intended to demonstrate that the radiological consequences actually experienced at facilities undergoing decommissioning were bounded either by the site's EIS for normal operations or by the 1988 GEIS. The data were also used to determine whether it was appropriate to update the estimates for these impacts as presented in the 1988 GEIS.

In estimating the health effects resulting from both offsite and occupational radiation exposures as a result of decommissioning of nuclear power facilities, the staff used the risk coefficients per unit dose recommended by the International Commission on Radiological Protection (ICRP) (1991) for stochastic health effects such as development of cancer or genetic effects. The coefficients consider the most recent radiobiological and epidemiological information available and are consistent with those used by the United Nations Scientific Committee on the Effects of Atomic Radiation. The coefficients used in this Supplement are the same as those published by ICRP (1991) in connection with a revision of its recommendations for public and occupational dose limits. Excess hereditary effects are listed separately because radiation-induced effects of this type have not been observed in any human population, as opposed to excess malignancies that have been identified among populations receiving instantaneous and near-uniform exposures in excess of 0.1 Sv (10 rem). Regulatory limits for radiation exposure to specific organs and tissues are set at levels that would prevent development of nonstochastic effects. Therefore, nonstochastic effects, such as development of radiation-induced cataracts, would not be expected in any individual whose exposure remains within the regulatory limits.

<u>Occupational Dose</u>: As part of the occupational dose analysis, data were collected for annual occupational doses, doses by activity, and total dose from decommissioning, when that information was available. Because many of the facilities that provided information have not completed the decommissioning process, the data included in this analysis is from both actual operating data and from projections for specific activities. Routine occupational doses as reported to the NRC were used to compare collective worker doses during normal operations to those experienced during decommissioning. Projections for specific activities were also used to determine which were the greatest contributors to the cumulative occupational doses over the entire decommissioning period.

The data used for this evaluation are presented in Appendix G. Average occupational doses during the 5 years of normal operations preceding shutdown ranged from about 1.5 to 5 person-Sv (150 to 500 person-rem) per year for each reactor. The average annual collective doses during the years following shutdown were generally lower, ranging from less than 0.1 to

1.8 person-Sv (10 to 180 person-rem), although specific years during the most active decommissioning period may have produced collective worker doses comparable to, or greater than, those typically experienced during normal operation. Average annual doses to individual workers are also generally lower during decommissioning than during normal operation.

Table 4-1 compares cumulative occupational dose estimates from the 1988 GEIS (NRC 1988) to estimates for plants that are currently in the decommissioning process. The types of activities included in these estimates may vary between plants. For example, some estimates include doses from transportation or from activities related to spent fuel management, which are not considered part of the decommissioning process, as defined in the scope of this document. In general, estimates for currently decommissioning plants fell within the range of estimates in the 1988 GEIS, and in some cases were substantially lower than the Supplement 1 estimates for the corresponding type of reactor and decommissioning option.

The estimated cumulative doses for the entire decommissioning process ranged from about 3.5 to 16 person-Sv (350 to 1600 person-rem) for the facilities that provided data. Estimated doses for the reference facilities discussed in the 1988 GEIS ranged from 3 to 19 person-Sv (300 to 1900 person-rem). Because the range of cumulative occupational doses reported by reactors undergoing decommissioning was similar to the range of estimates for reference plants presented in the 1988 GEIS, it was not considered necessary to update the estimates in the previous document at this time.

Activities that resulted in the largest doses during decommissioning included removal of large components, such as the reactor vessel and steam generators. Dismantling the internal structures within the containment building was the activity producing the largest overall doses. Transportation and management of spent fuel each accounted for less than 10 percent of the total. Appendix G provides a more in-depth review of the exposures recorded and anticipated for various activities.

One of the major decommissioning activities that is not performed during routine operation or refurbishment is removal of the reactor vessel. Industry experiences from this activity were reviewed to estimate worker exposure and the amount of radioactive material removed (see Appendix H). As each utility performed this major activity, experiences were shared within the industry and the lessons learned have been used to reduce collective dose to workers and improve the process. Collective worker dose at these sites ranged from 0.14 to 1.8 person-Sv (14 to 180 person-rem). The dismantlement of radioactive structures for the ENTOMB2 option would involve placement of contaminated SSCs in the reactor or containment building.

Facilities could use a demolition process for dismantlement of uncontaminated or slightly contaminated structures; there is a potential for this activity to occur during the dismantlement phases of SAFSTOR, DECON, or ENTOMB1 options. The demolition debris could be disposed of onsite if nonradiologically contaminated. If the debris is radiologically contaminated, it could be sent to a LLW site (except for the ENTOMB1 option, where it would be disposed of in the reactor or containment building structure). However, in cases where the remaining activity was

low enough that the licensee could meet the criteria in 10 CFR Part 20, Subpart E, and other regulations, the demolition debris could potentially be disposed onsite for either the DECON or SAFSTOR options. This process has been termed "Rubblization" (see Section 1.3). Rubblization would require a site-specific analysis. The site-specific analysis would be conducted at the time the LTP is submitted for the site. Occupational doses during the activity of crushing the material would be similar to those for dismantlement of the facility in preparation for demolition and offsite disposal. The occupational doses would need to meet the regulatory standards in 10 CFR Part 20. Disposal of the radiologically contaminated demolition debris onsite would also have to meet the radiological criteria for license termination given in 10 CFR Part 20, Subpart E.

Occupational doses to individual workers during decommissioning activities are estimated to average approximately 5 percent of the regulatory dose limits in 10 CFR Part 20, and to be similar to, or lower than, the doses experienced by workers in operating facilities. The average increase in fatal individual cancer risk to a worker during decommissioning, about 8×10^{-5} per year of employment, is less than 2 percent of the lifetime accumulation of occupational risk of premature death of 4.8×10^{-3}. Because the ALARA program continues to reduce occupational doses, no additional mitigation program is warranted.

<u>Public Dose</u>: This section addresses the impacts on members of the public from radiation doses caused by decommissioning activities, including doses from effluents as well as from direct radiation. To determine the relative significance of the estimated public dose for decommissioning, the staff compared dose projections for decommissioning with the historical (baseline) doses experienced at PWRs and BWRs during normal operations. The dose estimates were based on reports evaluating effluent releases during decommissioning efforts and are shown in Appendix G. Levels of radionuclide emissions from facilities undergoing decommissioning decreased because the major sources generating emissions in gaseous and liquid effluents are absent in facilities that have been shut down. However, decommissioning facilities continued to report low levels of radionuclide emissions that resulted from the residual radioactive materials remaining in the facilities. The doses to members of the public from these emissions were also very low. Collective doses to members of the public within 80 km (50 mi) were lower than 0.01 person-Sv (1 person-rem) per year at all decommissioning facilities for

Table 4-1. Comparison of Occupational Dose Estimates from NUREG-0586 (NRC 1988) to those for Decommissioning Reactors

Reactor Type/ Decommissioning Option	1988 GEIS Estimates - Cumulative Occupational Dose, person-Sv (person-rem)	Range of Estimates for Decommissioning Plants - Cumulative Occupational Dose, person-Sv (person-rem)[a]
Boiling Water Reactors		
DECON	18.74 (1874)	7 - 16 (700 - 1600)
SAFSTOR	3.26 - 8.34 (326 - 834)	3.5 (350)
ENTOMB	15.43 - 16.72 (1543 - 1672)	–
Pressurized Water Reactors		
DECON	12.15 (1215)	5.6 - 10 (560 - 1000)
SAFSTOR	3.08 - 6.694 (308 - 664)	4.8 - 11 (480 - 1100)[b]
ENTOMB	9.16 - 10.21 (916 - 1021)	–
Other Reactors (HTGR; FBR)	–[c]	4.3 (430)

(a) These data are based on information provided by plants that are undergoing or have completed the decommissioning process. For facilities that have been completely decommissioned, they represent actual doses accumulated during the decommissioning period For facilities that are still undergoing decommissioning, they represent a combination of actual doses accumulated during activities that have been completed and projected doses for future activities.

(b) The plant reporting a dose estimate of 1100 person-rem is designated as having elected the SAFSTOR option; however, the period between shutdown and active decommissioning was shorter than the minimum 10-year SAFSTOR period that was evaluated in the 1988 GEIS. Therefore, it may be more appropriate to compare the estimated dose for that facility to the 1988 GEIS estimates for the DECON option.

(c) The 1988 GEIS did not provide dose estimates for reactors other than reference light water reactors. Therefore, there are no previous estimates with which to compare the doses for decommissioning the HTGRs and FBR, which are somewhat unique in the commercial nuclear power industry. The dose estimates are expected to be consistent with PWRs and BWRs

which data were available, and, in most cases, they were comparable to or lower than the doses from operating facilities. Doses to a maximally exposed individual were less than 0.01 mSv/yr (1 mrem/yr) at both operating and decommissioning facilities, which is well within the regulatory standards in 10 CFR Part 20 and Part 50.

Offsite doses to the public attributable to decommissioning have been examined for both the maximally exposed individual and the collective doses to the population within 80 km (50 mi) of the plants. To date, effluents and doses during periods of major decommissioning have not differed substantially from those experienced during normal operation. Consequently, direct exposure and effluents in gaseous and liquid discharges are not expected to result in maximum individual doses exceeding the design objectives of Appendix I to 10 CFR Part 50, the dose and effluent concentration limits in 10 CFR Part 20, or the limits established by EPA in 40 CFR Part 190. Both the average individual dose and the 80-km (50-mi) radius collective doses are expected to remain at least 1000 times lower than the dose from natural background radiation. It should also be noted that the estimated increased risk of fatal cancer to an average member of the public is much less than 1×10^{-6}. Previous or anticipated decommissioning activities at the FBR or HTGR have not and are not expected to result in occupational or public doses that are different from those found at other nuclear facilities.

4.3.8.4 Conclusions

The staff has considered available information, including comments received on the draft of Supplement 1 of NUREG-0586, on the potential radiological impacts of decommissioning. This information indicates that the radiological impacts of decommissioning will remain within regulatory limits. Therefore, the staff makes the generic conclusion that the radiological impacts of decommissioning activities are SMALL. The staff has considered mitigation measures and concludes that no additional mitigation measures are likely to be sufficiently beneficial to be warranted.

The staff also determined that the issue of the long-term radiological aspects of Rubblization or onsite disposal of slightly contaminated material could not be evaluated generically and would require a site-specific analysis. The site-specific analysis would be conducted at the time the LTP for the site is submitted.

4.3.9 Radiological Accidents

As indicated in the Introduction to this Supplement, the staff relies on the Waste Confidence Rule for determining the acceptability of environmental impacts from the storage and maintenance of fuel in the spent fuel pool. The Rule states, in part, that there is, "reasonable assurance that, if necessary, spent fuel generated in any reactor can be stored safely and without significant impact for at least 30 yrs beyond the licensed life for operation...of that reactor at its spent fuel storage basin" (54 FR 39767).[a] However, for the purpose of public information, the staff has elected to include a discussion of potential accidents related to the spent fuel pool in this Supplement.

(a) The Commission reaffirmed this finding of insignificant environmental impacts in 1999 (64 FR 68005). This finding is codified in the Commission's regulations in 10 CFR 51.23(a).

The likelihood of a large offsite radiological release that impacts public health and safety from a facility that has permanently ceased operation is considerably lower than the likelihood of a release from an operating reactor that impacts public health and safety. This is because the potential accidents associated with reactor operation are no longer relevant after the reactor fuel has been removed.

Radiological accidents considered in licensing nuclear power plants are classified as design basis accidents (DBAs) and severe (beyond design basis) accidents. DBAs are those accidents that both the licensee and the NRC staff evaluate to ensure that the plant can withstand normal and abnormal transients and a broad spectrum of postulated accidents without undue hazard to the health and safety of the public. Severe accidents are those that are beyond the design basis of the plant. They are more severe than DBAs because they may result in substantial damage to the fuel, whether or not there are serious offsite consequences. For the most part, DBAs focus on reactor operation and are not applicable to plants undergoing decommissioning. The only DBAs or severe accidents (beyond design basis) applicable to a decommissioning plant are those involving the spent fuel pool. These postulated accidents are not expected to occur during the life of the plant, but are evaluated to establish the design basis for the preventive and mitigative safety systems of the spent fuel storage facility.

4.3.9.1 Regulations

Regulations governing accidents that must be addressed by nuclear power facilities, both operating and shutdown, are found in 10 CFR Part 50 and 10 CFR Part 100. The environmental impacts of DBAs, including those associated with the spent fuel pool, are evaluated during the initial licensing process. The ability of the plant to withstand these accidents is demonstrated to be acceptable before issuance of the operating license. The results of these evaluations are found in license documentation, such as the staff's safety evaluation report, the final environmental statement (FES), and in the licensee's Final Safety Analysis Report (FSAR) or equivalent. The consequences for these events are evaluated for the hypothetical maximally exposed individual. The licensee is required to maintain the acceptable design and performance criteria throughout the life of the plant.

In addition, Appendix E to 10 CFR Part 50 requires each licensee to develop emergency plans and implementing procedures to protect health and safety in the event of an accident. These plans and procedures are maintained up to date during the period of operation of the plant and until such time afer the cessation of plant operations that the NRC grants relief from the emergency planning requirements.

4.3.9.2 Potential for Radiological Accidents as a Result of Decommissioning Activities

Table E-3 in Appendix E indicates that fuel removal, organizational changes, stabilization, chemical decontamination, large component removal, decontamination and dismantlement, system dismantlement, entombment, and transportation are activities that may lead to radiological accidents. Many activities that occur during decommissioning are similar to activities, such as decontamination and equipment removal that commonly take place during maintenance outages at operating plants. However, during decommissioning such activities may be more extensive than similar activities during the period of reactor operations. Consequently, potential accidents associated with these activities may have a higher probability during decommissioning than when the plant is operating. Accidents that occur during these activities may result in injury and local contamination; they are not likely to result in contamination offsite. This section addresses worker injuries from radiological accidents. Injuries from other causes are addressed in Section 4.3.10,"Occupational Issues."

Once the reactor fuel has been moved to the spent fuel pool, the only DBAs contained in the plant's FSAR that are applicable are those associated with the spent fuel pool. These accidents are generally related to fuel handling or dropping heavy objects into the spent fuel pool. As long as the integrity of the spent fuel pool and its supporting systems is maintained, the potential impacts of accidents are bounded by the impacts of those for the spent fuel pool DBAs.

After permanent shutdown of the reactor, the only severe accident of concern is one where the fuel in the spent fuel pool becomes uncovered and results in a zircaloy fire. In this regard, the staff recently conducted a study of spent fuel pool accident risk at decommissioning nuclear power facilities to support development of a risk-informed technical basis for reviewing exemption requests and a regulatory framework for integrated rulemaking (NRC 2001b). As part of its effort to develop generic, risk-informed requirements for decommissioning, the staff determined the frequency of beyond-design-basis spent fuel pool accidents. The event initiators included:

- seismic events (earthquakes)aircraft crashes
- aircraft crashes
- tornadoes and high winds

- impact of a dropped heavy load (such as a fuel cask), resulting in pool drainage or compression or buckling of stored assemblies.

Those spent fuel pool accident sequences that resulted in the spent fuel being uncovered were assumed to culminate in a zirconium fire. The consequences of a zirconium fire event are likely to be severe. The staff's study performed some bounding-consequences analyses.

The impacts of accidents where onsite and offsite doses remain below those allowable for the workers or the public are considered to be undetectable. Accidents that are likely to be undetectable include temporary loss of services, certain decontamination-related accidents, such as liquid spills or leaks during in situ decontamination, and, in some cases, the temporary loss of offsite power or compressed air. The impacts of accidents that could result in offsite doses that exceed EPA's protective action guides (PAGs) (EPA 1991) are considered to be destabilizing. The only accidents that are likely to have destabilizing impacts are those that involve pool drainage that leads to a zirconium fire.

4.3.9.3 Evaluation

The information in this section is based on reviews of existing information from licensees' documents analyzing accidents from decommissioning activities and from a technical review of spent fuel pool accident risk at decommissioning nuclear power facilities. The review of spent fuel pool accidents at decommissioning reactors was performed to support development of a risk-informed technical basis for reviewing emergency plan exemption requests and a regulatory framework for integrated rulemaking (NRC 2001b). Further detail on the sources of information that were used to develop the analysis is given in Appendix I. Because the sources of information included the FBR and the HTGR, the results given in this section are applicable for these facilities.

The accidents and malfunctions covered by licensing documents can be divided into five main categories:

- Fuel-related accidents: These include maintenance and storage of fuel in the spent fuel pool and the movement of fuel into the pool, which could result in fuel rod drops, heavy load drops, and loss of water.

- Other radiological- (nonfuel)-related accidents: These include onsite accidents related to decontamination or dismantlement activities (e.g., material-handling accidents or accidental cutting of contaminated piping) or storage activities (e.g., fires or ruptures of liquid waste tanks).

- External events: These include aircraft crashes, floods, tornadoes and extreme winds, earthquakes, volcanic activity, forest fires, lightening storms, freezing, and sabotage.
- Offsite events: These consist solely of transportation accidents that occur offsite (transportation accidents are discussed in Section 4.3.17).
- Hazardous (nonradiological) chemical-related accidents: These have the potential for injury to the offsite public, either directly from the accident or as a result of further actions initiated by the accident.

A detailed list of the types of accidents that could occur in each of these five categories is given in Appendix I. Appendix I also contains a table showing the estimated dose consequences of accidents during the decommissioning period that were reported in various licensing-basis documents. The highest doses result from postulated fuel-related accidents and radioactive-material-related accidents. Information obtained from licensing-basis documents for the fuel-related accidents showed that the highest offsite doses were from the cask or heavy load-handling accidents, the accidents that assumed a 100 percent fuel failure, and the spent fuel-handling accidents. The postulated accident with the greatest estimated offsite dose was a spent resin-handling accident that had a calculated offsite dose consequence accident of 0.0096 Sv (0.96-rem) TEDE.

The likelihood of an accident as well as its consequence are activity-dependent. Accidents related to dropping fuel elements occur only when the fuel is being moved. Accidents related to dismantlement activities would occur only during the decontamination and dismantlement process and not during a storage period or after a facility has been entombed. External events, however, could occur during any activity or decommissioning option. Table I-5 in Appendix I compares the types of accidents with the different activities that are performed during SAFSTOR, ENTOMB, and DECON.

The staff has reviewed activities associated with decommissioning and determined that many decommissioning activities not involving spent fuel that are likely to result in radiological accidents are similar to activities conducted during the period of reactor operations. The radiological releases from potential accidents associated with these activities may be detectable. However, work procedures are designed to minimize both the likelihood of an accident and the consequences of an accident, should one occur, and emergency plans and procedures will remain in place to protect health and safety while the possibility of significant radiological accidents exists.

In addition to the licensing-basis documents reviewed, the staff's report, *Technical Study of Spent Fuel Pool Accident Risk at Decommissioning Nuclear Power Plants* (NRC 2001b), provides an analysis of the consequences of the spent fuel pool accident risk and includes a limited analysis of the offsite consequences of a severe spent fuel pool accident. These analyses showed that the consequences of a spent fuel accident could be comparable to those for a severe reactor accident. As part of its effort to develop generic, risk-informed requirements for decommissioning, the staff performed analysis of the offsite radiological consequences of beyond-design-basis spent fuel pool accidents using fission product inventories at 30 and 90 days and 2, 5, and 10 years. The results of the study indicate that the risk at spent fuel pools is low and well within the Commission's Quantitative Health Objectives. The risk is low because of the very low likelihood of a zirconium fire even though the consequences from a zirconium fire could be serious.

The Commission has considered the storage of spent fuel and has concluded in the Waste Confidence Rule in 10 CFR 51.23 that "... spent fuel generated in any reactor can be stored safely and without significant environmental impacts for at least 30 years beyond the licensed life for operation...." The staff has reviewed the potential accidents associated with spent fuel storage during decommissioning, the likelihood of the accidents, and the potential consequences of the accidents. Emergency plans and procedures will remain in place to protect health and safety while the possibility of significant radiological accidents associated with spent fuel exists.

4.3.9.4 Conclusions

The staff has considered available information, including comments received on the draft of Supplement 1 of NUREG-0586, concerning the potential impacts of non-spent-fuel-related radiological accidents resulting from decommissioning. This information indicates, that with the mitigation procedures in place, the impacts of radiological accidents are neither detectable nor destabilizing. Therefore, the staff makes the generic conclusion that the impacts of non-spent-fuel-related radiological accidents are SMALL. The staff has considered mitigation and concludes that no additional measures are likely to be sufficiently beneficial to be warranted.

The staff has considered available information, including comments received on the draft of Supplement 1 of NUREG-0586, on the potential impacts of spent-fuel-related radiological accidents resulting from decommissioning. The staff affirms the conclusions in the Waste Confidence Rule and concludes that the impacts of spent fuel storage are SMALL. The staff concludes that additional mitigation measures are not likely to be sufficiently beneficial to be warranted.

4.3.10 Occupational Issues

Occupational issues are related to human heath and safety. The discussion here includes physical, chemical, ergonomic, and biological hazards. This discussion does not include radiological impacts, which are discussed in Section 4.3.8.

4.3.10.1 Regulations

The Occupational Safety and Health Act of 1970 (29 USC 651 et seq.) was enacted to safeguard the health of the worker. Regulations implementing the act are found in Title 29 ("Labor") of the Code of Federal Regulations, Subtitle B, "Regulations Relating to Labor." Subpart A of 29 CFR Part 1910 adopts, by reference, occupational safety and health standards which have been found to be national consensus standards or established Federal standards. Standards adopted in 29 CFR 1910.6 include, among others, standards of the American National Standards Institute, the American Society for Testing and Materials, the American Welding Society, the National Fire Protection Association, the National Institute for Occupational Safety and Health, the Society of Automotive Engineers, and Underwriters Laboratories. Specific safety and health regulations for Construction are included in 29 CFR Part 1926. These regulations are administered by the Occupational Safety and Health Administration (OSHA).

States may also develop and enforce State standards for occupational safety and health. However, State agencies may not assert jurisdiction over any occupational safety or health issue with respect to which a Federal standard has been issued under Section 6 of the Occupational Safety and Health Act unless the State has a plan for the development and enforcement of State standards. State plans for development and enforcement of State standards are covered by 29 CFR Part 1902. Approved State plans for enforcement of State standards are listed in 29 CFR Part 1952. These plans identify the State agency responsible for development and enforcement of the State standards.

4.3.10.2 Potential Impacts of Decommissioning Activities on Occupational Issues

Table E-3 in Appendix E indicates that nearly all decommissioning activities may impact occupational issues. Typical hazards of concern can be grouped into the following categories: physical, chemical, ergonomic, biological, and radiological (Plog 1988). Radiological hazards are discussed in Section 4.3.8, and other hazards are discussed in this section in the context of decommissioning activities.

The impacts of decommissioning activities on occupational issues are considered detectable if the accident or injury rate during decommissioning exceeds average U.S. industrial accident rates. The impacts of decommissioning activities on occupational issues are considered destabilizing if the accident or injury rate during decommissioning becomes sufficiently large that decommissioning activities must be halted to address worker safety and the decommissioning schedule is threatened.

4.3.10.3 Evaluation

Typically, any significant operation, such as decommissioning, will have an environment, safety and health (ES&H) plan that serves as the guidebook for anticipating and preventing any injury or harm occurring to the worker while working on that particular job. This plan addresses all the major occupational hazards and is used to ensure that OSHA, State, and other local standards are met. The site-specific ES&H plan for a decommissioning activity should be referred to for detailed information regarding specific worker health and safety information; the occupational hazards described in this Supplement should not be used for ensuring the protection of an individual worker health and safety.

Physical hazards: During the decommissioning process, the major sources of physical occupational hazards involve the operation and use of construction and transportation equipment. Vehicles, grinders, saws, pneumatic drills, compressors, and torches are some of the more common equipment that can cause injury if improperly used. Heavy loads, which are often moved about by cranes and loaders, must be controlled to avoid injury. The majority of these hazards will be part of dismantlement. Workplace designs and controls should be the first line of defense when preventing workplace injuries. Hard hats and other personal protective equipment (PPE) are also important interventions and can serve as a secondary protective measure should workplace controls fail.

Many activities during decommissioning, for example, the use of cutting torches, have the potential to initiate fires. These activities, which are common during construction and demolition, should be identified in advance. It is expected that precautions will be taken to minimize the likelihood of fires and that suitable measures will be available for dealing with fires should they occur.

Table 4-2. Predicted Noise Ranges from Significant Construction Equipment (EPA 1971)

Equipment	Levels in dBA at 15 m (50 ft)
Trucks	82-95
Front loader	73-86
Cranes (derrick)	86-89
Pneumatic impact equipment	83-88
Jackhammers	81-98
Pumps	68-72
Generators	71-83
Compressors	75-87
Back hoe	73-95
Tractor	77-98
Scraper/grader	80-93

Noise is also a physical hazard that will be significant during decommissioning. The majority of noise will come from equipment such as rivet busters, grinders, and fans. Table 4-2 lists the typical A-weighted sound levels (decibel [dBA] levels) of standard construction equipment without the use of noise control devices or other noise-reducing design features. Although workplace controls and designs are the best methods for reducing noise, PPE (e.g., earplugs) can also be used to protect against hearing loss. If workers need to use PPE, their ability to communicate effectively is reduced and safety may be compromised.

Temperature is a physical hazard that will vary, depending on the decommissioning location and the amount of indoor versus outdoor activity. Heat and cold stress should be considered in any decommissioning plans. Normal core temperatures are 37.6°C (99.6°F) or 37°C (98.6°F) as measured by mouth. Fluctuations in core temperatures of 1.1°C (2°F) below or 1.7°C (3°F) above the normal impair performance markedly. If this range is exceeded, health hazards, e.g., hypothermia or heatstroke, exist (Plog 1988).

Physical hazards are prevalent at all the decommissioning sites. The loudest dBA noise hazard at one plant was the fan noise of 107 dBA (see Section 4.3.16, "Noise"). One facility undergoing decommissioning provided information on the number of safety occurrences (minor and injuries), accident prevention notices, PPE violations, near misses, and OSHA reportables. Many PPE violations appear to be repeat offenders. Most of the injuries and incidents noted occur in the construction area. The maximum yearly number of incidents and injuries (37) appeared in 1998 with a high number of PPE violations (53) also occurring during this reporting year. Typically, no lost work time is attributed to injuries or incidents.

Electrical hazards are a significant concern during decommissioning. During stabilization, licensees often rewire the site to eliminate unneeded electrical circuits or repower certain operations from outside. For SAFSTOR, monitoring equipment may need to be installed and some systems will need to be de-energized. All of these activities, plus various other activities (operating cranes near power lines, digging near buried cables, etc.), pose electrical threats to workers. Proper precautions should be taken to avoid injury.

Chemical hazards: Inhalation and dermal contact with chemicals are serious worker health hazards. Ingestion is typically not a voluntary route of exposure but accidental ingestions (pipetting with mouth, siphoning gasoline, etc.) have been known to occur at the job site. Solvents and particulates are the two contaminants of greatest concern. Some of the key chemicals of concern found in building materials, paints, light bulbs, light fixtures, switches, electrical components, and high-voltage cables include asbestos, lead, polychlorobiphenyls (PCBs), and mercury. Other chemicals that have been found during decommissioning activities include low levels of potassium, sodium chromate, and nickel found in the suppression chamber. Also, quartz and cristobalite silica were detected during concrete demolition. Fumes, often including lead and arsenic, and smoke from flame cutting and welding are significant sources of chemical exposure during decommissioning.

Decommissioning involves many activities that expose workers to chemical hazards:

- chemical decontamination of the primary loop
- removal of reactor components
- decontamination of the piping walls
- removal of contaminated soil
- removal of radioactive structures

- removal of hydrocarbon fuel from storage
- removal of hazardous coatings
- removal of asbestos
- removal of chemical-containing systems, such as demineralizers and acid- and caustic-containing tanks
- removal of sodium and NaK residue.

Proper planning, workplace design, and engineering controls should be supplemented with PPE and appropriate administrative solutions to ensure adequate worker protection from not only chemical hazards but all hazards.

Chemical hazards at one facility undergoing decommissioning included lead and arsenic vapors, created from torch cutting and using the plasma arc, and quartz and cristobalite particulates, created from chipping and hammering. At the facility, air sample summary logs indicate a few exposures that exceeded OSHA's permissible exposure limit (PEL). Arsenic (PEL = 0.01 mg/m^3) levels exceeded the PEL four times during the sampling period. The highest arsenic reading was 0.03 mg/m^3 when using the torch and grinder to cut a hole during one activity. The same activity reported the only lead (PEL = 0.05 mg/m^3) reading above PEL at 1.5 mg/m^3. Quartz (PEL = 0.1 mg/m^3) and cristobalite (PEL = 0.05 mg/m^3) particulates greatly exceeded the PELs when using the chipping hammer (817.84 and 1.5 mg/m^3, respectively). The drill and chipping hammer also created too much quartz dust (9.2 mg/m^3).

Ergonomic hazards: The physiological and psychological demands of decommissioning work create ergonomic hazards in the workplace. Discomfort and fatigue are two indicators of ergonomic stress that can lead to decreased performance, decreased safety, and increased chance of injury (Plog 1988). The typical sources of ergonomic stress during decommissioning activities include mechanical vibrations, lifting, and static work. Workplace designs, work shifts, and breaks should be planned accordingly to avoid ergonomic stress.

Biological hazards: Biological hazards include any virus, bacteria, fungus, parasite, or living organism that can cause a disease in human beings (Plog 1988). Typical sanitation practices can help avoid the obvious vectors for disease. Having clean, potable drinking water, marking nonpotable water, and providing cleansing areas are the most important elements of a sanitation system.

Given that many nuclear reactor facilities undergoing decommissioning are old, there is an increased chance that workers will be exposed to molds and other biological organisms that grow in and on the buildings. Molds and fungus, when inhaled, can cause minor to serious pulmonary problems. Dermal contact could cause rash and/or irritation. A thorough inspection of the facility should be conducted and proper cleansing and PPE should be used when biological agents are identified.

In general, human health risks for most decommissioning options are expected to be dominated by occupational injuries to workers engaged in activities such as construction, maintenance, and excavation. Historically, actual injury and fatality rates at nuclear reactor facilities have been lower than the average U.S. industrial rates. Occupational injury and fatality risks are reduced by strict adherence to NRC and OSHA safety standards, practices, and procedures. Appropriate State and local statutes must also be considered when assessing the occupational hazards and health risks for any decommissioning activity. The staff assumes strict adherence to NRC, OSHA, and State safety standards, practices, and procedures during decommissioning.

Previous or anticipated decommissioning activities at the FBR or HTGR have not and are not expected to result in occupational hazard issues that are different from those found at other nuclear reactor facilities.

4.3.10.4 Conclusions

The staff has considered available information, including comments received on the draft of Supplement 1 of NUREG-0586, on the potential impacts of decommissioning activities on occupational issues. This information indicates that the impacts on occupational issues are not detectable or destabilizing. Therefore, the staff makes a generic conclusion that for all plants, the potential impacts on occupational issues are SMALL. The staff has considered mitigation measures and concludes that no additional mitigation measures are likely to be sufficiently beneficial to be warranted.

4.3.11 Cost

A decommissioning cost assessment is not a NEPA requirement. However, an accurate decommissioning cost estimate is necessary for a safe and timely plant decommissioning. Therefore, this Supplement includes a decommissioning cost evaluation, but the cost is not evaluated using the environmental significance levels nor identified as a generic or site-specific issue.

4.3.11.1 Regulations

The regulatory procedure for decommissioning a nuclear power facility is set out principally in NRC regulations in 10 CFR 50.75, 50.82, 51.53, and 51.95. The regulations to ensure the safe and timely decommissioning of nuclear power facilities and the availability of decommissioning funds were originally established by the NRC in 1988. These regulations, principally 10 CFR 50.75, specify the minimum amount of funds that a LWR licensee must have to demonstrate reasonable assurance of sufficient funds for decommissioning. The minimum decommissioning funds required by the NRC reflect only the efforts necessary to achieve termination of the 10 CFR Part 50 license. Costs associated with other activities related to facility deactivation and site closure, including operation of the spent fuel storage pool, construction, operation, and decommissioning of an ISFSI, demolition of uncontaminated or decontaminated structures that meet release criteria, and site restoration activities after sufficient residual radioactivity has been removed to meet NRC license termination requirements are not included in the minimum decommissioning fund requirement.

The regulations in 10 CFR 50.75 also require that licensees submit, at least once every 2 years, a report on the status of its decommissioning fund, including specifying the amount of funds accumulated, and a schedule for accumulating the remainder to be collected. This report is to be submitted annually for plants that are within 5 years of the end of licensed operations. 10 CFR 50.75 (f)(i) also requires that each power reactor licensee shall report the status of its decommissioning trust fund annually if the facility has already closed (before the end of its licensed life).

In addition to the financial assurance requirements for decommissioning in 10 CFR 50.75, other requirements in 10 CFR 50.75 and 50.82 specify requirements for submitting cost estimates for decommissioning to the NRC:

- 10 CFR 50.75(f)(2) requires that a licensee shall, at or about 5 years prior to the projected end of operations, submit a preliminary decommissioning cost estimate.

- 10 CFR 50.82(a)(4)(i) requires a licensee to provide an estimate of expected costs for the activities being proposed in the PSDAR.

- 10 CFR 50 82(a)(8)(iii) requires a licensee to provide a site-specific decommissioning cost estimate within 2 years following permanent cessation of operations.

- 10 CFR 50.82(a)(9)(ii)(F) requires a licensee to provide an updated site-specific estimate of remaining decommissioning costs as part of its LTP.

The regulations in 10 CFR 50.82 also specify the criteria that a licensee must meet before they can withdraw funds from the decommissioning fund for decommissioning activities.

4.3.11.2 Potential Impacts of Decommissioning Activities on Cost

As indicated in Table E-3 in Appendix E, all aspects of decommissioning will have an impact on decommissioning costs. The potential impacts of decommissioning activities on cost vary due to the cost of waste management and disposal of the LLW generated during decommissioning and to the uncertainty associated with regulatory requirements.

The variability in waste management and disposal arises because the Barnwell Low-Level Radioactive Waste Management Disposal Facility, the last remaining facility that is available to dispose of all classifications of LLW generated by all but two nuclear power facilities located throughout the United States, is scheduled to stop accepting waste from all NRC licensees except those located in the Atlantic Compact by 2009 (see NUREG-1307, Rev. 9, *Report on Waste Burial Charges* [NRC 2000]). However, decommissioning of most of the nuclear power facilities in the United States is not expected to occur until sometime after 2009. This cost uncertainty is generally applicable to most of the nuclear power facilities that are currently being decommissioned and those that will be decommissioned in the future. This cost uncertainty, however, is somewhat mitigated by the availability of the Envirocare disposal facility in Utah. Envirocare can accept most Class A LLW for disposal from any generator in the United States. (More than 95 percent of LLW generated during nuclear power facility decommissioning is Class A.) Other LLW storage and disposal sites are also currently being proposed.

The uncertainty associated with regulatory requirements is a reflection of the different requirements and standards for cleanup applied by different States and localities. While NRC cleanup requirements for terminating a license are well defined, these other external requirements may significantly influence the cost of decommissioning. For example, local jurisdictions might impose additional requirements than those imposed by the NRC. The cost of the extra cleanup is not reflected in the decommissioning fund required by the NRC.

4.3.11.3 Evaluation

The estimated cost of decommissioning all of the nuclear power facilities that have been built and operated in the United States is provided in Table 4-3 (in January 2001 dollars). The costs provided in the table are those estimated by the owners of the individual plants and reported to the NRC.

Shown in the table are the actual costs to complete the decommissioning and terminate the 10 CFR Part 50 licenses for each of those facilities that have reached this milestone of their life-cycle. Facility-specific estimates are also provided for each plant that has been permanently shut down and is either actively undergoing decommissioning or is in safe storage awaiting active decontamination and dismantlement. The costs shown are estimates developed by the licensee and reported in their PSDARs, site-specific cost estimate reports, LTPs, etc. These estimates are adjusted to January 2001 dollars.

Table 4-3 provides the range of costs estimated by utilities to decommission all of the nuclear power facilities that are currently operating or have not indicated an intent to permanently shut down. Cost ranges, rather than facility-specific cost estimates, are provided for these plants, reflecting the fact that these estimates are not as well developed as for those plants that have already permanently shut down. These cost ranges were developed from licensee-provided estimates in the March 1999 biennial decommissioning reports adjusted to January 2001 dollars.

Finally, Table 4-3 provides a range of decommissioning cost estimates for the ENTOMB options. These options have not been used or considered by any U.S. nuclear power facility licensee to date. Cost estimation methods for the ENTOMB options are, thus, not as well developed as for the DECON and SAFSTOR methods. The values quoted in the table were developed from an analysis of the two entombment scenarios described in Chapter 3 for a "reference" (i.e., typical) PWR and BWR. The reference PWR was assumed to be the Trojan Plant in Oregon; the reference BWR was assumed to be the Columbia Generating Station in Washington.

The cost of decommissioning results in impacts on the price of electricity paid by ratepayers. These impacts generally occur over the life of the facility as the decommissioning fund is being collected. However, for those nuclear reactor facilities that shut down prematurely (as is the case for the majority of the facilities identified in Table 4-3), the impact may also occur for a number of years after permanent shutdown while the under-collected portion of the fund continues to be collected.

This analysis assesses the impact of cost by evaluating the total cost to decommission a nuclear power facility and terminate its Part 50 license. This impact is summarized in Table 4-4. As can be seen, the cost to decommission a large (>200 MWe) nuclear power facility is estimated to range from $150 million to $700 million and is highly dependent on the factors discussed previously.

4.3.11.4 Conclusions

The staff has reviewed these data, recognizing that an evaluation of decommissioning cost is not a NEPA requirement. This information is presented here as a summary of actual and predicted decommissioning costs based on recently available data.

4.3.12 Socioeconomics

There are two primary pathways through which nuclear power plant activities create socioeconomic impacts on the area surrounding the plant. The first is through expenditures in the local community by the plant work force, and direct purchases of goods and services required for plant activities. The second pathway for socioeconomic impact is through the effects on local government tax revenues and services. When a nuclear power plant is closed and decommissioned, most of the important socioeconomic impacts will be associated with the plant closure rather than with the decommissioning process.

4.3.12.1 Regulations

There are no Federal or State regulations pertaining to any particular level of socioeconomic impacts, as there are for some environmental effects. Socioeconomic impacts are an element of NEPA documentation that must be addressed and mitigated, if warranted.

4.3.12.2 Potential Impacts of Decommissioning Activities on Socioeconomics

As indicated in Table E-3 in Appendix E, all of the socioeconomic impacts of decommissioning are related to organizational or staffing changes. The impacts of decommissioning were assessed recognizing that the potentially large impacts of plant closure may occur simultaneously with those of the actual decommissioning activities. However, as indicated in Section 1.3, impacts related to the decision to permanently cease operations are outside the scope of this Supplement.

Socioeconomic changes related to direct expenditures in the local community are considered not detectable if there is little or no impact on housing values, education and other public services, and local government finances, are not distinguishable from normal background variation due to other causes. Impacts on housing are considered not detectable when no discernable change in housing availability occurs, changes in rental rates and housing values are similar to those occurring statewide, and little or no housing construction or conversion

Table 4-3. Cost Impacts of Decommissioning (in January 2001 Dollars)

Nuclear Plant	Electric Power Generation Rating	Reactor Type	Decommissioning Option	Estimated Decommissioning Cost, $ million
Decommissioning Completed				
Fort St. Vrain	330 MWe	HTGR	DECON	230 (189 [1996])[a]
Pathfinder	59 MWe	BWR	SAFSTOR	20 (13 [1992])[a]
Shoreham	809 MWe	BWR	DECON	258 (182 [1994])[a]
Currently Being Decommissioned				
Big Rock Point	67 MWe	BWR	DECON	364
Dresden, Unit 1	200 MWe	BWR	SAFSTOR	340
Fermi, Unit 1	61MWe	FBR	SAFSTOR	36
GE-VBWR	13 MWe	BWR	SAFSTOR	10
Haddam Neck	619 MWe	PWR	DECON	404
Humboldt Bay, Unit 3	65 MWe	BWR	SAFSTOR	284
Indian Point, Unit 1	257 MWe	PWR	SAFSTOR	259
La Crosse	50 MWe	BWR	SAFSTOR	111
Maine Yankee	860 MWe	PWR	DECON	400
Millstone, Unit 1	660 MWe	BWR	SAFSTOR	563
Peach Bottom, Unit 1	40 MWe	HTGR	SAFSTOR	65
Rancho Seco	913 MWe	PWR	SAFSTOR	394
San Onofre, Unit 1	410 MWe	PWR	SAFSTOR	427
Saxton	NA	PWR	SAFSTOR	44
Three Mile Island, Unit 2	792 MWe	PWR	SAFSTOR	502
Trojan	1130 MWe	PWR	DECON	250
Yankee Rowe	167 MWe	PWR	DECON	244
Zion, Unit 1	1085 MWe	PWR	SAFSTOR	386
Zion, Unit 2	1085 MWe	PWR	SAFSTOR	495
Currently Operating				
69 PWR Reactors	486 - 1270 MWe	PWR	DECON/SAFSTOR	264 - 695
35 BWR Reactors	514 - 1265 MWe	BWR	DECON/SAFSTOR	152 - 663
"Reference PWR"	1130 MWe	PWR	ENTOMB1/ ENTOMB2	290 - 400
"Reference BWR"	1100 MWe	BWR	ENTOMB1/ ENTOMB2	410 - 750

(a) Actual cost to complete the decommissioning and the year the license was terminated.

Table 4-4. Summary of Cost Impacts by Decommissioning Option and Reactor Type and Size (January 2001 Dollars)

	Decommissioning Cost Range, $million					
Decommissioning Option	**PWR < 200 MWe**	**PWR ≥ 200 MWe**	**BWR < 200 MWe**	**BWR ≥ 200 MWe**	**HTGR**	**FBR**
DECON	244	250 - 404	364	>182[(a)]	189	--
SAFSTOR	44	259 - 597	13 - 284	340 - 563	65	36
DECON/SAFSTOR (currently operating reactors)	--	264 - 695	--	152 - 663	--	--
ENTOMB1/ENTOMB2	--	290 - 400	--	410 - 750	--	--

(a) Cost data from the Shoreham plant, which only generated one effective full power day. There was little or no contamination to many plant systems. Not representative of other large BWRs.

occurs. Detectable impacts result when there is a discernable increase or reduction in housing availability, rental rates and housing values exceed the inflation rate elsewhere in the State, or more than minor housing conversions and additions or abandonments occur. Destabilizing impacts occur when project-related demand results in a very large excess of housing or very limited housing availability, where there are considerable increases or decreases in rental rates and housing values, or when substantial conversion or abandonment of housing units occurs.

Socioeconomic changes related to tax revenues and services (education, transportation, public safety, social services, public utilities, and tourism and recreation) are considered not detectable if the existing infrastructure (facilities, programs, and staff) could accommodate changes in demand related to plant closure and decommissioning without a noticeable effect on the level of service. Detectable impacts arise when the changes in demand for service or use of the infrastructure is sizeable and would noticeably decrease the level of service or require additional resources to maintain the level of service. Destabilizing impacts would result when new local government programs, upgraded or new facilities, or substantial numbers of additional staff and unsupportable levels of resources are required because of facility-related demand.

4.3.12.3 Evaluation

The size of the work force varies considerably among operating U.S. nuclear power facilities, with the onsite staff generally consisting of 600 to 800 personnel per reactor unit. The average permanent staff size at a nuclear power facility ranges from 600 to 2400 people, depending on the number of operating reactors at the site. In rural or low-population communities, this number of permanent jobs can provide employment for a substantial portion of the local work force. In addition to the work force needed for normal operations, many temporary personnel are required for various tasks that occur during outages. Between 200 and 900 additional workers may be employed during these outages to perform the normal outage maintenance work. These are work force personnel who may be in the local community only a short time, but during these periods of extensive maintenance activities, the additional personnel could have a substantial effect on the locality. If, as expected, the decommissioning process requires a smaller work force than the onsite operating staff (typically 100 to 200 staff) and if the local economy is stable or declining, the result of the reduction in work force related to plant closure could be economic hardships, including declining property values and business activity, and problems for local government as it adjusts to lower levels of tax revenues. However, even the small decommissioning work force will tend to mitigate temporarily the full adverse socioeconomic effects of terminating operations.

If there is a net reduction in the community work force but the economy is growing, the adverse impacts of this ongoing growth (e.g., housing shortages and school overcrowding) could be reduced.

If the decommissioning work force were substantially larger than the operating work force, the result could be increased demand for housing and public services but also increased tax revenues and higher real estate values. If the economy is characterized by decline, then decommissioning could temporarily reverse the adverse economic effects.

In a stable economy, a net increase in the community work force could lead to some shortages in housing and public services, as well as to the higher tax revenues and real estate values mentioned previously. In a growing economy, decommissioning could act as an exacerbating factor to the ongoing shortages that already might exist.

<u>Changes in work force and population</u>: Changes of over 3 percent to local population in a single year are expected to have detectable effects, while changes of over 5 percent are expected to result in destabilizing impacts. These negative impacts include reduction of school system enrollments, weakened housing markets, and loss of demand for goods and services provided by local businesses. The size of the work force required during decommissioning, relative to that during operations, is an important determinant of population growth or decline.

The impact from facility closure depends on the rate and amount of population change. If decommissioning begins shortly after shutdown with a large work force, then the impact of facility closure is mitigated. Facilities where layoffs are sudden and there is a long delay before active decommissioning begins are more likely to experience negative population-related socioeconomic impacts. Thus, large plants located in rural areas that permanently shut down early and choose the SAFSTOR option are the likeliest to have negative impacts. Considering all variables such as plant size and community size as the same, plants that go into immediate

DECON have less immediate negative impacts; the impacts from the ENTOMB option, assuming those preparations were made immediately after shutdown, would be less significant than those of SAFSTOR.

Data on changes in work force were collected at facilities that are being decommissioned where information on operational and decommissioning work force is available. This information is presented in Appendix J, Table J-1. The table also shows total population in the host county at the time of plant shutdown, to indicate the potential importance of the facility closure.

In order to identify any unusual downward trends in county population around the time of a facility shutdown, data were collected showing the range of percentage changes in population that have occurred at facilities currently being decommissioned. U.S. Census population data for the counties that house the decommissioning facility are used to assess changes in population around the time of shutdown by comparing percentage changes in the county population with State population changes during the same time period. This information is provided in Appendix J, Table J-2.

In only two cases did the corresponding county populations decline around the time of the closure (Indian Point, Unit 1, in Westchester, New York, and Millstone, Unit 1, in New London, Connecticut). However, during the same time period that the host counties experienced population declines, the hosting States also experienced population declines. This suggests that the decline in the county population was part of an overall State population trend. Observing population trends over a decade may not capture small population declines or reductions in the rate of growth from one year to the next; however, longer trends should indicate whether or not the county had any large destablizing population or housing impacts from the facility closure.

In 18 out of the 20 facility case studies where populations grew, the populations of the counties where the facilities are located increased more rapidly or at the same rate as the State population. The two cases where the populations of the counties grew at a slower rate include relatively rural counties in California (Humboldt and Alameda) during time periods when the State of California experienced very high urban population growth. In general, experience of decommissioning facilities to date does not show any impacts from population change, either because the closure-related changes were small relative to the population base or because they were offset by other growth in the area.

<u>Local tax revenues</u>: Changes in tax revenues of less than 10 percent are considered not detectable, i.e., they result in little or no change in local property tax rates and the provision of public services. Losses between 10 percent and 20 percent result in detectable impacts, with increased property tax levies (where State statutes permit) and decreased services by local municipalities. Changes over 20 percent have destabilizing impacts on the governments involved. Tax levies must usually be increased or services cut substantially, and the payment of debt for any substantial infrastructure improvements made in the past becomes problematic.

Borrowing costs for local jurisdictions may also increase because bond rate agencies downgrade their credit rating. However, it is important to remember that these rules of thumb are based on uncompensated changes. For example, if a local taxing jurisdiction lost a nuclear facility that amounted to 35 percent of its tax base, but 30 percentage points of this loss were made up by the opening of a new manufacturing facility, the net impact would be 5 percent or not detectable. Small, rural areas are more likely to be affected than more urban areas having a wider variety of economic opportunities and more sources of tax revenue. Impacts depend on the type of plant, size of plant, and whether or not there are multiple units at a site, all of which help determine the net loss in employment at plant closure as well as the loss of tax base.

More information is available for facilities that have recently closed than for facilities closed more than 10 years ago (see Appendix J, Table J-3). The findings from this body of evidence confirm the findings discussed above. The primary taxing authorities for most of the decommissioning plants are the county and city in which the facility is sited. Tax information is typically provided by local taxing authorities (assessor's office) or from town planners familiar with the tax revenues generated by the facility.

The tax revenue impacts on the local communities of facility closure range from zero impact (tax-exempt plants) to loss of 90 percent of the community tax base. The magnitude of tax-related impacts varies primarily by the size of the taxing jurisdiction and the taxing structure of the State in which the plant is sited, as well as certain plant characteristics. Hence, the smaller the taxing community (less economically diverse), the greater the tax revenue impact when the nuclear facility closes down.

In communities where the revenues from the facility made up over 50 percent of the tax revenue base (with the remaining tax revenues made up primarily of private residential real estate), there were significant increases in the tax rates on the remaining real estate as well as cut-backs in services provided by property-tax revenues. The manner in which a State calculates the value of the plant also affects both the amount and timing of tax losses when a nuclear power facility closes and how much such a closure disrupts the tax revenue stream in a given community:

- At one plant, the assessed value of the plant was calculated as a proportional share of the value of the parent corporation, where the percentage is based on the book value of assets in the State (or sub-State taxing jurisdiction) compared with the book value of the assets of the entire corporation. This approach kept the plant at full assessed value for 7 years after its permanent closure until it was dropped from the books of the parent corporation as an asset. Several other approaches are discussed in Appendix J.

- Tax rules may or may not permit gradual phase-out. In some cases, the taxable asset value of the plants was allowed to phase out over a period of time (3 to 5 years). In other cases, the plants were simply taken off the tax roles in 1 year.

- The State may or may not share the burden with local government. In one State, school districts' lost property-tax collections were offset by equalization methods at the State level, which reduced the impact due to plant closures. In another State, the small neighboring township was the sole recipient of all property-tax revenues generated by the plant. Thus, the community's tax revenues were significantly reduced when the revenue source shut down.

- Utility ratepayers in some jurisdictions are entitled to share in funds recovered from sale of plant components and commodities and unspent decommissioning funds. These are not taxes but are available to general fund revenues.

In addition to characteristics specific to the taxing jurisdiction, the size, age, and ownership of the facilities play a role in how much the facilities affect tax revenues. Generally, the larger the facility (MWt), the larger the tax revenue impact. In addition, aging of the facility depreciates its book value and its assessed value over time. Usually, the falling assessed value of an aging facility will have reduced the tax revenue of the facility before closure, thus lessening the change in tax revenues generated by the facility after closure. A facility that closes suddenly, well before the end of its license expiration, will have a greater impact on the community tax base. Finally, if a facility is owned by a public entity, there is no effect on the tax base from closure because the facility was never taxable.

The choice of the decommissioning option appears to have had no bearing on the loss of tax receipts. The impact has to do with the size and suddenness of the loss of tax revenue (size and age of facility) related to plant closure only. The length of delay between shutdown and decommissioning does not appear to affect the size of the impact on tax revenue losses. No commercial nuclear power reactor has used the ENTOMB options, but there is no reason to expect ENTOMB to have any different impact on tax revenue losses than SAFSTOR or DECON.

Public services: The impacts of decommissioning on public services are generally much smaller than the impacts of plant closure. Impacts of closure are closely related to the tax-related impacts on the community and are affected by the same characteristics of the plant (size and age, tax treatment, and dependence of the local community on plant-related revenues), but not on the choice of decommissioning option or the amount of time between shutdown and active decommissioning. Inquiries were made to local governments in the vicinity of closed plants about public service impacts during and after shutdown and decommissioning. Their assessments are discussed in Appendix J and data are shown in Table J-4. Analysis was also conducted in the course of preparing NUREG-1437 (NRC 1996). Based on that experience, the following generalizations can be made.

Detectable impacts on housing result when there is a discernable increase or reduction in housing availability, when rental rates and housing values exceed the inflation rate elsewhere in the State, or when minor housing conversions and additions or abandonments occur.

Destabilizing impacts occur when project-related demand results in a very large excess of housing or very limited housing availability, where there are considerable increases or decreases in rental rates and housing values, and when there is substantial conversion or abandonment of housing units. The prevailing belief of realtors and planners in communities surrounding the case study facilities is that closing the facilities has had a range of effects on the marketability or value of homes in the vicinity. Housing choices of local residents are rarely affected by the presence of the facility, but people may move into the area in response to (temporarily) softer housing prices and commute to a nearby urban area. However, the decommissioning process itself does not appear to have produced any detectable impacts on housing.

The impacts to the following public services may occur as a result of plant closure: education, transportation, public safety, social services, public utilities, and tourism and recreation.

In general, detectable impacts arise when the demand for service or use of the infrastructure is sizeable. Impacts would noticeably decrease the level of service or require additional resources to maintain the level of service. Destabilizing impacts would result when new programs, upgraded or new facilities, or substantial additional resources and staff are required because of facility-related demand. Specific information for each of the areas of public service for closed plants is provided in Appendix J.

In general, the communities that suffered the most from the tax-related impacts of plant closure also experienced the greatest impacts on public services. To some extent, the communities themselves control the amount of impact by how they allocate property taxes to local budgets before shutdown, and how they prioritize these services post-shutdown. For example, one community channeled a great deal of the surplus revenues into building extensive social services for the elderly and for local youth in its community. After the plant ceased operations, the tax revenues decreased, all of the social services were downsized, and many will have to be eliminated because they are not considered priority programs (relative to public safety and education). In a second case, the county provided relatively few social services. Thus, the impact on social services after the shutdown was minor, although several other categories of public service experienced larger impacts. For example, education was largely funded by plant tax revenues and the responsible school district has recently indicated that it may have to file for bankruptcy, so the impact there was substantial[a]. However, all of these impacts were related to plant closure; in no case did the decommissioning process itself result in detectable impacts on public services.

(a) The size of impact can be significantly influenced by the mechanism that the State uses for funding, e.g., if the State makes up the difference between what the local school districts can fund from the local property tax and what the State has decided is the appropriate level of per-student expenditures.

Previous or anticipated decommissioning activities at the FBR or HTGR have not and are not expected to result in impacts on socioeconomics that are different from those found at other nuclear facilities.

Summary: The impacts of plant closure are those that are observed by the community, rather than the impacts from decommissioning activities because they occur at about the same time. The impacts occur either through changing employment levels and local demands for housing and infrastructure, or through decline of the local tax base and the ability of local government entities to provide public services. The effects of employment changes on population growth are expected to be not detectable if population changes (reductions or increases) are less than 3 percent per year, detectable but not destabilizing if the population change is between 3 percent and 5 percent, and destabilizing if the population change is greater than 5 percent per year. Experience so far has shown that in most cases, reductions in employment related to plant closure even at fairly large sites do not generally produce local population changes greater than 3 percent, regardless of the type of plant and decommissioning option selected. The impacts of the decommissioning work force are even smaller.

The effect on the local tax base and public services related to closure depends on the size of the plant-related tax base relative to the overall tax base of local government, as well as on the rate at which the tax base is lost. Changes in annual tax revenues less than about 10 percent are considered nondetectable, i.e., they result in little or no change in local property tax rates and the provision of public services. Losses between 10 percent and 20 percent result in detectable but not destabilizing impacts, with increased property tax levies (where State statutes permit) and decreased services by local municipalities. Changes over 20 percent have destabilizing impacts on the governments involved. Experience has shown that publicly owned tax-exempt plants will not have an impact through this mechanism. In addition, fully depreciated plants, or a plant that is located in an urban or urbanizing area with a large or rapidly growing tax base will also not be impacted by this mechanism. A large, newer, relatively undepreciated plant, located in a small, isolated community, is much more likely to exceed the 20-percent criterion. If the plant tax base is phased out slowly after closure in these circumstances, the impact is more likely to be mitigated. Neither the type of reactor nor the method chosen for decommissioning matters.

Decommissioning itself has no impact on the tax base and no detectable impact on the demand for public services.

4.3.12.4 Conclusions

The staff has considered available information, including comments received on the draft of Supplement 1 of NUREG-0586, on the potential impacts of decommissioning on socioeconomics. This information indicates that the impacts of decommissioning on socioeconomics are neither detectable nor destabilizing. Therefore, the staff makes the generic conclusion that the impacts on socioeconomics are SMALL. The staff has considered mitigation and concludes that no additional measures are likely to be sufficiently beneficial to be warranted.

4.3.13 Environmental Justice

An evaluation of environmental justice is performed to determine if minority and/or low-income groups bear a disproportionate share of negative environmental consequences. Executive Order 12898, dated February 16, 1994 (59 FR 7629), directs Federal executive agencies to consider environmental justice under NEPA. The Executive Order does not create whole new categories of impacts that need to be considered; nor does it create any right, benefit, or trust responsibility, substantive or procedural, that can be enforced by law or equity. It is designed to improve internal management of agencies to ensure that low-income and minority populations do not experience disproportionately high and adverse human health or environmental effects because of Federal actions.

Environmental justice has not been evaluated previously for decommissioning activities at reactor facilities.

4.3.13.1 Regulations

The CEQ has provided *Environmental Justice: Guidance Under the National Environmental Policy Act* (CEQ 1997). Although NRC is an independent agency, the Commission has committed to undertake environmental justice reviews, and has provided specific information in Office Instruction LIC-203, Nuclear Reactor Regulation (NRR), *Procedural Guidance for Preparing Environmental Assessments and Considering Environmental Issues* (NRC 2001a). The CEQ guidance and NRR instructions provide several key definitions and the framework for analysis.

Low-income population: Low-income populations in an environmental impact area should be identified where census block groups within the environmental impact area have (1) more than 50 percent low-income persons or (2) the percentage of persons in households below the poverty level is significantly greater (typically, at least 20 percentage points) than in the geographical area chosen for comparative analysis. In identifying low-income populations, agencies may consider as a community either a group of individuals living in geographic proximity to one another or a set of individuals (e.g., migrant workers or American Indians[(a)]), where either type of group experiences common conditions of environmental exposure or effect.

Minority: Individuals who are members of the following population groups: American Indian and Alaska Native; Asian; Native Hawaiian and other Pacific Islander; Black or African

(a) For consistency, the term "American Indian" is used throughout this document to conform to the definition of "minority population."

American, not of Hispanic or Latino origin; or some other race and Hispanic or Latino (of any race).[(a)]

Minority population: According to the CEQ, minority populations should be identified where either (a) the minority population of the affected area exceeds 50 percent or (b) the minority population percentage of the affected area is meaningfully greater than the minority population percentage in the general population or other appropriate unit of geographic analysis. In identifying minority communities, agencies may consider as a community either a group of individuals living in geographic proximity to one another or a geographically dispersed/transient set of individuals (e.g., migrant workers or American Indians), where either type of group experiences common conditions of environmental exposure or effect. The selection of the appropriate unit of geographic analysis may be a governing body's jurisdiction, a neighborhood, census tract, or other similar unit that is to be chosen so as not to artificially dilute or inflate the affected minority population. A minority population also exists if there is more than one minority group present and the minority percentage, as calculated by aggregating all minority persons, meets one of the above-stated thresholds. NRR adopted a standard of 20 percentage points as "meaningfully greater."

Disproportionately high and adverse human health effects: When determining whether human health effects are disproportionately high and adverse, agencies are to consider the following three factors to the extent practicable: (a) whether the health effects, which may be measured in risks and rates, are significant (as used by NEPA), or above generally accepted norms (adverse health effects may include bodily impairment, infirmity, illness, or death); (b) whether the risk or rate of hazard exposure by a minority or low-income population, to an environmental hazard is significant (as used by NEPA) and appreciably exceeds or is likely to appreciably exceed the risk or rate to the general population or other appropriate comparison group; and (c) whether health effects occur in a minority or low-income population, affected by cumulative or multiple adverse exposures from environmental hazards.

Disproportionately high and adverse environmental effects: When determining whether environmental effects are disproportionately high and adverse, agencies are to consider the following three factors to the extent practicable: (a) whether there is or will be an impact on the natural or physical environment that significantly (as used by NEPA) and adversely affects a minority or low-income population (such effects may include ecological, cultural, human health, economic, or social impacts on minority communities, low-income communities, or American Indian tribes when those impacts are interrelated to impacts on the natural or physical environment); (b) whether environmental effects are significant (as used by NEPA) and are or may be having an adverse impact on minority populations, low-income populations, or

(a) "Other" may be considered a separate minority category. In addition, the 2000 Census included multi-racial data. Multi-racial individuals should be considered in a separate minority, in addition to the aggregate minority category.

American Indian tribes that appreciably exceeds or is likely to appreciably exceed those on the general population or other appropriate comparison group; and (c) whether the environmental effects occur or would occur in a minority or low-income population, affected by cumulative or multiple adverse exposures from environmental hazards.

4.3.13.2 Potential Impacts of Decommissioning Activities on Environmental Justice

As indicated in Table E-3 in Appendix E, decommissioning activities that may affect environmental justice are related to organizational or staffing changes and offsite transportation issues. However, the assessment of environmental justice is related to most of the other specific issues discussed throughout this Supplement. Any decommissioning activity that results in a disproportionate share of negative environmental consequences to minority or low-income groups has the potential to be an adverse environmental justice impact.

Detectability and destabilization, as they relate to environmental justice, must be defined in proportion to the minority and low-income populations that reside in the area of the power plant. Proportionment must be determined at each site at the time of decommissioning.

4.3.13.3 Evaluation

Most of the environmental justice impacts relate to land use, environmental and human health, and socioeconomics. Impacts due to onsite land disturbance are likely to be not detectable because the amounts of land disturbance are generally very small and usually occur in areas of the site previously disturbed by construction or operation of the facility. Impacts from disturbances to offsite land will generally not occur because offsite land generally is not disturbed as a result of decommissioning. If offsite land disturbance is required (e.g., if a new offsite road or rail spur is needed to transport large components or waste from decommissioning), the impact on environmental justice is site-specific because it will depend on the location of the new route relative to low-income populations or other affected resources on which they may depend. Some minority and low-income populations normally live along rail lines and truck routes. Previous transportation analyses have found that the impacts would be small from normal operations or from accidents. Thus, no disproportionately high and adverse effects are expected for any particular segment of the population, including minority and low-income populations, that may live along proposed rail and truck routes. Siting and construction of these offsite transportation upgrades would include an evaluation of cultural and other resources in the disturbed areas. Usually, offsite physical environmental impacts of decommissioning will be not be detectable because offsite environmental impacts from decommissioning are generally not detectable.

Socioeconomic impacts on minority and low-income populations due to plant closure could range from nondetectable to destabilizing, depending on the distribution of job impacts within the community and the effects of plant closure on local tax revenues and public services; however, the impact of decommissioning would generally not be detectable. More generic information on overall socioeconomic impacts can be obtained by observing demographic statistics. In the 21 decommissioning case studies observed, it was concluded that facility closure would not have a detectable socioeconomic impact on low-income and minority populations. In other words, there appears to be no indication that minority or low-income populations would suffer disproportionately high and adverse impacts from the closure of the facilities. Because decommissioning has even smaller effects, its impact also would have been not detectable. The environmental justice conclusions are based on demographic information, i.e., the overall impact of the facility on the community. Discussions were also held with community members at some sites.

In addition, information provided by local government and social service providers helps determine the socioeconomic impacts on low-income and minority populations. In many of these case studies, the nuclear facilities are located in primarily white communities and tend to be located near bodies of water where upper-income real estate is built. Those that are employed by the facility tend to fall into the upper-income bracket within the communities where the facilities are located. Selected socioeconomic indicators are found in Appendix J, Table J-5, for the closed nuclear power plants studied.

The determination of whether the minority or low-income populations are disproportionately highly and adversely impacted by facility decommissioning activities needs to be made on a site-by-site basis because their presence and their socioeconomic circumstances will be site-specific. Data indicate there is no reason to expect adverse socioeconomic impacts to be correlated with type of plant (see Table J-5). However, adverse socioeconomic impacts are correlated with large facility size, early shutdown, and small, isolated host communities. If minority and low-income populations are present, adverse impacts from facility closure would be somewhat more likely in small, isolated communities than in larger urban areas. It is not clear whether these effects would be disproportionately high and adverse.

Previous or anticipated decommissioning activities at the FBR or HTGR have not and are not expected to result in environmental justice considerations that are different from those found at other nuclear facilities.

4.3.13.4 Conclusions

The staff has considered available information on the potential impacts of decommissioning on environmental justice, including comments received on the draft of Supplement 1 of NUREG-0586. Based on this information, the staff has concluded that the adverse impacts and associated significance of the impacts must be determined on a site-specific basis. Executive Order 12898 (59 FR 7629), dated February 16, 1994, directs Federal executive agencies to consider environmental justice under the National Environmental Policy Act 1969 (NEPA). Although the NRC is an independent agency, the Commission has committed to undertake environmental justice reviews. Subsequent to the submittal of the PSDAR, the NRC staff will consider the impacts related to environmental justice from decommissioning activities.

4.3.14 Cultural, Historic, and Archeological Resources

Cultural resources include any prehistoric or historic archeological site or historic property, site, or district listed in or eligible for inclusion in the National Register of Historic Places or otherwise having significant local importance. The Federal agency (in this case the NRC) is responsible for the evaluations through consultations with the State Historic Preservation Officer (SHPO), or if appropriate, the Tribal Historic Preservation Officer (THPO), that is responsible for determining which sites or properties are of significant historic or archeological importance. The NRC is also responsible for including other interested parties and affected American Indian tribes. Disagreements between the parties are resolved by the Advisory Council on Historic Preservation.

Evaluation of the potential presence of cultural resources should not rely solely on a query of the SHPO database, but should be based on field surveys and evaluations of the site. Although these evaluations may have been performed as part of the initial environmental evaluation for the sites or as part of another licensing action (e.g., license renewal), the coverage and adequacy of earlier survey efforts needs to be re-evaluated in cases where an impact may occur. Earlier field surveys and methods may not conform to current standards.

4.3.14.1 Regulations

The Federal statute that is most directly applicable to cultural resource issues during the decommissioning process is the National Historic Preservation Act (NHPA) of 1966 as amended (16 USC 470 et seq.). This Act created the National Register of Historic Places (National Register) and requires the heads of all Federal agencies to consider the impacts of the undertakings on any cultural properties that are listed on the National Register or that are eligible for listing. Section 106 of the NHPA requires each Federal agency to identify, evaluate, and determine the effects of an undertaking on any cultural resource site that may be within the area impacted by that undertaking. This section also requires consultation to resolve adverse effects of an undertaking and establishes mechanisms to obtain and incorporate comments from consulting parties. Federal agencies are directed by 36 CFR Part 800 to comply with the stipulations of NHPA as well as pertinent cultural, historical, and archeological protection provisions of NEPA, the Historic Sites Act of 1935, and the Antiquities Act of 1906 and their implementing regulations. The Historic Sites Act of 1935 (16 USC 461-467) declared a national policy of preserving for the public historic sites, buildings, and objects of national significance. It also led to the establishment of the Historic Sites Survey, the Historic American Buildings Survey, and the Historic American Engineering Record within the National Park Service.

Most other cultural, historical, and archeological protection regulations are primarily directed at resource protection on Federal lands, but in some cases these statutes may be applicable to the decommissioning of commercial power reactors. Several commercial nuclear power reactors are located on Federal lands. The Antiquities Act of 1906 (16 USC 431-433) prohibits destruction of vertebrate fossils and archeological sites on Federal lands and regulates their removal under a permitting procedure. These regulations were further strengthened by the Archeological Resources Protection Act of 1979 (16 USC 470aa-47011), which prohibits the willful or knowing destruction and unauthorized collection of archeological sites and objects located on Federal lands. It also establishes a permitting system for archeological investigations and requires consultation with concerned tribes prior to permit issue. The Native American Graves Protection and Repatriation Act of 1990 (25 USC 3001 et seq.) protects graves on Federal lands and establishes tribal ownership of human remains and/or associated funerary objects taken from Federal lands and requires the inventory and repatriation to the tribes of any remains or funerary objects held by Federal agencies. Certain more recent Executive Orders regarding consultation with American Indian tribes and protection of religious sites and values could also be relevant.

Many of the States also have statutes that protect cultural, historical, and archeological resources on State lands. Some States also have burial and cemetery statutes that apply to private land as well. These State-level statutes are usually administered through the appropriate SHPO.

4.3.14.2 Potential Impacts of Decommissioning Activities on Cultural, Historic, and Archeological Resources

As indicated in Table E-3 in Appendix E, decommissioning activities that have a potential to adversely impact cultural resources include stabilization, decontamination and dismantlement, and large component removal. These activities adversely impact cultural resources primarily via land disturbance, which could damage or destroy the resource, or alter the contextual setting of the resource. In addition to the direct effects of land clearing, indirect effects such as erosion and siltation may adversely affect some cultural resources. Decommissioning activities also may alter the site access and administrative protection of the resources.

In a few situations, the nuclear facility itself could be potentially eligible for inclusion in the National Register of Historic Places, especially if it is older than 50 years and represents a significant historic or engineering achievement. In this case, appropriate mitigation would be developed in consultation with the SHPO. Even for buildings that are less than 50 years old, the processes and engineering that were employed may be of interest and may be eligible for the Historic American Engineering Record.

Impacts to cultural, historical, or archeological resources are considered detectable if the activity has a potential to have a discernable adverse affect on the resources. The impacts are destabilizing if the activity would degrade the resource to the point that it would be of significantly reduced value to the future generations, such as physically damaging structures or artifacts or destroying the physical context of the resource in its environment.

4.3.14.3 Evaluation

In most cases, the amount of land required to support the decommissioning process is relatively small and is a small portion of the overall plant site. Usually, the areas disturbed or utilized to support decommissioning are within the operational areas of the site and typically are within the protected area. Usually, there is sufficient room within the operational areas to function as temporary storage, laydown, and staging sites. In most cases, management, engineering, and administrative staff would be assigned space in existing support or administration buildings. In some cases, the licensees have installed trailers or temporary buildings to house engineering and administrative staff or to otherwise support decommissioning. In most cases examined, the licensees expect to restrict decommissioning activities to highly disturbed operational areas but a few do expect to use lands beyond the operational areas. The licensees typically anticipate utilizing an area of between 0.4 ha (1 ac) to approximately 10.5 ha (26 ac) to support the decommissioning process. One facility (Big Rock Point) required a new transmission line right of way (ROW) to provide electrical power to the plant site during decommissioning (this line will also provide power to the onsite independent spent fuel storage installation [ISFSI] after decommissioning is completed). However, construction of a new transmission line ROW is considered an unusual situation. It is expected that some sites will require the reconstruction or installation of new transportation links, such as railroad spurs, road upgrades, or barge slips. Activities conducted within the operational areas are not expected to have a detectable effect on important cultural resources because these areas have normally been highly degraded during facility construction and operation. Activities conducted outside of the operational areas may have detectable impacts, depending on the size and type of impact, and the cultural resources potentially affected.

The potential for adverse impacts is probably not affected by the type of facility (BWR, PWR, HGTR, or FBR) or the decommissioning option selected. However, the different decommissioning options are likely to alter the timing of the impact to cultural resources more than the magnitude of the impacts. DECON may require slightly more land area to support a larger number of activities occurring at the same time. ENTOMB2 would probably have the least likelihood of adverse impacts because some large components may be left in place, reducing the land requirements needed for large construction equipment, as well as waste storage and barge or rail loading areas. The potential impacts of SAFSTOR may be smaller than DECON or ENTOMB1, depending on the time period over which activities are performed. If dismantling and decontamination occur slowly over many years (incremental decontamination and dismantlement), the same storage and staging areas can be reused for sequential activities; however, if many activities are performed over a short time period at the end of the SAFSTOR period, the impacts may be as large as DECON.

4.3.14.4 Conclusions

The staff has considered available information on the potential impacts of decommissioning on cultural, historic, and archeological resources, including comments received on the draft of

Supplement 1 of NUREG-0586. For plants where the disturbance of lands beyond the operational areas is not anticipated, the impacts on cultural, historic, and archeological resources are not considered to be detectable or destabilizing. Therefore, the staff makes a generic conclusion that for such plants, the potential impacts to cultural, historic, and archeological resources are SMALL. The staff has considered mitigation measures and concludes that no additional mitigation measures are likely to be sufficiently beneficial to be warranted.

If disturbance beyond the operational areas is anticipated, the impacts may or may not be detectable or destabilizing, depending on site-specific conditions, and cannot be predicted generically. Therefore, the staff concludes that if disturbance beyond the operation areas is anticipated, the potential impacts may be SMALL, MODERATE, or LARGE and must be determined through site-specific analysis. Before the licensee conducts any decommissioning activity that might result in the disturbance of historic properties or archeological resources outside the site operational area, the NRC will, in accordance with the National Historic Preservation Act of 1966 as amended (16 USC 470 et seq.), consult with the appropriate SHPO or THPO to evaluate potential impacts.

4.3.15 Aesthetic Issues

Aesthetics is the study or theory of beauty and the psychological responses to it. Aesthetic resources include natural and man-made landscapes and the way the two are integrated. In this evaluation, aesthetic resources are considered to be primarily visual and relate the structures and the visual attributes of the decommissioning site.

4.3.15.1 Regulations

There are no regulations that relate specifically to the degree to which aesthetics may be impacted by a Federal project. The Bureau of Land Management (BLM), however, has developed a Visual Resource Management (VRM) system,[a] which involves cataloging scenic values, establishing management objectives for those values through the resource-management planning process, and evaluating proposed activities to determine whether they conform with the management objectives. This system provides tools for identifying the visual resources of an area and assigning them to inventory classes. It also provides tools for determining whether the potential visual impacts from proposed activities or developments meet the management objectives established for an area or whether design adjustments will be required. This tool was designed to meet the BLM's responsibilities for maintaining scenic values of public lands. However, it does not directly apply to a decommissioning facility, where the landscape has already been altered by the facility's structure.

(a) VRM System (http://www.blm.gov/nstc/VRM/vrmsys.html), accessed July 7, 2001.

4.3.15.2 Potential Impacts of Decommissioning Activities on Aesthetics

Table E-3 in Appendix E indicates that structure dismantlement and entombment are activities that may have aesthetic impacts. Nuclear power facilities generally contain four main buildings or structures, as described in Chapter 3: the containment or reactor building, the turbine building, auxiliary building, and cooling towers (if any). Cooling towers and stacks may be clearly visible from a distance. Sites also contain a number of storage tanks, a large switchyard, and various administrative and security buildings. Decommissioning may include demolition or dismantlement of any of these structures. The switchyard may be left in place after the termination of the license because it is an integral part of the power distribution grid.

Levels of impacts for aesthetic resources are defined largely by the impact of the proposed changes as perceived by the public, not merely the magnitude of the changes themselves. The potential for significance arises with the introduction (or continued presence) of an intrusion into an environmental context, resulting in measurable changes to the community (e.g., population declines, property value losses, increased political activism, tourism losses).

Decommissioning activities and the changes that they bring are considered to have a nondetectable impact on the host communities' aesthetic resources if there are (1) no complaints from the affected public about a changed sense of place or a diminution in the enjoyment of the physical environment and (2) no measurable impact on socioeconomic institutions and processes. They are considered to have detectable but not destablizing impacts on the host communities' aesthetic resources if there are (1) some complaints from the affected public about a changed sense of place or a diminution in the enjoyment of the physical environment and (2) measurable impacts that do not alter the continued functioning of socioeconomic institutions and processes. The activities are considered to have detectable and destabilizing impacts on the host community's aesthetic resources if there are (1) continuing and widely shared opposition to the activities or the changes the activities bring based solely on a perceived degradation of the area's sense of place or a diminution in the enjoyment of the physical environment and (2) measurable social impacts that perturb the continued functioning of community institutions and processes.

4.3.15.3 Evaluation

The aesthetic impacts of decommissioning fall into two sets: (a) impacts, such as noise, associated with decommissioning activities that are temporary and cease when decommissioning is complete and (b) the changed appearance of the site when decommissioning is complete.

Typically, nuclear power facilities are located in flat-to-rolling countryside in wooded or agricultural areas. In some cases, the facility structures are visible for many miles. In other cases, there are only a few views of the facility from the land, although it is more obvious from the water (lake, ocean, or bay).

Aesthetic issues related to construction and operation of facility structures were addressed in many (but not all) of the Final EISs prepared in response to applications for construction permits and operating licenses. In most cases, the visual impacts of the plant were said to have been mitigated to some extent by the surrounding topography or vegetation. In other cases, visible structures (such as cooling towers) were said to be "highly visible" but "the staff does not consider such an impact to be unacceptable." For decommissioning, the issue related to aesthetics is not one of placing another facility or building on a site, but one of removing buildings or structures.

The issues evaluated in this section concern the impacts of decommissioning activities on aesthetic resources at and around all types of nuclear power facilities (PWRs, BWRs, HTGR, or FBR). During the decommissioning period, the appearance of the facility will be slowly altered if the buildings are dismantled.

During decommissioning, the impact of activities on aesthetic resources would be temporary. The impacts would be limited both in terms of land disturbance and the duration of activity and would have characteristics similar to those encountered during industrial construction: dust and mud around the construction site, traffic and noise of trucks, and construction disarray on the site itself. In most cases, these impacts would not easily be visible offsite. Aesthetic impacts could improve fairly rapidly in the case of an immediate DECON if the licensee chooses to dismantle the facility, remove the structures, and regrade and revegetate the site before license termination. Impacts could also remain the same or similar in the case where the licensee maintains the structures throughout the decommissioning period and leaves them standing even after license termination (either after decontamination of the structures or possibly along with entombment of the reactor building) or throughout a long SAFSTOR period or ENTOMB. In these latter cases, the aesthetic impacts of the plant would be similar to those that occurred during the operational period.

The removal of structures is generally considered beneficial to the aesthetic impacts of the site. In a few cases, where facilities have been located on the Great Lakes or ocean coast, the facility may have been used by boaters as a landmark. However, it is highly unlikely that this would become an issue that would preclude dismantlement of the facility structures.

The retention of the structures during a SAFSTOR period or the retention of structures onsite at the time the license is terminated is likewise not an increased visual impact, but instead a continuation of the visual impact analyzed in the facility construction or operations FES. The staff has not identified any mechanism that would result in a greater negative aesthetic impact than had previously been considered during the development of the construction FES.

Decommissioning activities will be conducted onsite, both inside and outside existing buildings (in the case of dismantlement or shipping activities). Any visual intrusion (such as the dismantlement of buildings or structures) would be temporary and would serve to reduce the aesthetic impact of the site. At a minimum, the aesthetic impact of the site would not be improved but would remain that of an industrial site as evaluated in the facility's original FES.

Licensees are expected to use best-management practices (BMPs) to control many of the potentially adverse impacts of decommissioning activities on aesthetics (e.g., dust and noise), as discussed in other sections.

4.3.15.4 Conclusions

The staff has considered available information, including comments received on the draft of Supplement 1 of NUREG-0586, on the potential impacts of decommissioning activities and the changes in plant appearance on aesthetics. This information indicates that the impacts on aesthetics are not detectable or destabilizing. Therefore, the staff makes a generic conclusion that for all plants, the potential impacts on aesthetics are SMALL. The staff has considered mitigation measures and concludes that no additional mitigation measures are likely to be sufficiently beneficial to be warranted.

4.3.16 Noise

Noise is a "direct effect," as defined by Section 1508 of the CEQ Regulations for Implementing NEPA, i.e., effects caused by an action that occur at the same time and place as that action. For NRC licensees, the implementing regulations for NEPA are given in 10 CFR Part 51.

Noise is usually defined as sound that is undesirable because it interferes with speech, communication, or hearing; is intense enough to damage hearing, or is otherwise annoying. Noise levels often change with time. To compare levels over different time periods, several descriptors were developed that take into account this time-varying nature. These descriptors are used to assess and correlate the various effects of noise, including land-use compatibility, sleep and speech interference, annoyance, hearing loss, and startle effects:

- A-weighted sound levels (dBA) - typically used to account for the response of the human ear
- C-weighted scale (dBC) - generally used to measure impulsive noise such as air blasts from explosions, sonic booms, and gunfire
- day-night average sound level (DNL) - used to evaluate the total community noise environment. The DNL is the average A-weighted sound level during a 24-hour period with 10 dB added to nighttime levels (between 10 p.m. and 7 a.m) to account for the increased human sensitivity to night-time noise events.

The discussions in this section relate to noise and related impacts that may be heard offsite. The impacts from noise to workers is addressed in Section 4.3.10.

4.3.16.1 Regulations

The EPA was given the jurisdiction in the Noise Control Act of 1972 (42 USC 4901 et seq.) to promulgate and enforce the regulations that were issued under the Act. Funding for EPA to perform this function was eliminated in early 1981. However, Congress did not repeal the Noise Control Act. The DNL was endorsed by the EPA and is mandated by the U.S. Department of Housing and Urban Development (HUD), the Federal Aviation Administration (FAA), and the Department of Defense (DoD) for land-use assessments. The EPA has determined that no significant effects on public health and welfare occur for the most sensitive portion of the population (within an adequate margin of safety) if the prevailing DNL is less than 55 dB (NAS 1977). The FAA bases its noise guidelines on land use. For residential uses, sound levels up to 65 dB are acceptable. Certain residential areas with sound-blocking features can handle up to 75 dB. For livestock farming and breeding, compatibility is considered to exist up to 75 dBA. These guidelines are advisory in nature and are not mandatory (14 CFR Part 150).

The Federal Housing Administration (FHA), under HUD, established noise assessment guidelines under 24 CFR 51B (1979; amended April 25, 1996). The FHA/HUD site acceptability levels are summarized as follows:

- Acceptable (DNL is 65 dBA or less) - Typical building materials and construction will make any impacts to indoor noise minimal. Outdoor recreation and activities would not be impacted. No approval requirements or abatement measures are needed under this condition.

- Normally unacceptable (DNL is 65 to 75 dBA) - Noise exposure will impact outdoor use of the area and indoor use may be affected. Walls or other barriers may be needed to reduce outdoor noise levels. Indoor noise levels may need to be reduced using special construction methods.

- Unacceptable (DNL above 75 dBA) - The noise conditions in this situation are unacceptable and activities need to be approved on a case-by-case basis.

Local and State regulations may also exist regarding noise restrictions and abatement decisions. Many States prohibit only nuisance noise and have not established specific numerical environmental noise standards, while others have very specific requirements. For example, the State of Maine has sound-level limitations for construction that are a function of time of day, area characteristics, and duration of the noise.

4.3.16.2 Potential Impacts from Noise of Decommissioning Activities

Table E-3 in Appendix E indicates that structure dismantlement is an activity that may have noise impacts. During the decommissioning process, the sounds that might be heard at offsite locations include noise from construction, vehicles, grinders, saws, pneumatic drills, compressors, and loudspeakers. Noise levels from these sources have to be compared to current noise levels of the operating facility and background noise present at the site to determine potential impacts. Table 4-5 lists predicted noise ranges for significant sources of noise during decommissioning.

Noise level increases larger than 10 dBA to the DNL at the site boundary during the day might be expected to lead to interference with outdoor speech communication, particularly in rural areas or low-population areas where the day-night background noise level is in the range of 45 to 55 dBA.

The noise impacts of decommissioning activities are considered detectable if sound levels are sufficiently high to disrupt normal human activities on a regular basis. The noise impacts of decommissioning activities are considered destabilizing if sound levels are sufficiently high that the affected area is essentially unsuitable for normal human activities, or if the behavior or breeding of a threatened or endangered species is affected.

Table 4-5. Predicted Noise Ranges from Significant Decontamination and Dismantlement Sources (INEEL 1999)

Source	Source Strength dBA	Reference Distance, m	Predicted Noise Level Ranges (dBA) at Various Distances from the Reference Distance			
			150 m (500 ft)	300 m (1000 ft)	0.8 km (0.5 mi)	1.6 km (1 mi)
Construction Equipment	85-90	15[a]	65-75	59-69	51-61	45-55
Truck	85-90	15	65-75	59-69	51-61	45-55
Rail Engine	86-96	30[b]	76-86	71-81	64-74	58-68
Rail Car, 64 km/h (40 mph)	80-86	30	68-74	62-68	53-59	48-54

(a) 15 m ≈ 50 ft.
(b) 30 m ≈ 100 ft.

4.3.16.3 Evaluation

When noise levels are below those that result in hearing loss, impacts are judged primarily in terms of adverse public reactions to the noise. Generally, surveys around major sources of noise such as large highways and airports find that, when the DNL increases above 60 to 65 dBA, noise complaints increase significantly (FICN 1992). FHA/HUD uses a DNL of 65 dBA as the primary criterion for impact on residential properties and nearby populations. The staff believes that noise levels below 60 to 65 dBA are considered to be insignificant. Business and institutional properties may be less sensitive to changes in noise levels, but all populations of concern should be considered when estimating the noise impact of decommissioning activities.

Typically, operating reactor facilities do not result in offsite sound levels greater than 10 dBA above background. However, at some sites, sound levels at and above this level have been calculated at critical receptor locations. The principal sources of noise from facility operations are natural-draft and mechanical-draft cooling towers, transformers, and loudspeakers. Other occasional noise sources may include auxiliary equipment, such as pumps to supply cooling water from a remote reservoir. Generally, noise from these sources is not heard by a large number of people offsite. Of these sources, only loudspeakers would be anticipated to continue during the decommissioning period. The staff assumes that decommissioning activities will be scheduled to minimize high noise levels during the night and during critical periods for important animal species.

In most cases, during decommissioning the sources of noise would be sufficiently distant from critical receptors outside the plant boundaries that the noise would be attenuated to nearly ambient levels and would be scarcely noticeable, as in the case for operating plants. However, in some cases, such as the use of equipment to demolish concrete, the noise levels offsite could be sufficiently loud (60 to 65 dBA at the nearest receptor site) that activities may need to be curtailed during early morning and evening hours. It is highly unlikely, based on past decommissioning experience, that the offsite noise level from a plant during decommissioning would be sufficient to cause hearing loss. However, in one case, noises at a facility being decommissioned have been reported at levels of up to 107 dB (dropping to 50 dB less than 1.6 km [1 mi] away) as a result of the spent fuel pool cooling system. Nearby residents complained to the plant staff about these noise levels; engineering changes were made in the fans that were causing the noise and the issue was resolved.

The timing of the noise impacts and the duration or intensity will vary depending on the decommissioning option and the procedures that are used. More noise will occur during active dismantlement than during the storage period of SAFSTOR. Some demolition activities could increase noise levels temporarily. In addition to mitigation of noise levels based on engineering design, noise abatement procedures can be considered in decommissioning plans to reduce noise, particularly at night.

No differences are expected between the noise levels of future decommissioning activities at operating plants and the noise levels observed at facilities undergoing decommissioning. It is anticipated that most decommissioning activities will not represent an audible intrusion on the community for any type of nuclear power facility (BWR, PWR, HGTR, or FBR).

4.3.16.4 Conclusions

The staff has considered available information, including comments received on the draft of Supplement 1 of NUREG-0586, on the potential noise impacts of decommissioning activities. This information indicates that the noise impacts are not detectable or destabilizing. Therefore, the staff makes a generic conclusion that for all facilities, the potential noise impacts are SMALL. The staff has considered mitigation measures and concludes that no additional mitigation measures are likely to be sufficiently beneficial to be warranted.

4.3.17 Transportation

In considering activities for decommissioning, transportation can be considered both an activity and an issue. Transportation of equipment, material, and waste is an activity that is performed throughout the entire decommissioning process. However, it is treated as an issue in this Supplement and is given its own section.

This section addresses impacts related to transporting equipment and materials (radiological and nonradiological) offsite. Materials transported to offsite disposal facilities include nonhazardous waste, LLW, hazardous waste, and mixed waste. As discussed in Chapter 1, the shipment of spent nuclear fuel is not within the scope of this Supplement. Radiological impacts include exposure of transport workers and the general public along transportation routes. Nonradiological impacts include additional traffic volume, additional wear and tear on roadways, and potential traffic accidents.

4.3.17.1 Regulations

Regulations that apply to the transportation of hazardous, mixed waste, and radioactive material promulgated by the U.S. Department of Transportation (DOT) are contained in 49 CFR Parts 171-177. NRC regulations related to transportation of LLW are contained in 10 CFR Part 71, "Packaging and transportation of radioactive material." These regulations contain requirements for transport vehicles, maximum radiation levels for packages and vehicles, special packaging requirements, driver training, vehicle and packaging inspections, marking and labeling of packages, placarding of vehicles, and training of emergency personnel to respond to mishaps. Highway routing restrictions for certain shipments of LLW are also included in DOT regulations. NRC regulations contain performance requirements for certain types of transportation packages of radioactive material. In addition, Federal and State regulations govern the size and weights of trucks. The staff assumes that equipment, materials, and waste transportation are conducted within applicable regulations.

4.3.17.2 Potential Decommissioning Impacts from Transportation

Table E-3 in Appendix E indicates that transportation-related activities may impact the transportation infrastructure and public health and safety. The types of transportation impacts for decommissioning nuclear power facilities and operating plants are similar. The factors that determine the magnitude of transportation impacts of decommissioning include:

- changes in waste production due to decontamination and dismantlement activities that increase the amount of waste shipped offsite
- changes in the transportation methods (rail, truck, or barge) related either to the increased amount to be shipped offsite or to the type of material to be shipped.
- changes in the mix of types of waste categories shipped offsite.

The public health impacts result from exposures of transport workers and the general public along transportation routes during normal shipments and from material released as a result of transportation accidents, as well as from transportation accidents that do not involve the release of radioactive material. The radiological impacts to public health and safety are considered detectable if the dose rates from shipping containers exceed regulatory limits. They are considered destabilizing if material is shipped in unapproved containers. The nonradiological impacts of transportation of radioactive waste are considered detectable or destabilizing if the vehicles are maintained or driven in a manner that would result in a significantly greater accident rate than experienced by the trucking industry.

The nonradiological, infrastructure impacts are increases in traffic density, wear and tear on roadways and railways, and transportation accidents. The impacts of decommissioning activities on the transportation infrastructure are considered detectable if the increased traffic causes a decrease in level of service or measurable deterioration of affected roads that can be directly tied to activities at the plant. The impacts of decommissioning activities are considered destabilizing if the level of service becomes unacceptable or roads become unusable because of activities at the plant.

4.3.17.3 Evaluation

The transportation impacts are dependent on the number of shipments to and from the facility, the type of shipments, the distance that material is shipped, and the nonradiological waste/fixed waste quantities and disposal plans. The distance that the waste travels depends on the plant's proximity to a disposal site. One decommissioning facility, located in Oregon, ships LLW 480 km (300 mi) to the U.S. Ecology burial site on the Hanford Reservation in Richland, Washington. Another decommissioning facility located in California ships LLW 4300 km (2700 mi) to the Barnwell facility in South Carolina.

The number of shipments and volume of waste shipped during the decontamination and dismantlement phases of decommissioning are greater than during operations. Information on shipments, which was received from nine plants, is shown in Appendix K. Because data on the waste volume of shipments were received from only seven plants, estimates of waste volume and shipment numbers in several cases (as footnoted in the table) reflect only a single facility and may be significantly higher or lower than for the average facility in that grouping. The impacts from FBRs and HTGRs would be encompassed by those for the PWRs and BWRs since the distance shipped is less and the plant sizes are generally smaller.

Nonradioactive material from the site for general disposal will likely be shipped to landfills. However, because licensees cannot release material with detectable amounts of radioactive material, a number of sites may ship much of their solid waste to vendors specializing in the management of LLW or to LLW sites such as that at Clive, Utah.

A generic analysis was conducted to estimate human health impacts associated with transporting decontamination and dismantlement wastes from reactor sites to LLW burial grounds. The RADTRAN 4 computer code (Neushauser and Kanipe 1992), which is commonly used for transportation impact calculations in support of environmental documentation, was used for the analysis. RADTRAN 5 (Neushauser and Kanipe 1996) is the latest version of the code, originally developed by Sandia National Laboratories to support the NUREG-0170 environmental impact analysis (NRC 1977). It uses the same basic methods for calculating impacts but does the calculations in a probabilistic framework.

Based on information from Trojan and Maine Yankee, LLW was categorized as one of three types--high activity, low activity, and very low activity--and a typical volume and activity were estimated for each type of LLW. The impacts of transporting each type of LLW were estimated. There are likely to be additional nonradiological impacts on public health and safety from transportation accidents associated with transportation of uncontaminated material.

Radiological impacts: For this Supplement, the public health and safety impacts of transportation of radioactive waste are evaluated on the basis of compliance with applicable regulations. The Commission has taken the position (46 FR 21619) that its "...regulations are adequate to protect the public against unreasonable risk from the transportation of radioactive materials." This evaluation was based, in part, on the findings of NUREG-0170 (NRC 1977). A recent re-evaluation of transportation risks, using updated information and assessment tools (Sprung et al. 2000), found that risks are lower than estimated in NUREG-0170. Licensees are expected to comply with all applicable regulations when shipping radioactive waste from decommissioning. Therefore, the effects of transportation of radioactive waste on public health and safety are considered to be neither detectable nor destabilizing.

Nevertheless, the staff performed an evaluation of the likely magnitude of these impacts using available data. Radiological impacts are divided into those for "routine" or incident-free shipments (i.e., the shipment reaches its destination without incident) and those for shipments that involve an accident with a subsequent radiological release. In each case, the impact is expressed in cumulative dose for the transport workers and public. The results of the calculations are shown in Table 4-6. The details of the assumptions made in the analysis are discussed in Appendix K. In order to bound the impacts, a distance of 4800 km (3000 mi) was selected. Dose rates for incident-free shipment of high-activity LLW were assumed to be at the regulatory limits, and dose rates for incident-free shipment of low-activity LLW were assumed to be at one-tenth of regulatory limits. Radiological impacts of shipment of very low-level activity LLW were assumed to be negligible compared to shipments of high-level and low-level activity LLW. However, shipment of very low-level activity waste was considered in evaluating nonradiological transportation of LLW. With these assumptions and the additional assumptions listed in Appendix K, the results of the analysis should bound the transportation impacts for all decommissioning options for PWRs and BWRs.

Ramsdell et al. (2001) indicate that shipment of spent fuel by rail reduces the radiological impacts significantly (more than a factor of 10 for shipments from the northeast to Nevada). Similar reductions would be expected in the radiological impacts of the shipment of LLW from decommissioning if shipments were made by rail rather than by truck. Barge shipments of the high-activity waste could reduce the radiological impacts even further.

Nonradiological impacts: Nonradiological impacts of transportation of LLW include increased traffic and wear and tear on roadways. Decommissioning experience has been that the number of LLW shipments from a site averages much less than 1 per day. This number of shipments per day is not nearly large enough to have a detectable or destabilizing effect on traffic flow or road wear.

Nonradiological impacts of transportation accidents are typically expressed in terms of fatalities. RADTRAN estimates fatalities caused by traffic accidents using the distance traveled and average fatality rates per unit distance. Traffic accidents are not related to radioactivity; therefore, the impacts of transportation accidents should be based on the round-trip distance between the decommissioning site and the waste facility. For consistency, a 9600-km (6000-mi) round-trip distance is assumed for the fatality estimates shown in Table 4-6. Again, these numbers reflect the entire decommissioning period. The fatality estimates would be the same for shipments of any other commodity.

The following values may provide some perspective for evaluating the values in Table 4-6. A recent publication (Saricks and Tompkins 1999) gives average accident rates on interstate highways. The average accident rates for trucks are 3.15×10^{-7}, 3.66×10^{-7} and 6.54×10^{-7} per kilometer (5.07×10^{-7}, 5.89×10^{-7}, and 1.05×10^{-6} per mile) for highways in rural, suburban, and urban areas, respectively. The national average fatality rate for trucks is 5.5×10^{-9} fatalities per

Table 4-6. Impacts of Transportation of LLW from Decommissioning

	High-Activity Waste	Low-Activity Waste	Very Low-Activity Waste	Total
Number of Shipments during Decommissioning	227	84	360	671[a]
Incident-Free Transportation Impacts – Cumulative Dose, person-Sv (person-rem)				
Crew	0.496 (49 6)	0.184 (18.4)	--	0.680 (68 0)
Public along route	0.129 (12 9)	0 020 (2 00)	--	0.149 (14 9)
Onlookers	0.123 (12 3)	0 019 (1.90)	--	0.142 (14.2)
Total	0.748 (74.8)	0 223 (22.3)	--	0 971 (97.1)
Incident-Free Transportation Impacts – Latent Cancer Fatalities (LCF)				
Crew[b]	0 0198	0.00736	--	0.0272
Public along route[c]	0 0065	0 00100	--	0 00744
Onlookers[c]	0 0062	0 00096	--	0.00711
Total	0.0324	0 00931	--	0.0417
Accident Impacts				
Cumulative Dose, person-Sv (person-rem)	5.39×10^{5} (5.39×10^{3})	1.28×10^{4} ($1\ 28\times10^{2}$)	--	1.82×10^{4} (1.82×10^{2})
Nonradiological Fatalities	0 0120[d]	0 00465[d]	0.019[d]	0.0356[d,e]
Total				
Cumulative Dose, person-Sv (person-rem)	0.748 (74.8)	0 223 (22.3)	--	0 971 (97.1)
Fatalities	0 0419	0.0136	0 0190	0 0745[e]

(a) The total number of shipments during decommissioning may be significantly increased if State or local government agencies require removal of all structures and concrete from the site. However, the additional shipments would be uncontaminated material.
(b) Assuming 4.0×10^{2} LCF/person-Sv (4.0×10^{4} LCF/person-rem) for crew.
(c) Assuming 5.0×10^{2} LCF/person-Sv (5.0×10^{4} LCF/person-rem) for general public.
(d) Based on fatal accident rate of 5.5×10^{9} per km (8.8×10^{9} per mi).
(e) The number of fatalities will increase if there are additional shipments of uncontaminated material in proportion to the number of miles driven.

kilometer (8.8×10^{-9} fatalities per mile). Historically, the accident rate for activities at nuclear facilities has been lower than the national average for similar activities because of the industry emphasis on training and adherence to established procedures.

It is not likely that the actual nonradiological impacts of transportation accidents would be as high as indicated or that they would be either detectable or destabilizing.

The number of shipments into the decommissioning facility would be much smaller than the number of shipments from the facility. The concrete used to entomb a plant would be manufactured at a batch plant onsite, or the licensee would use local sources for the materials needed for entombing a facility. Shipments of materials into the facility during decommissioning or following the preparation for entombment of the facility would be minimal. It is anticipated that many of the shipments to the facility undergoing decommissioning, including shipments of equipment and heavy machinery, would come from local sources and, thus, the distance traveled would be minimal. Therefore, the staff concludes that transporting the materials to the site would not significantly impact the overall traffic volume or compromise the safety of the public,

Previous or anticipated decommissioning activities at the FBR or HTGR have not and are not expected to result in impacts on transportation that are different from those found at other nuclear facilities.

4.3.17.4 Conclusions

The staff has considered available information, including comments received on the draft of Supplement 1 of NUREG-0586, on the potential transportation impacts of decommissioning activities. This information indicates that the transportation impacts are not detectable or destabilizing. Therefore, the staff makes a generic conclusion that for all plants, the potential transportation impacts are SMALL. The staff has considered mitigation measures and concludes that no additional mitigation measures are likely to be sufficiently beneficial to be warranted.

4.3.18 Irreversible and Irretrievable Commitment of Resources

Irreversible commitments are commitments of resources that cannot be recovered, and irretrievable commitments of resources are those that are lost only for a period of time. The irreversible and irretrievable commitments of resources that are anticipated during the decommissioning process are similar to those that were considered in the FESs for facility construction permits and operating licenses. The FESs for plant operation cite uranium as the principal natural resource irretrievably consumed in facility operation. However, following permanent cessation of operations, uranium is no longer consumed. As discussed in Chapter 1, disposal of uranium as part of spent nuclear fuel is not within the scope of this Supplement. Other resources considered in some FESs include land, water, human resources, cultural, and threatened and endangered species.

4.3.18.1 Regulations

CEQ regulations at 40 CFR 1502.13 and NRC regulations at 10 CFR 51, Appendix A to Subpart A, state that an environmental impact statement include a discussion of any irreversible or irretrievable commitments of resources. In addition, there are regulations that deal with the use of land (addressed in Section 4.3.1, "Onsite/Offsite Land Use"), water use and quality (Sections 4.3.2 and 4.3.3), and air quality (Section 4.3.4). Disposal of uranium is not within the scope of this document. Land devoted to LLW disposal sites or in industrial landfills is also not within the scope of this document and is addressed in the licensing documents for the disposal site.

4.3.18.2 Potential Impacts of Decommissioning Activities on Irretrievable Resources

Table E-3 in Appendix E indicates that decommissioning activities with the potential to impact irreversible and irretrievable commitment of resources include structural dismantlement; LLW packaging, storage, and disposal; and transportation.

An irreversible commitment of resources is defined as a loss that is detectable and destabilizing, such as when a species becomes extinct, or, in the case of mining, when ore is removed. Irretrievable commitments can be considered as a tradeoff. If a transportation corridor is constructed, the land uses are not available for as long as the corridor remains. The destabilizing impacts are those that adversely impact the resources discussed in this Supplement (Sections 4.3.1 through 4.3.17).

4.3.18.3 Evaluation

Although most FESs addressed primarily uranium fuel, other resources were discussed in some of the FESs. This included land used for plant buildings, components such as large underground concrete foundations, and certain other equipment considered irretrievable due to practical aspects of reclamation and/or radioactive decontamination. The use of the environment (air, water, and land) by the facilities was not deemed to represent significant irreversible or irretrievable resource commitments but rather a relatively short-term investment.

Whether land is considered to be an irretrievable resource depends largely on the decisions at the time of license termination. If the license is terminated for unrestricted use, then the land will be available for other uses, whether or not the decommissioning process returned the land to a "Greenfield" site or to an industrial complex. If ENTOMB1 is selected, license termination could still allow unrestricted access after 30 to 60 years. However, if the ENTOMB2 option is selected, the land under the facility will not be available for alternative uses and would be considered irretrievable.

The only other irretrievable resources that would occur during the decommissioning process would be materials used to decontaminate the facility (e.g., rags, solvents, gases, and tools), and fuel used for construction machinery and for transportation of materials to and from the site. However, these resources are minor.

Although the use of land, water, air, and fuel oil during decommissioning is minimal or nonexistent, the disposal of radioactive waste and nonradioactive waste would be considerable for some options, such as DECON to a "Greenfield" (nonindustrial) site. Even though the disposal of radioactive waste is outside the scope of this document, the volume of land required for radioactive waste disposal is estimated in Table 4-7 for the SAFSTOR and DECON options, based on data obtained from six plants. The quantities of waste shown in Table 4-7 for the two

ENTOMB options were estimated based on the scenarios described in Chapter 3. The greatest estimated volume of radwaste is from a facility that is being decommissioned to "Greenfield" (no structures remaining onsite). It is located in a State that does not allow disposal of the industrial waste within an in-state industrial waste site.

Table 4-7. Volumes of Land Required for LLW Disposal[a]

Decommissioning Option	Reactor Type	Volume of Land Required for LLW Disposal, m^3 (ft^3)	Plant Size (Electrical Capacity, MWe)
DECON	PWR	8000 - 10,000 (282,500 - 353,000)	1130 to 1825
	BWR	2000 (71,000)	240
SAFSTOR	PWR	600 - 45,000 (21,000 -1.5 million)	23 to 1437
	BWR	18,000 (636,000)	660
ENTOMB1	Either	<5000 (<177,000)	Variable
ENTOMB2	Either	<500 (<17,700)	Variable

(a) Data were available from a limited number of facilities and based on actual estimates provided by the licensees.

4.3.18.4 Conclusions

The staff has considered available information on the potential impacts of decommissioning on irreversible and irretrievable commitments of resources, including comments received on the draft of Supplement 1 of NUREG-0586. This information indicates that the impacts of decommissioning on irreversible and irretrievable commitments are neither detectable nor destabilizing. Therefore, the staff makes the generic conclusion that the impacts on irreversible and irretrievable commitments are SMALL. The staff has considered mitigation and concludes that no additional measures are likely to be sufficiently beneficial to be warranted.

4.4 References

10 CFR 20. Code of Federal Regulations, Title 10, *Energy*, Part 20, "Standards for protection against radiation."

10 CFR 50. Code of Federal Regulations, Title 10, *Energy*, Part 50, "Domestic licensing of production and utilization facilities."

10 CFR 51. Code of Federal Regulations. Title 10, Energy, Part 51, "Environmental protection regulations for domestic licensing and related regulatory functions."

10 CFR 71. Code of Federal Regulations, Title 10, *Energy*, Part 71, "Packaging and

transportation of radioactive material."

10 CFR 100. Code of Federal Regulations, Title 10, *Energy*, Part 100, "Reactor site criteria."

14 CFR 150. Code of Federal Regulations, Title 14, *Aeronautic and Space*, Part 150, "Airport noise compatibility planning."

24 CFR 51B. Code of Federal Regulations, Title 24, *Housing and Urban Development*, Part 51B, "Environmental criteria and standards."

29 CFR 1902. Code of Federal Regulations, Title 29, *Labor*, Part 1902, "State plans for the development and enforcement of State standards."

29 CFR 1910. Code of Federal Regulations, Title 29, *Labor*, Part 1910, "Occupational safety and health standards."

29 CFR 1926. Code of Federal Regulations, Title 29, *Labor*, Part 1926, "Safety and health regulations for construction."

29 CFR 1952. Code of Federal Regulations, Title 29, *Labor*, Part 1952, "Approved State plans for enforcement of State standards."

36 CFR 800. Code of Federal Regulations, Title 36, *Parks, Forests, and Public Property*, Part 800, "Protection of historic properties."

40 CFR 50. Code of Federal Regulations, Title 40, *Protection of Environment*, Part 50, "National primary and secondary ambient air quality standards."

40 CFR 51. Code of Federal Regulations, Title 40, *Protection of Environment*, Part 51, "Requirements for preparation, adoption, and submittal of implementation plans."

40 CFR 61. Code of Federal Regulations, Title 40, *Protection of Environment*, Part 61, "National emission standards for hazardous air pollutants; regulation of radionuclides."

40 CFR 81. Code of Federal Regulations, Title 40, *Protection of Environment*, Part 81, "Designation of areas for air quality planning purposes."

40 CFR 82. Code of Federal Regulations, Title 40, *Protection of Environment*, Part 82, "Protection of stratospheric ozone."

40 CFR 190. Code of Federal Regulations, Title 40, *Protection of Environment*, Part 190, "Environmental radiation protection standards for nuclear power operations."

40 CFR 1502. Code of Federal Regulations, Title 40, *Protection of Environment*, Part 1502, "Environmental Impact Statement."

40 CFR 1508. Code of Federal Regulations, Title 40, *Protection of Environment*, Part 1508, "Terminology and index."

49 CFR 171 - 177. Code of Federal Regulations, Title 49, *Transportation*, Parts 171-177, "General information, regulations, and definitions"; "Hazardous materials table, special provisions, hazardous materials, communications, emergency response information, and training requirements"; "Shippers--general requirements for shipments and packagings"; "Carriage by rail"; "Carriage by aircraft"; "Carriage by vessel"; "Carriage by public highway."

46 FR 21619. "Radioactive Material; Packaging and Transportation by Air." *Federal Register*, April 13, 1981.

54 FR 39767. "10 CFR Part 51 Waste Confidence Decision Review." *Federal Register*, September 28, 1989.

61 FR 39278. "Decommissioning of Nuclear Power Reactors. Final Rule." *Federal Register*. July 29, 1996.

64 FR 68005. "Waste Confidence Decision Review." *Federal Register*. December 6, 1999.

Antiquities Act of 1906, 16 USC 431 et seq.

Archaeological Resources Protection Act of 1979, 16 USC 470aa et seq.

Clean Air Act, as amended, 42 USC 7401 et seq.

Council on Environmental Quality (CEQ). 1997. *Environmental Justice: Guidance under the National Environmental Policy Act*. CEQ, Executive Office of the President, Washington, D.C.

Endangered Species Act of 1973, as amended, 16 USC 1531 et seq.

Executive Order 12898. 1994. "Environmental Effects of Federal Programs on Minority and Low-Income Populations." 59 FR 7629, February 16, 1994.

Executive Order 13186. 2001. "Responsibilities of Federal Agencies to Protect Migratory Birds." 66 FR 3853, January 10, 2001.

Federal Interagency Committee on Noise (FICN). 1992. *Federal Agency Review of Selected Airport Noise Issues*. FICN, Washington, D.C.

Federal Water Pollution Control Act of 1972, as amended by the Clean Water Act, 33 USC 1251 et seq.

Fish and Wildlife Coordination Act, 16 USC 661 et seq.

Hazardous Air Pollutants, 42 USC 7412.

Historic Sites Act of 1935, 16 USC 461 et seq.

Idaho National Environmental and Engineering Laboratory (INEEL). 1999. "Environmental Impact Statement for the Advanced Mixed Waste Treatment Project." Available URL: http://nepa.eh.doe.gov/eis/eis0290/Ch_5/5_10/5_10Noise.HTML

International Commission on Radiological Protection (ICRP). 1991. *Recommendations of the International Commission on Radiological Protection.* Publication 60, Oxford Press, Oxford.

Krupa, K. M., and R. J. Serne. 1988. *Effects on Radionuclide Concentrations by Cement/Ground-Water Interactions in Support of Performance Assessment of Low-Level Radioactive Waste Disposal Activities.* NUREG/CR-6377, NRC, Washington, D.C.

Migratory Bird Treaty Act, 16 USC 703 et seq.

National Academy of Sciences (NAS). 1977. *Guidelines for Preparing Environmental Impact Statements on Noise.* Report of Working Group 69 on Evaluation of Environmental Impact of Noise, NAS, Washington, D.C.

National Council on Radiation Protection and Measurements (NCRP). 1991. *Effects of Ionizing Radiation on Aquatic Organisms.* NCRP Report No. 109, NCRP, Bethesda, Maryland.

National Environmental Policy Act (NEPA) of 1969, as amended, 42 USC 4321 et seq.

National Historic Preservation Act of 1966, as amended, 16 USC 470 et seq.

Native American Graves Protection and Repatriation Act of 1990, 25 USC 3001 et seq.

National Primary and Secondary Ambient Air Quality Standards, 42 USC 7409.

Neushauser, K. S., and F. L. Kanipe. 1996. *RADTRAN 5–A Computer Code for Transportation Risk Analysis.* SAND91-2600C, Sandia National Laboratories, Albuquerque, New Mexico.

Neuhauser, K. S., and F. L. Kanipe. 1992. RADTRAN 4 – Volume 3:User's Guide. SAND89-2370. Sandia National Laboratories, Albuquerque, New Mexico.

Noise Control Act of 1972, as amended, 42 USC 4901 et seq.

Occupational Safety and Health Act of 1970, as amended, 29 USC 651 et seq.

Plog, B., ed. 1988. *Fundamentals of Industrial Hygiene.* 3rd ed., National Safety Council, Washington, D.C.

Ramsdell, J. V., Jr., C. E. Beyer, D. D. Lanning, U. P. Jenquin, R. A. Schwarz, D. L. Strenge, P. M. Daling, and R. T. Dahowski. 2001. *Environmental Effects of Extending Fuel Burnup Above 60 GWd/MTU.* NUREG/CR-6703 (PNNL-13257), NRC, Washington, D.C.

Resource Conservation and Recovery Act (RCRA) of 1976, as amended by the Hazardous and Solid Waste Amendments Act of 1984, 42 USC 6901 et seq.

Sackschewsky, M. R. 1997. *Threatened and Endangered Species Evaluation for 75 Licensed Commercial Nuclear Power Generating Plants.* PNNL-11524, Pacific Northwest National Laboratory, Richland, Washington.

Saricks, C. L., and M. M. Tompkins. 1999. *State-Level Accident Rates of Surface Freight Transportation: A Reexamination.* ANL/ESD/TM-150, Argonne National Laboratory, Argonne, Illinois.

Sprung, J. L., D. J. Ammerman, N. L. Breivik, R. J. Dukhart, F. L. Kanipe, J. A. Koski, G. S. Mills, K. S. Neushauser, H. D. Radloff, R. F. Weiner, and H. R. Yoshimura. 2000. *Reexamination of Spent Fuel Shipment Risk Estimates.* NUREG/CR-6672 (SAND2000-0234), U.S. Nuclear Regulatory Commission, Washington, D.C.

Tennessee Valley Authority (TVA). 1978a. (Yellow Creek Nuclear Plant Units 1 and 2), LBP-78-7, 7 NRC 215.

Tennessee Valley Authority (TVA). 1978b. (Yellow Creek Nuclear Plant Units 1 and 2), LAB-515, 8 NRC 702.

U.S. Environmental Protection Agency (EPA). 1971. "Noise from Construction Equipment and Operations." *Building Equipment and Home Appliances.* PB 206717, EPA, Washington, D.C.

U.S. Environmental Protection Agency (EPA). 1991. *Manual of Protective Action Guides and Protective Actions for Nuclear Incidents.* 400-R-92-001, EPA, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 1977. *Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes.* NUREG-0170, Vol. 1, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 1988. *Final Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities.* NUREG-0586, NRC, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 1996. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants.* NUREG-1437, NRC, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 1997. *Final Generic Environmental Impact Statement in Support of Rulemaking on Radiological Criteria for License Termination of NRC-Licensed Nuclear Facilities.* NUREG-1496, Vol. 1, NRC, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 2000. *Report on Waste Burial Charges.* NUREG-1307, Rev. 9, NRC, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 2001a. *Procedural Guidance for Preparing Environmental Assessments and Considering Environmental Issues.* Office Instruction LIC-203, Nuclear Reactor Regulation, NRC, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 2001b. *Technical Study of Spent Fuel Pool Accident Risk at Decommissioning Nuclear Power Plants.* NUREG-1738, NRC, Washington, D.C.

4.5 Related Documents

Big Rock Point (BRP). 1998. "Big Rock Point Performance Indicators."

Big Rock Point (BRP). 1999. "Big Rock Point Performance Indicators."

Big Rock Point (BRP). 2000. "Big Rock Point Performance Indicators."

Haddam Neck Plant (HNP). 2000. "Haddam Neck Plant License Termination Plan," Rev. 0.

Humboldt Bay Plant (HBP). 1997. "Humboldt Bay Unit 3 Caisson In-leakage Repair Project Summary."

http://www.blm.gov/nstc/VRM/vrmsys.html.

http://nepa.eh.doe.gov/eis/eis0290/Ch_5/5_10/5_10Noise.html.

5.0 No-Action Decommissioning Alternative

The action discussed in this Supplement and in the *Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities* (1988 GEIS; NRC 1988) is decommissioning. The only alternative to the action of decommissioning is not to decommission the facility. The option to restart the reactor is not considered to be an alternative to decommissioning because the regulations do not allow the licensee to reload fuel and restart the facility after submitting a certification that the fuel has been removed from the reactor vessel.

The alternative to decommissioning at the end of the licensing period is a "no action" alternative, implying that a licensee would simply abandon or leave a facility after ceasing operations. Once the facility permanently ceases operation, if the licensee does not conduct decommissioning activities to an extent that meets the license termination criteria in 10 CFR 20 Subpart E, then the license will not be terminated (although the licensee will not be authorized to operate the reactor). The licensee will be required to comply with the necessary requirements for the operating license. As a result, the environmental impacts for maintaining the nuclear reactor facility will be considered to be in the bounds of the appropriate, previously issued Environmental Impact Statements.

The objective of decommissioning is to restore a radiologically contaminated facility to a condition such that there is no unreasonable risk from the decommissioned facility to the public health and safety. The U.S. Nuclear Regulatory Commission (NRC) regulations do not allow the option of not decommissioning. Under NRC regulations, the original operating license for a nuclear power plant is issued for up to 40 years. The license may be renewed for additional 20-year periods if NRC requirements are met. However, at the end of the term of the license (whether it has been extended or not), the regulations require that the facility be decommissioned.

5.1 Reference

U.S. Nuclear Regulatory Commission (NRC). 1988. *Final Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities.* NUREG-0586, NRC, Washington, D.C.

6.0 Summary of Findings and Conclusions

6.1 Summary of Findings

This chapter summarizes the findings and conclusions from the evaluation of environmental impacts related to decommissioning of permanently shutdown commercial nuclear power reactors. Table 6-1 presents each environmental issue that was evaluated and identifies whether the issue is considered generic or site-specific. Of the environmental issues assessed (see Table 6-1), most of the impacts are generic and SMALL for all plants regardless of the decommissioning activity and identified variables (see Appendix E for a list of the variables).

Two issues were identified that require a site-specific analysis: threatened and endangered species and environmental justice.

In accordance with the Endangered Species Act of 1973 (16 USC 1531 et seq.), the appropriate Federal agency (either the U.S. Fish and Wildlife Service or the National Marine Fisheries Service) must be consulted about the presence of threatened or endangered species. Informal consultation will be initiated by the U.S. Nuclear Regulatory Commission (NRC) staff with the appropriate service after the licensee announces permanent cessation of operations. It is expected that any formal or informal consultation will be completed prior to the licensee beginning major decommissioning activities, which can occur 90 days after the submission of the post-shutdown decommissioning activities report (PSDAR). At that time, it will be determined whether such species could be affected by decommissioning activities and whether formal consultation will be required to address the impacts. Each State should also be consulted about its own procedure for considering impacts to State-listed species.

Executive Order 12898 (59 FR 7629), dated February 16, 1994, directs Federal executive agencies to consider environmental justice under the National Environmental Policy Act of 1969 (NEPA). Although the NRC is an independent agency, the Commission has committed to undertake environmental justice reviews. Subsequent to the submittal of the PSDAR, the NRC staff will consider the impacts related to environmental justice from decommissioning activities.

Four issues were determined to be, depending on the circumstances, either generic or site-specific: land use, aquatic ecology, terrestrial ecology, and cultural and historic resources. Impacts resulting from onsite land use, impacts to aquatic and terrestrial resources resulting from activities occurring within the facility's operational areas, and impacts to cultural or historic resources resulting from activities within the facility operational area were determined to be generic and SMALL.

Table 6-1. Summary of the Environmental Impacts from Decommissioning Nuclear Power Facilities

Issue	Generic	Impact
Onsite/Offsite Land Use		
- Onsite land use activities	Yes	SMALL
- Offsite land use activities	No	Site-specific
Water Use	Yes	SMALL
Water Quality		
- Surface water	Yes	SMALL
- Groundwater	Yes	SMALL
Air Quality	Yes	SMALL
Aquatic Ecology		
- Activities within the operational area	Yes	SMALL
- Activities beyond the operational area	No	Site-specific
Terrestrial Ecology		
- Activities within the operational area	Yes	SMALL
- Activities beyond the operational area	No	Site-specific
Threatened and Endangered Species	No	Site-specific
Radiological		
- Activities resulting in occupational dose to workers	Yes	SMALL
- Activities resulting in dose to the public	Yes	SMALL
Radiological Accidents	Yes	SMALL
Occupational Issues	Yes	SMALL
Cost	NA[a]	NA
Socioeconomic	Yes	SMALL
Environmental Justice	No	Site-specific
Cultural and Historic Resource Impacts		
- Activities within the operational areas	Yes	SMALL
- Activities beyond the operational areas	No	Site-specific
Aesthetics	Yes	SMALL
Noise	Yes	SMALL
Transportation	Yes	SMALL
Irretrievable Resources	Yes	SMALL

(a) A decommissioning cost assessment is not a specific National Environmental Policy Act (NEPA) requirement. However, an accurate decommissioning cost estimate is necessary for a safe and timely plant decommissioning. Therefore, this Supplement includes a decommissioning cost evaluation, but the cost is not evaluated using the environmental significance levels nor identified as a generic or site-specific issue.

Impacts resulting from offsite land use to support decommissioning activities, impacts to aquatic and terrestrial resources resulting from activities occurring outside the facility's operational areas, and impacts to cultural, historic or archeological resources resulting from activities beyond the operational areas cannot be evaluated generically and would require a site-specific analysis before undertaking the activity. These are termed conditionally site-specific.

Before a licensee conducts any decommissioning activity that might result in the disturbance of historic properties or archeological resources outside the site operational area, the NRC will, in accordance with the National Historic Preservation Act of 1966, as amended (16 USC 470 et seq.), consult with the appropriate State (or Tribal) Historic Preservation Officer to evaluate potential impacts.

The issue of cost was addressed in this Supplement but was not evaluated.

The staff also determined that the issue of long-term radiological aspects of Rubblization or onsite disposal of slightly contaminated material could not be evaluated generically and would require a site-specific analysis. The site-specific analysis would be conducted at the time the license termination plan (LTP) for the site is submitted.

For the 19 reactors listed in Table F-1 that have permanently ceased operation during the period 1963 through 1997, the staff has determined that no issue or activity must be re-evaluated immediately, provided that the licensee does not change the decommissioning option previously chosen. The NRC staff conducted a detailed environmental review on a number of these facilities prior to 1996 as part of the decommissioning plan review. Licensees for several of these reactors have submitted LTPs for NRC review and approval, and the staff has evaluated or is evaluating site-specific environmental impacts as part of that review. Therefore, for many of the 19 facilities, a site-specific assessment has been performed. Because decommissioning is substantially underway at all 19 reactors, the impacts for the issue of environmental justice have already occurred and an evaluation at the present time would provide little value and opportunity for mitigation. Impacts on threatened and endangered species are considered on an ongoing basis and the issuance of this Supplement would not accelerate a review of the issue solely because the issue is one that cannot be evaluated generically. The staff will continue to conduct site-specific consultations with the appropriate resource agency, as the need arises.

Therefore, the NRC has determined that it is not necessary at this time to conduct an evaluation of the environmental justice or impacts on threatened and endangered species at the 19 permanently shutdown reactors listed in Table F-1. However, should a licensee choose a different decommissioning option from its current choice (e.g., SAFSTOR rather than DECON), then the site-specific issues would need to be considered prior to undertaking a decommissioning activity not previously evaluated.

For the 19 facilities listed in Table F-1 that have initiated decommissioning, as well as for any facilities that permanently cease operation in the future, any planned decommissioning activity would require a site-specific analysis prior to undertaking the proposed activity (see Section 1.5) if the activity:

- results in an impact outside the range of impacts postulated by this Supplement or
- raises environmental issues that were not considered in this Supplement or
- involves an issue determined to be site specific or conditionally site-specific as described above in this Supplement or
- involves a combination of the above.

6.2 Conclusions

A licensee undergoing or planning decommissioning of a nuclear reactor facility may use this Supplement in its evaluation of the environmental consequences from decommissioning activities. The impacts identified in this Supplement are designed to span the range of impacts for all commercial power reactor facilities that have permanently shut down as well as for the reactor facilities that are currently operating, including the facilities that have, or may, renew their operating license beyond the original 40-year license.

For those issues that have been determined to be generic, licensees may proceed with the decommissioning activity without further analysis provided that the impacts resulting from those activities fall within the range of impacts as described in Chapter 4. However, if the impacts of an activity fall outside the range predicted in Chapter 4, or if the activity results in impacts to environmental issues not considered in this Supplement, or if the impact involves an environmental issue determined to be conditionally site-specific as defined above, then the activity cannot be performed until a further site-specific analysis is completed along with a license-amendment request and NRC has approved the license amendment (the license-amendment request will provide an opportunity for a public hearing).

6.3 References

Endangered Species Act of 1973, as amended, 16 USC 1531 et seq.

Executive Order 12898. 1994. "Environmental Effects of Federal Programs on Minority and Low-Income Populations." 59 FR 7629, February 16, 1994.

National Environmental Policy Act (NEPA) of 1969, as amended, 42 USC 4321 et seq.

National Historic Preservation of 1966, as amended, 16 USC 470 et seq.

Appendix A

Appendixes A and B have been moved and redesignated as Appendixes N and O. All comments and responses, whether written or oral, are now contained in Appendixes N, O, and P, which comprise Volume 2 of this Supplement.

Appendix B

Appendixes A and B have been moved and redesignated as Appendixes N and O. All comments and responses, whether written or oral, are now contained in Appendixes N, O, and P, which comprise Volume 2 of this Supplement.

Appendix C

Contributors

Appendix C

Contributors

The overall responsibility for the preparation of this Supplement to the Generic Environmental Impact Statement (GEIS) on Decommissioning was assigned to the Office of Nuclear Reactor Regulation (NRR), U.S. Nuclear Regulatory Commission (NRC). This Supplement was prepared by members of the NRR with assistance from other NRC organizations and the Pacific Northwest National Laboratory.

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James V. Ramsdell, Jr.	Staff Scientist	Air Quality
Melissa Peffers	Research Scientist	Industrial Hygiene
Steve Short	Staff Engineer	Cost
Phil Daling	Staff Engineer	Transportation
Mark C. Bierschbach	Development Engineer	Cost
Dennis Haffner	Senior Research Scientist	Cost
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Jean M. Cheyney	Text Processor	Administrative Support
Rose M. Urbina	Text Processor	Administrative Support
Tara O. Eschbach	Research Scientist	Assistant
Bev Miller	Research Scientist	Assistant
Sue Gulley	Program Administrator	Assistant
Amanda Stegen	Research Scientist	Assistant
Terri Miley	Research Scientist	Assistant

(a) Retired in January 2002.
(b) Nuclear Materials Safety and Safeguards.
(c) Pacific Northwest National Laboratory is operated for the U.S. Department of Energy by Battelle.
(d) Currently with the Office of Nuclear Regulatory Research, NRC.

Appendix D

Further Discussion of Out-of-Scope Activities

Appendix D

Further Discussion of Out-of-Scope Activities

Various activities that are performed during decommissioning may seem intuitively to be part of the decommissioning process. However, they are not considered within the scope of this Supplement because these activities have already received an environmental review during the promulgation of the U.S. Nuclear Regulatory Commission (NRC) regulations governing such activities. They are reviewed and regulated by the NRC under other regulations. These activities include the following:

- Independent Spent Fuel Storage Installation (ISFSI): construction/maintenance/ decommissioning: An ISFSI is a facility designed and constructed for the interim storage of spent nuclear fuel and other radioactive materials associated with spent fuel storage. The ISFSI may be located at the same site as the nuclear power facility or at another location. ISFSIs are used by operating plants that require increased spent fuel storage capacity because their spent fuel pools have reached their capacity and the U.S. Department of Energy (DOE) facility for disposing of spent fuel and high-level nuclear waste is not yet available. Decommissioning facilities may use ISFSIs as an alternative to leaving the fuel in the spent fuel pool while waiting for DOE to take ownership of the spent fuel. Licensees that remove the spent fuel from their pools and place it in an ISFSI can then complete the decommissioning process on the power-generation facilities and subsequently terminate the facility license. In some instances, the license for the nuclear power reactor can be terminated while the ISFSI, which has a separate license and is located on the facility site, would continue to be regulated by the NRC.

  An ISFSI can be operated either under the same license that is used for the operating or decommissioning facility (called a "Part 50 license," referring to 10 CFR Part 50), or under a site-specific license (called a "Part 72 license," referring to 10 CFR Part 72). Regulations for the licensing and operation of an ISFSI, including quality assurance and quality control requirements, are found in 10 CFR Part 72. If a licensee chose to operate the ISFSI under a Part 50 license, they could, by way of a license-amendment request, change the ISFSI to a Part 72 license, thus allowing termination of the Part 50 license at the end of the reactor facility decommissioning process.

The decommissioning of the ISFSI is also handled separately from the decommissioning of the nuclear power facility. The 1988 Generic Environmental Impact Statement (GEIS) (NRC 1988) contained a section on decommissioning of ISFSIs, which is not updated in this Supplement.

- Spent fuel storage and maintenance: The Commission has independently, in a separate proceeding, the "Waste Confidence Proceeding," made a finding that there is:

  > reasonable assurance that, if necessary, spent fuel generated in any reactor can be stored safely and without significant environmental impacts for at least 30 years beyond the licensed life for operation (which may include the term of a revised license) of that reactor at its spent fuel storage basin, or at either onsite or offsite independent spent fuel storage installations. (54 FR 39767)

  The Commission has committed to review this finding at least every 10 years. In its most recent review, the Commission concluded that experience and developments since 1990 were not such that a comprehensive review of the Waste Confidence Decision was necessary at that time (64 FR 68005). Accordingly, the Commission reaffirmed its finding of insignificant environmental impacts cited above. This finding is codified in the Commission's regulations at 10 CFR 51.23(a). The operation of a spent fuel pool or an ISFSI is not uniquely linked to decommissioning. All operating nuclear power facilities have spent fuel pools and some (with the number anticipated to increase) have ISFSIs generally located adjacent or near to the power reactor facility.

- Spent fuel transport and disposal away from the reactor location: The temporary storage or future permanent disposal of spent fuel at a site other than the reactor site is not within the scope of this Supplement. Licensees are prohibited from shipping spent fuel from one reactor's spent fuel pool to another's without NRC approval. Amendment of one or both of the facilities' licenses would be required before fuel transfer.

  Transportation of spent fuel and other high-level nuclear wastes is governed by regulations in 10 CFR Part 71, "Packaging and Transportation of Radioactive Material." Disposal of spent fuel and high-level wastes (HLW) are governed by the Nuclear Waste Policy Act (NWPA) of 1982, as amended, which defined the goals and structure of a program for permanent, deep geologic repositories for the disposal of high-level radioactive waste and non-reprocessed spent fuel. Under this Act, the DOE is responsible for developing permanent disposal capacity for spent fuel and other high-level nuclear wastes. On July 9, 2002, the U.S. Congress approved Yucca Mountain as the first long-term geologic repository for spent nuclear fuel and high-level radioactive waste. A HLW repository will be built and operated by DOE and licensed by the NRC. Title 10 CFR Part 61 contains rules governing the licensing to receive and possess source, special nuclear, and by-product material at a geological repository operations area that is sited, constructed, or operated in accordance with the NWPA (1982). However, the Commission proposes to supersede the generic criteria in Part 60 for disposal at a waste repository with specific criteria in a new 10 CFR Part 63 issued on February 22, 1999 (64 FR 8640).

- Interim storage of Greater-than-Class-C (GTCC) Waste: The NRC regulations at 10 CFR 61.55 define three classes of low-level waste (LLW) (A, B, and C) that are suitable for near-surface disposal. Class C waste is required to meet the most rigorous disposal requirements. The LLW that exceeds the concentration limits set for Class C waste is referred to as GTCC waste. Typically, GTCC waste is composed of activated metal components and process wastes.

  On October 11, 2001 the NRC amended its regulations (in 66 FR 51823), to permit interim storage of GTCC waste used or generated by commercial power reactors within an ISFSI or monitored retrievable storage (MRS) facility. This change permits the co-locating of spent fuel and solid reactor-related GTCC waste in different casks and containers within the ISFSI or MRS. Commingling of spent fuel and GTCC waste in the same storage cask is not permitted, except on a case-by-case basis. Ultimately, GTCC waste must be disposed of in a geologic repository.

- LLW disposal at a licensed LLW site or treatment of LLW at compactor facilities: The disposal of LLW is not within the scope of this Supplement. LLW is defined as any radioactive waste that is not classified as HLW, spent nuclear fuel, transuranic waste,[a] or uranium or thorium mill tailings. LLW often contains small amounts of radioactivity dispersed in large amounts of material, but may also have activity levels requiring shielding and remote handling. LLW that is generated during decommissioning is usually composed of the following material contaminated with radionuclides: rags, papers, filters, solidified liquids, ion-exchange resins, tools, equipment, discarded protective clothing, dirt, construction rubble, concrete, and piping.

  Regulations related to LLW disposal are in 10 CFR Part 61 and 10 CFR Part 20, Subpart K. A final GEIS supporting the regulations in 10 CFR Part 61, was published in 1982 as "Final Generic Environmental Impact Statement for 10 CFR Part 61," NUREG-0945 (NRC 1982). A license for the LLW disposal site is not issued until the applicant provides an environmental report (ER) indicating that the applicant's proposed disposal site, design,

(a) Transuranic waste contains man-made elements heavier than uranium that decay by emitting alpha particles. Such waste is produced during reactor fuel assembly, weapons fabrication, and chemical processing operations.

operations, site closure, and post-closure institutional controls are adequate to protect public health and safety. The licensee for the LLW site must show that there is reasonable assurance that (1) the general population will be protected from releases of radioactivity, (2) that individual inadvertent intruders are protected, (3) that standards for radiation protection in 10 CFR Part 20 are met, and (4) that the long-term stability of the disposed waste and the disposal site will be achieved and will eliminate, to the extent practical, the need for ongoing active maintenance of the disposal site following closure. The ER will be reviewed by the NRC and the impacts of LLW disposal evaluated in an Environmental Impact Statement (EIS) that is written for the specific LLW site. The technical requirements for land-disposal facilities are covered in Subpart D of 10 CFR Part 61. The financial assurance requirements are covered in Subpart E of 10 CFR Part 61.

- <u>Activities related to the ENTOMBMENT Period</u>:

  On October 16, 2001, the Commission issued an advance notice of proposed rulemaking (ANPR) inviting input from stakeholders on "Entombment options for Power Reactors" (66 FR 52551). Consistent with the environmental evaluation of the DECON and SAFSTOR decommissioning options, the staff has limited its environmental evaluation of ENTOMB to those issues related to activities necessary to prepare the facility for entombment.

  Issues and resulting impacts related to the ENTOMB option after the facility begins entombment, such as NRC oversight and monitoring requirements, durability of institutional controls and engineered barriers, indefinite retention onsite of radioactive materials, and other long-term site-specific issues are outside the scope of this Supplement.

  A future environmental assessment in support of NRC rulemaking related to the entombment options may address these issues depending on the proposed changes to the regulations.

- <u>Activities following license termination under restricted use conditions</u>: Licensees are allowed by regulations in 10 CFR Part 20, Subpart E, "Radiological Criteria for License Termination," to release the site for restricted use. The impacts following a restricted release license termination will not be considered by this Supplement because the licensee is required to conduct a site-specific analysis to support development of an NRC site-specific EIS.

- <u>Activities and impacts from living or working on the site after license termination</u>: Analysis of radiological impacts from unrestricted use after decommissioning and license termination are presented in NUREG-1496, *Generic Environmental Impact Statement in Support of Rulemaking on Radiological Criteria for License Termination of NRC-Licensed Nuclear Facilities* (NRC 1997). This GEIS analyzed regulatory alternatives for establishing radiological criteria for decommissioning structures and lands of licensed facilities. The scope included both radiological and nonradiological impacts on human health and safety, including radiation exposure resulting from occupancy of site buildings and residence on site lands following decommissioning and license termination.

D.1 References

10 CFR 20. Code of Federal Regulations, Title 10, *Energy*, Part 20, "Standards for protection against radiation."

10 CFR 50. Code of Federal Regulations, Title 10, *Energy*, Part 50, "Domestic licensing of production and initialization facilities."

10 CFR 51. Code of Federal Regulations, Title 10, *Energy*, Part 51, "Environmental protection regulations for domestic licensing and related regulatory functions."

10 CFR 61. Code of Federal Regulations, Title 10, *Energy*, Part 61, "Licensing requirements for land disposal of radioactive waste."

10 CFR 63. Code of Federal Regulations, Title 10, *Energy*, Part 63, "Disposal of high-level radioactive wastes in a geologic repository at Yucca Mountain, Nevada."

10 CFR 71. Code of Federal Regulations, Title 10, *Energy*, Part 71, "Packaging and transportation of radioactive material."

10 CFR 72. Code of Federal Regulations, Title 10, *Energy*, Part 72, "Licensing requirements for the independent storage of spent nuclear fuel and high-level radioactive waste."

54 FR 39767. "10 CFR Part 51 Waste Confidence Decision Review." *Federal Register*. September 28, 1989.

64 FR 8640. "10 CFR Parts 2, 19, 20, 21, 30, 40, 51, 60, 61, and 63 Disposal of High-Level Radioactive Wastes in a Proposed Geologic Repository at Yucca Mountain, Nevada." *Federal Register*. February 22, 1999.

64 FR 68005. "Waste Confidence Decision Review." *Federal Register*. December 6, 1999.

66 FR 51823. "Interim Storage for Greater Than Class C Waste 10 CFR Parts 30, 70, 72, and 150." *Federal Register*. October 11, 2001.

66 FR 52551. "Entombment Options for Power Reactors." *Federal Register.* October 16, 2001.

Nuclear Waste Policy Act of 1982, as amended, 42 USC 10.101 et seq.

U.S. Nuclear Regulatory Commission (NRC). 1982. *Final Generic Environmental Impact Statement for 10 CFR Part 61.* NUREG-0945, NRC, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 1988. *Final Generic Environmental Impact Statement for Decommissioning of Nuclear Facilities.* NUREG-0586, NRC, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 1997. *Final Generic Environmental Impact Statement in Support of Rulemaking on Radiological Criteria for License Termination of NRC-Licensed Nuclear Facilities.* NUREG-1496, Vol. 1, NRC, Washington, D.C.

Appendix E

Evaluation Process for Identifying the Environmental Impacts of Decommissioning Activities

Appendix E

Evaluation Process for Identifying the Environmental Impacts of Decommissioning Activities

This appendix describes the process that the staff used to determine the environmental impacts from decommissioning nuclear power facilities. Figure E-1 is a flowchart showing the evaluation process. The staff first created an initial list of environmental issues and decommissioning activities that this Supplement should address (Table E-1). The initial list of environmental issues was developed from the issues identified in the 1988 GEIS and the list specified in 10 CFR Part 51, Subpart A, Appendix B, for license renewal. The initial list of decommissioning activities was based on experience and the literature discussed in Section 3.2 of this Supplement. The staff used these initial lists of environmental issues and decommissioning activities for discussions during the scoping process (Section 1.3). At the conclusion of the scoping process and after conducting visits to six sites, the staff refined these two lists, based on comments from the public, the industry, the specific sites visited, the States, and other Federal agencies. During the scoping process, the staff visited the sites listed in Table E-2 and gathered information about the sites' decommissioning experiences. The sites were chosen to represent a variety of types of sites in various stages of decommissioning.

The staff designed a two-tier matrix system to document the evaluation process. In the Tier 1 (Table E-3) matrix, the environmental issues are listed on the horizontal axis and the decommissioning activities are listed on the vertical axis. Each activity in the list is grouped into broad categories designed to include a variety of specific activities. The list of activities is comprehensive and includes new technologies that were considered in this Supplement. Other innovative decommissioning options or activities not included in this document are expected to be developed by licensees in the future. Such options or activities do not fall under the conclusions of this Supplement and would need to be analyzed on a site-specific basis.

After compiling the environmental issue and decommissioning activity lists, the staff assessed which activities might have environmental impacts for each of the issues. The Tier 1 matrix (Table E-3) also shows the result of this evaluation. The Tier 1 matrix identifies impacts that occur for issues related to specific activities during the decommissioning process. In developing the Tier 1 matrix, the staff resolved whether the issue applies to the activity and whether there were potential environmental impacts. If the answer was "yes," the impacts in the matrix were marked with an "X" to designate the need for an analysis in the Supplement. For example, the transfer of the fuel from the reactor vessel to the spent fuel pool (an activity that occurs inside

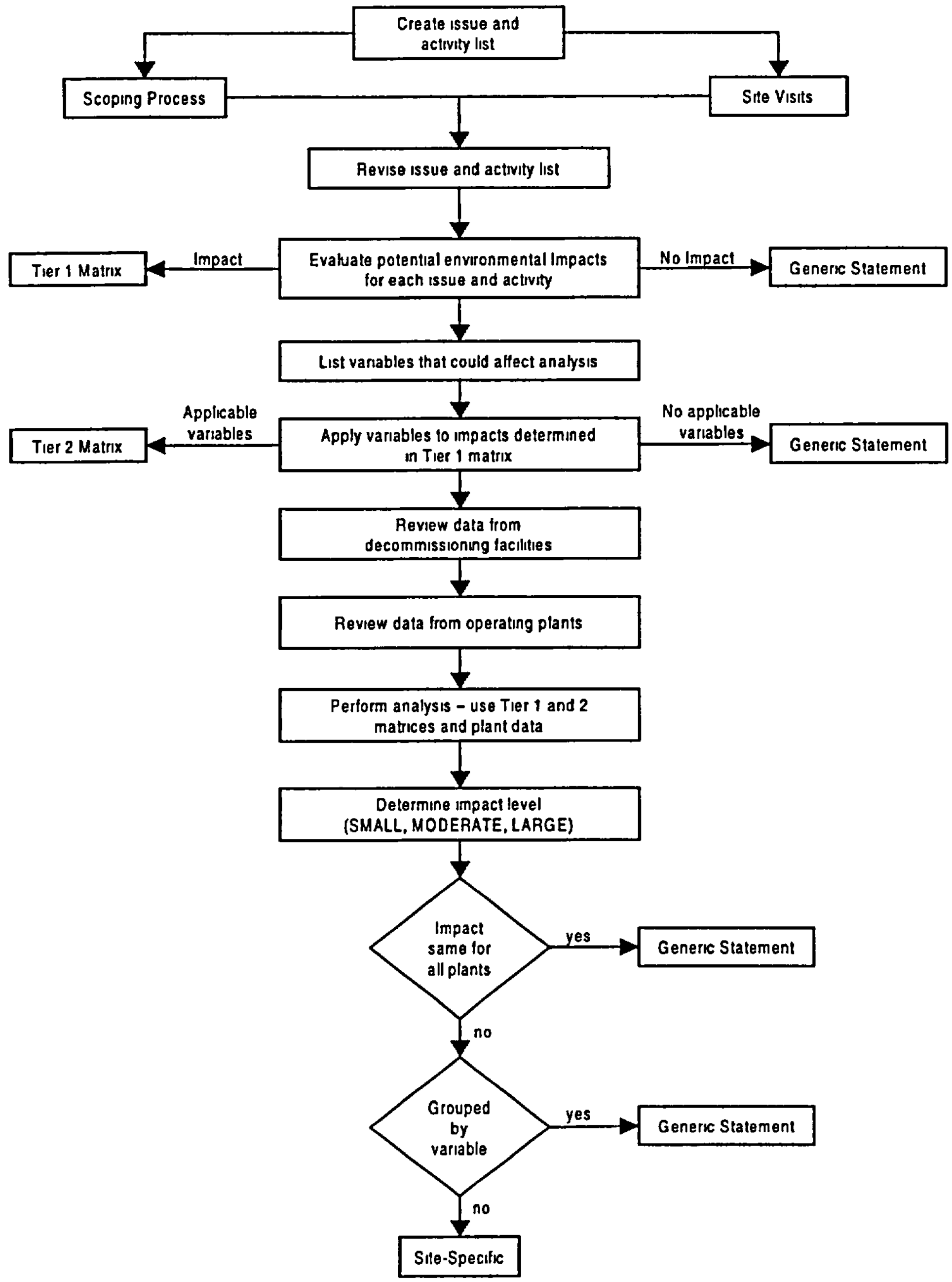

Figure E-1. Environmental Impact Evaluation Process

Table E-1. First- and Second-Tier Matrices Issues and Activities

Issues
Onsite/offsite land use
Water use
Water quality
Air quality
Aquatic ecology
Terrestrial ecology
Threatened and Endangered Species
Radiological
Radiological accidents
Occupational issues
Cost
Socioeconomics
Environmental justice
Cultural impacts
Aesthetic issues
Noise

Activities
Remove fuel
Organizational changes
Stabilization
Post-shutdown surveys
Create nuclear island
Chemical decontamination of primary loop
Large component removal
Storage preparation activities for SAFSTOR
Storage (SAFSTOR)
Decontamination and Dismantlement phases of DECON, SAFSTOR, and ENTOMB1
System dismantlement
Structure dismantlement
Entombment
Low-level waste packaging and storage
Transportation
License termination activities

Table E-2. Site Visits

Nuclear Plant	Description	Plant Type	Thermal Power	Decommissioning Method
Big Rock Point	Single nuclear unit	BWR[(a)]	240 MW	DECON
Humboldt Bay, Unit 3	Single nuclear plant at multi-unit fossil fuel facility	BWR	200 MW	SAFSTOR
Maine Yankee	Single nuclear unit	PWR[(b)]	2700 MW	DECON
Rancho Seco	Single nuclear unit	PWR	2772 MW	SAFSTOR
Trojan	Single nuclear unit	PWR	3411 MW	DECON
Zion, Units 1 and 2	Multiple nuclear units	PWR	3250 MW	SAFSTOR

(a) boiling water reactor.
(b) pressurized water reactor.

the facility) would not result in aesthetic or noise issues. On the other hand, this activity would result in a radiation dose to the workers (radiological) and could potentially cause a radiological accident. In some cases, correlation between the activity and the issue was not evident. In these cases, the matrix was marked conservatively to ensure further analysis of the impact. This is the case with the issues of water use for the activity of transferring fuel to the spent fuel pool. The water that is used in this process is very small compared to the amount of water used to cool the reactor during operations. However, the matrix was marked to ensure that the water-use issue was addressed completely in this Supplement.

Typically, environmental impact statements would consider transportation as an issue and not as an activity. However, the staff determined that in the case of decommissioning nuclear power reactors, transportation is an activity, not an issue. Because there are several transportation-based impacts related to decommissioning nuclear power facilities, transportation was addressed in its own section (4.3.17) in this Supplement.

After completing the Tier 1 matrix, the next step was to identify the variables that might affect the environmental impact for a specific issue. These variables include some of the obvious differences between reactor facilities, such as whether the facility is a pressurized water reactor, boiling water reactor, or other type of reactor, whether it is a multi-unit site and what type of cooling system is used. The staff also considered variables that would impact a licensee's decision concerning types of activities or how an activity would be conducted. For example, the proximity of the facility to a barge slip or railroad might affect a licensee's decision to remove the steam generator or other large components intact and ship them to a waste site. If the barge slip needs additional dredging or an additional railroad line needs to be installed, then the environmental impacts may change. Table E-4 lists the variables, their abbreviations as they appear in the Tier 2 matrix (Table E-5), and the characteristics, if appropriate, for each variable.

The staff then considered each of the impact areas identified in the Tier 1 matrix, and determined if the variables influenced the environmental impacts. If no change would occur, then the "X" in the box was retained to signify that the variables do not change the analysis. If a change would occur, then the staff needs a second determination as to which variables could significantly change the impact. Variables that could significantly change the impact were listed by their abbreviation in the appropriate box in the matrix (see Table E-3 for the abbreviations). By resolving these questions, the staff developed the Tier 2 matrix shown in Table E-5. The staff used the Tier 2 matrix as the starting point for the analysis of the environmental impacts of the decommissioning activities for each of the applicable issues and variables.

The analyses that are presented in the following sections were based on the information in the Tier 2 matrix. The data used in the analyses was obtained from several sources:

- documents such as post-shutdown decommissioning activity reports, final environmental statements, environmental reports, and license termination plans for permanently shutdown and decommissioning facilities
- site visits
- information gathered from permanently shutdown and decommissioning facilities with the assistance of the Nuclear Energy Institute
- currently operating facilities (primarily from NUREG-1437 [NRC 1996]).

The analyses in this Supplement include data from both operating and decommissioning facilities in order to appropriately span the range of impacts so that future decommissioning facilities could consider using this Supplement. The data from the decommissioning facilities was used to determine whether an activity and associated issue could be considered generic. The reason for including the operating facilities is that they will eventually decommission. Also, many of the plants that have decommissioned were the smaller, older facilities.

E.1 References

10 CFR 51. Code of Federal Regulations, Title 10, *Energy*, Part 51, "Environmental protection regulations for domestic licensing and related regulatory functions."

U.S. Nuclear Regulatory Commission (NRC). 1996. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants.* NUREG-1437, NRC, Washington, D.C.

Table E-3. Tier 1 Matrix - Decommissioning Activities and Issues

Activities	Issues																
	Onsite/Offsite Land Use	Water Use	Water Quality	Air Quality	Aquatic Ecology	Terrestrial Ecology	Threatened and Endangered Species	Radiological	Radiological Accidents	Occupational	Cost	Socioeconomic	Environmental Justice	Cultural Impacts	Aesthetic issues	Noise	Irretrievable Resources
1. Remove Fuel																	
- Transfer fuel to spent fuel pool		X	X					X	X	X							
- Drain primary system			X					X	X	X	X						
- Process liquid			X					X	X	X	X						
2. Organizational Changes																	
- Reduce staff		X						X			X	X	X				
- Employ contractor or other additional staff		X		X				X			X	X	X				
- Adjust site training								X	X	X	X						
- Changes to licensing basis - site-specific											X						
3. Stabilization																	
- Drain and flush system			X	X				X	X	X	X						
- Isolate systems, structures, and components that are no longer required				X				X		X	X						
- Rewiring of site to eliminate unneeded electrical circuits						X	X	X		X	X			X			
4. Post-Shutdown Surveys																	
- Baseline surveys for the decontamination work								X			X						
- Continual surveys								X			X						
5. Create Nuclear Island																	
- Install electrical power supply to spent fuel pool								X		X	X						
- Reduce the security area to just that around the fuel											X						
- Change security function											X						

"X" indicates where there may be am impact from decommissioning activities.

Table E-3. (contd)

Activities	Issues																
	Onsite/Offsite Land Use	Water Use	Water Quality	Air Quality	Aquatic Ecology	Terrestrial Ecology	Threatened and Endangered Species	Radiological	Radiological Accidents	Occupational	Cost	Socioeconomic	Environmental Justice	Cultural Impacts	Aesthetic issues	Noise	Irretrievable Resources
- Install or modify chemistry controls										X							
- Move old or install new security-related equipment								X		X	X						
6. Chemical Decontamination of primary loop																	
- Cutting, chemicals in, chemicals out, cleanup/decon								X	X	X	X						
7. Large Component Removal																	
- Remove reactor vessel and internals intact or cut up	X	X				X	X	X	X	X	X			X			
- Steam generator and other large components removed intact or cut up	X					X	X	X	X	X	X			X			
8. Storage Preparation Activities for SAFSTOR																	
- Establish a reactor coolant system vent pathway				X				X		X	X						
- Establish containment vent pathway				X				X		X	X						
- De-energize systems, put in monitors where they are needed								X		X	X						
- Perform a radiological assessment								X			X						
9. Storage (SAFSTOR)																	
- Monitor systems and radiation levels etc.								X			X						
- Do preventive and corrective maintenance on SSCs								X		X	X						
- Maintain the security system											X						

"X" indicates where there may be an impact from decommissioning activities.

Table E-3. (contd)

Activities	Issues																
	Onsite/Offsite Land Use	Water Use	Water Quality	Air Quality	Aquatic Ecology	Terrestrial Ecology	Threatened and Endangered Species	Radiological	Radiological Accidents	Occupational	Cost	Socioeconomic	Environmental Justice	Cultural Impacts	Aesthetic issues	Noise	Irretrievable Resources
- Maintain effluent and environmental monitoring programs				X							X						
10. Decontamination and Dismantlement phases of DECON, SAFSTOR, and ENTOMB 1																	
- Chemical decontamination (surface/specific components)								X	X	X	X						
- Decontamination of piping inside walls								X	X	X	X						
- High-pressure water sprays of surface		X	X					X	X	X	X						
- Remove contaminated soil from specific areas						X	X	X		X	X			X			
- Do preventive and corrective maintenance on SSCs								X		X	X						
- Maintain the security system											X						
- Maintain effluent and environmental monitoring programs				X							X						
11. System Dismantlement																	
- Cut out radioactive piping								X	X	X	X						X
- Remove large and small tanks or other radioactive components from the facility								X	X	X	X						X
12. Structure Dismantlement																	
- Rubblization	X	X	X	X				X		X	X				X	X	X
- Remove structures that were necessary for plant operation	X	X		X	X	X	X	X	X	X	X				X	X	X

"X" indicates where there may be an impact from decommissioning activities.

Table E-3. (contd)

Activities	Issues																
	Onsite/Offsite Land Use	Water Use	Water Quality	Air Quality	Aquatic Ecology	Terrestrial Ecology	Threatened and Endangered Species	Radiological	Radiological Accidents	Occupational	Cost	Socioeconomic	Environmental Justice	Cultural Impacts	Aesthetic issues	Noise	Irretrievable Resources
13. Entombment																	
- Install engineered barriers				X				X		X	X				X	X	
- Disconnect operational systems (e.g. electrical and fire protection)								X		X	X						
- Remove all radioactive material that is outside of containment								X		X	X					X	
- Place material inside containment								X		X	X						
- Lower containment ceiling (optional)		X		X				X	X	X	X						
- Entomb facility in concrete		X		X						X	X				X	X	
14. LLW packaging and storage	X							X	X	X	X						X
15. Transportation																	
- Large components				X				X	X	X	X		X				X
- LLW				X				X	X	X	X		X				X
- Equipment into site				X							X						
- Backfill trucked into site				X							X						X
- Nonradioactive waste				X							X						X
16. License Termination Activities																	
- Complete final radiation survey								X		X	X						
- Partial site release								X			X						

"X" indicates where there may be an impact from decommissioning activities.

Table E-4. Tier 2 Matrix Variables

Variable Abbreviation	Variable	Variable Characteristics
Type	Type of plant	PWR, BWR, HTGR, FBR
Size	Size of plant	Based on the facility thermal power capability
Loc	Population charactenstics	Rural, urban
Env	Environmental features	Coastal, desert, lake, nver shoreline, other
Cool Sys	Cooling system type	Closed cycle, once-through cooling
Cool	Cooling water source	Reservoir, lake, nver or creek, ocean, canal, bay, pond, canal, sewage treatment plant
Grdwater	Groundwater usage/proximity to groundwater	
Fuel Loc	Fuel location - as a function of time	Spent fuel pool, ISFSI, away from reactor
Ops	Off-normal radiological operational events	Failed or leaking fuel, contaminated soil
Intenm Time	Time between last shutdown and initiation of decommissioning	
Decom Opt	Decommissioning option	SAFSTOR, DECON, ENTOMB
Store Time	Duration of storage period for plants in deferred DECON/SAFSTOR	
Struct	Disposition of structures dunng decommissioning	Remain onsite, sent to a LLW site or vendor, entombed, landfill, rubblized
LLW	Distance traveled for disposal of LLW	
Gas Emissions	Method used to control gaseous radioactive effluents	
Land Mass	Land mass (footpnnt) of the site	
Culture	Cultural resources	Known/unknown, present/absent
Multi-Unit	Single unit versus multi-unit sites with other operating units	
Trans Prox	Proximity of barge/train transportation	

Table E-5. Tier 2 Matrix - Decommissioning Activities, Issues, and Variables

Activities	Issues																
	Onsite/Offsite Land Use	**Water Use**	Water Quality	Air Quality	Aquatic Ecology	Terrestrial Ecology	Threatened and Endangered Species	Radiological	Rad Accidents	Occupational Issues	Cost	Socioeconomic	Environmental Justice	Cultural Impacts	Aesthetic Issues	Noise	Irretrievable Resources
1. Remove fuel																	
Transfer fuel to spent fuel pool		X	X					Ops; Interim Time	Ops; Interim Time	X							
Drain primary system			X					Ops; Interim Time; Decom Opt; Store Time	Ops; Interim Time; Decom Opt; Store Time	X	Interim Time; Decom Opt; Store Time						
Process liquid			X					Ops; Interim Time	Ops; Interim Time	X	Type; Size						
2. Organizational changes																	
Reduce staff		X						Type; Size			Type; Size; Decom Opt; Store Time	Size; Loc; Multi-Unit	Size; Loc; Multi-Unit				
Employ contractor or other additional staff		X		Size Loc; Decom Opt				Type; Size; Decom Opt; Store Time			Type; Size, Decom Opt; Store Time	Type; Size; Loc; Multi-Unit	Type; Size; Loc; Multi-Unit				

"X" indicates that none of the variables change the analysis.

Table E-5. (contd)

Activities	Issues: Onsite/Offsite Land Use	Water Use	Water Quality	Air Quality	Aquatic Ecology	Terrestrial Ecology	Threatened and Endangered Species	Radiological	Rad Accidents	Occ Issues	Cost	Socioeconomic	Env Justice	Cultural Impacts	Aesthetic Issues	Noise	Irretrievable Resources
Adjust site training								Type; Size; Decom Opt; Store Time	X	X	Type; Size; Decom Opt; Store Time						
Changes to licensing basis - site-specific											Type; Size; Decom Opt; Store Time						
3. Stabilization																	
Drain and flush system			X	X				Type; Size; Ops; Interim Time; Decom Opt; Store Time	Type; Size; Ops; Interim Time; Decom Opt; Store Time	Type; Size; Ops; Interim Time; Decom Opt; Store Time	Type; Size; Ops; Interim Time; Decom Opt; Store Time						

"X" indicates that none of the variables change the analysis.

Table E-5. (contd)

Activities	Issues																
	Onsite/Offsite Land Use	Water Use	Water Quality	Air Quality	Aquatic Ecology	Terrestrial Ecology	Threatened and Endangered Species	Radiological	Rad Accidents	Occ Issues	Cost	Socioeconomic	Env Justice	Cultural Impacts	Aesthetic Issues	Noise	Irretrievable Resources
Isolate systems, structures, and components that are no longer required				X				Type; Size; Ops; Interim Time; Decom Opt; Store Time		Type; Size, Ops; Interim Time; Decom Opt; Store Time	Type; Size; Ops; Interim Time; Decom Opt; Store Time						
Rewiring of site to eliminate unneeded electrical circuits						Loc; Env; Land Mass	Loc; Env; Land Mass	Type; Size; Ops; Interim Time; Decom Opt; Store Time		Type; Size; Decom Opt	Type; Size; Ops; Interim Time; Decom Opt; Store Time			Loc; Land Mass			

"X" indicates that none of the variables change the analysis.

Table E-5. (contd)

Activities	Issues																
	Onsite/Offsite Land Use	Water Use	Water Quality	Air Quality	Aquatic Ecology	Terrestrial Ecology	Threatened and Endangered Species	Radiological	Rad Accidents	Occ Issues	Cost	Socioeconomic	Env Justice	Cultural Impacts	Aesthetic Issues	Noise	Irretrievable Resources
4. Post-shutdown surveys																	
Baseline surveys for the decontamination work								Type; Size; Ops; Interim Time; Decom Opt; Land Mass			Type; Size; Ops; Interim Time; Decom Opt; Land Mass						
Continual surveys								Type; Size; Ops; Interim Time; Decom Opt; Store Time; Land Mass			Type; Size; Ops; Interim Time; Decom Opt; Land Mass						
5. Create nuclear island																	
Install electrical power supply to spent fuel pool								Ops; Interim Time		Size	X						
Reduce the security area to just that around the fuel											X						

"X" indicates that none of the variables change the analysis.

Table E-5. (contd)

Activities	Issues																
	Onsite/Offsite Land Use	Water Use	Water Quality	Air Quality	Aquatic Ecology	Terrestrial Ecology	Threatened and Endangered Species	Radiological	Rad Accidents	Occ Issues	Cost	Socioeconomic	Env Justice	Cultural Impacts	Aesthetic Issues	Noise	Irretrievable Resources
Change security function											X						
Install or modify chemistry controls										Size							
Move old or install new security-related equipment								Ops; Interim Time		Size, Land Mass	X						
6. Chemical decontamination of primary loop																	
Cutting, chemicals in, chemicals out, cleanup/ decontamination								Type; Size; Ops; Interim Time; Decom Opt; Store Time	Type; Size; Ops; Interim Time; Decom Opt; Store Time	Type; Size; Decom Opt	Type; Size; Ops; Interim Time; Decom Opt; Store Time						

"X" indicates that none of the variables change the analysis.

Table E-5. (contd)

Activities	Issues																
	Onsite/Offsite Land Use	Water Use	Water Quality	Air Quality	Aquatic Ecology	Terrestrial Ecology	Threatened and Endangered Species	Radiological	Rad Accidents	Occ Issues	Cost	Socioeconomic	Env Justice	Cultural Impacts	Aesthetic Issues	Noise	Irretrievable Resources
7. Large component removal																	
Remove reactor vessel and internals intact or cut up	Env; Land Mass	X				Trans Prox	Trans Prox	Type; Size; Ops; Interim Time; Decom Opt; Store Time	Type, Size, Ops; Interim Time, Decom Opt; Store Time	Type; Size; Decom Opt	Type; Size; Ops; Interim Time; Decom Opt; Store Time; Trans Prox			Trans Prox			
Steam generator and other large components removed intact or cut up	Env; Land Mass					Trans Prox	Trans Prox	Type; Size, Ops; Interim Time; Decom Opt; Store Time	Type, Size, Ops; Interim Time; Decom Opt; Store Time	Type, Size; Decom Opt	Type; Size; Ops; Interim Time; Decom Opt; Store Time; Trans Prox			Trans Prox			

"X" indicates that none of the variables change the analysis

Table E-5. (contd)

Activities	Issues																
	Onsite/Offsite Land Use	Water Use	Water Quality	Air Quality	Aquatic Ecology	Terrestrial Ecology	Threatened and Endangered Species	Radiological	Rad Accidents	Occ Issues	Cost	Socioeconomic	Env Justice	Cultural Impacts	Aesthetic Issues	Noise	Irretrievable Resources
8. Storage preparation activities for SAFSTOR																	
Establish a reactor coolant system vent pathway				Gas Emissions				Type; Size; Ops; Interim Time; Store Time		Type; Size; Ops; Interim Time; Store Time	Type; Size; Ops; Interim Time; Store Time						
Establish containment vent pathway				Gas Emissions				Type; Size; Ops; Interim Time; Store Time		Type; Size; Ops; Interim Time; Store Time	Type; Size; Ops; Interim Time; Store Time						
De-energize systems, put in monitors where they are needed								Type; Size; Ops; Interim Time; Store Time		Type; Size	Type; Size; Ops; Interim Time; Store Time						

"X" indicates that none of the variables change the analysis.

Table E-5. (contd)

Activities	Onsite/Offsite Land Use	Water Use	Water Quality	Air Quality	Aquatic Ecology	Terrestrial Ecology	Threatened and Endangered Species	Radiological	Rad Accidents	Occ Issues	Cost	Socioeconomic	Env Justice	Cultural Impacts	Aesthetic Issues	Noise	Irretrievable Resources
	Issues																
Perform a radiological asessment								Type; Size; Ops; Interim Time; Store Time			Type; Size; Ops; Interim Time; Store Time						
9. Storage (SAFSTOR)																	
Monitor systems and radiation levels, etc.								Type; Size, Interim Time; Store Time		Type, Size; Store Time	Type, Size; Store Time						
Do preventive and corrective maintenance on SSCs								Type; Size, Interim Time; Store Time			Type; Size; Store Time						
Maintain the security system											Store Time; Multi-Unit						

"X" indicates that none of the variables change the analysis.

Table E-5. (contd)

Activities	Issues																
	Onsite/Offsite Land Use	Water Use	Water Quality	Air Quality	Aquatic Ecology	Terrestrial Ecology	Threatened and Endangered Species	Radiological	Rad Accidents	Occ Issues	Cost	Socioeconomic	Env Justice	Cultural Impacts	Aesthetic Issues	Noise	Irretrievable Resources
Maintain effluent and environmental monitoring programs				Gas Emissions							Store Time; Multi-Unit						
10. Decontamination and Dismantlement phases of DECON, SAFSTOR, and ENTOMB1																	
Chemical decontamination (surface/specific components)								Type; Size; Ops, Interim Time; Store Time	Type; Size; Ops; Interim Time; Store Time	Type; Size	Type; Size; Ops; Interim Time; Store Time						
Decontamination of piping inside walls								Type; Size; Ops; Interim Time; Store Time	Type; Size; Ops; Interim Time; Store Time	Type; Size	Type; Size; Ops; Interim Time; Store Time						
High-pressure water sprays of surface		X	X					Type; Size; Ops; Interim Time; Store Time	Type; Size; Ops; Interim Time; Store Time		Type; Size; Ops; Interim Time; Store Time						

"X" indicates that none of the variables change the analysis.

Table E-5. (contd)

Activities	Issues																
	Onsite/Offsite Land Use	Water Use	Water Quality	Air Quality	Aquatic Ecology	Terrestrial Ecology	Threatened and Endangered Species	Radiological	Rad Accidents	Occ Issues	Cost	Socioeconomic	Env Justice	Cultural Impacts	Aesthetic Issues	Noise	Irretrievable Resources
Remove contaminated soil from specific areas						Loc; Env, Land Mass	Loc; Env; Land Mass	Type; Size; Ops; Interim Time; Store Time		Type; Size	Type; Size; Ops; Interim Time; Store Time			Loc; Land Mass			
Do preventive and corrective maintenance on SSCs								Type; Size; Ops; Interim Time; Store Time		Type, Size	Type; Size; Ops; Interim Time; Store Time						
Maintain the security system											Type; Multi-Unit						
Maintain effluent and environmental monitoring programs				Gas Emissions							Type; Multi-Unit						

"X" indicates that none of the variables change the analysis.

Table E-5. (contd)

Activities	Issues																
	Onsite/Offsite Land Use	Water Use	Water Quality	Air Quality	Aquatic Ecology	Terrestrial Ecology	Threatened and Endangered Species	Radiological	Rad Accidents	Occ Issues	Cost	Socioeconomic	Env Justice	Cultural Impacts	Aesthetic Issues	Noise	Irretrievable Resources
11. System dismantlement																	
Cut out radioactive piping								Type; Size; Ops; Interim Time; Decom Opt; Store Time; Struct	Type; Size; Ops; Interim Time; Decom Opt; Store Time; Struct	Type; Size; Ops; Interim Time; Decom Opt; Store Time; Struct	Type; Size; Ops; Interim Time; Decom Opt; Store Time; Struct						
Remove large and small tanks or other radioactive components from the facility								Type; Size; Ops; Interim Time; Decom Opt; Store Time; Struct	Type; Size; Ops; Interim Time; Decom Opt; Store Time; Struct	Type; Size; Ops; Interim Time; Decom Opt; Store Time; Struct	Type; Size; Ops; Interim Time; Decom Opt; Store Time; Struct						

"X" indicates that none of the variables change the analysis.

Table E-5. (contd)

	Issues																
Activities	Onsite/Offsite Land Use	Water Use	Water Quality	Air Quality	Aquatic Ecology	Terrestrial Ecology	Threatened and Endangered Species	Radiological	Rad Accidents	Occ Issues	Cost	Socioeconomic	Env Justice	Cultural Impacts	Aesthetic Issues	Noise	Irretrievable Resources
12. Structure Dismantlement																	
Rubblization	Size	Size	Grd-water	Size; Loc; Land Mass				Type; Size; Loc; Ops; Interim Time; Decom Opt; Store Time		X	Size				X	X	X
Remove structures that are necessary for plant operation	Size; Loc; Land Mass	Size; Struct		Type, Size; Struct	Size; Loc	Size, Loc	Size, Loc	Type; Size; Loc; Ops; Interim Time, Decom Opt; Store Time	Type; Size; Loc; Ops; Interim Time; Decom Opt; Store Time	Size; Decom Opt; Land Mass	Type; Size, Loc; Ops; Interim Time, Decom Opt; Store Time				Size, Loc	Size; Loc	Size; Decom Opt

"X" indicates that none of the variables change the analysis.

Table E-5. (contd)

Activities	Onsite/Offsite Land Use	Water Use	Water Quality	Air Quality	Aquatic Ecology	Terrestrial Ecology	Threatened and Endangered Species	Radiological	Rad Accidents	Occ Issues	Cost	Socioeconomic	Env Justice	Cultural Impacts	Aesthetic Issues	Noise	Irretrievable Resources
	Issues																
13. Entombment																	
Install engineered barriers				Size				Size		X	Size				X	X	
Disconnect operational systems (e g., electrical and fire protection)								Size		X	Size						
Remove all radioactive material that is outside of containment								Type; Size		X	Type; Size					Type; Size; Land Mass	
Place material inside containment										X	Size						
Lower containment ceiling (optional)		X		Type; Size				Type; Size; Ops; Interim Time	Type; Size; Ops; Interim Time	X	Size						
ENTOMB facility in concrete		X		Type; Size				Type; Size; Ops; Interim Time		X	Size				X	X	

"X" indicates that none of the variables change the analysis.

Table E-5. (contd)

Activities	Issues: Onsite/Offsite Land Use	Water Use	Water Quality	Air Quality	Aquatic Ecology	Terrestrial Ecology	Threatened and Endangered Species	Radiological	Rad Accidents	Occ Issues	Cost	Socioeconomic	Env Justice	Cultural Impacts	Aesthetic Issues	Noise	Irretrievable Resources
14. LLW packaging and storage and disposal	X							Type; Size; Ops; Interim Time; Decom Opt; Store Time	Type; Size; Ops; Interim Time; Decom Opt; Store Time	Type, Size; Ops; Interim Time; Decom Opt, Store Time	Type; Size; Ops, Interim Time; Decom Opt; Store Time						Type; Size; Ops; Interim Time; Decom Opt; Store Time
15. Transportation																	
Large components				Size; Loc; Env; Decom Opt				LLW; Trans Prox	LLW; Trans Prox	X	LLW; Trans Prox		LLW; Trans Prox				X
LLW				Trans Prox; Size; Loc; Env; Decom Opt; LLW				LLW	LLW	X	LLW		Size; Loc; Env				X

"X" indicates that none of the variables change the analysis.

Table E-5. (contd)

Activities	Issues																
	Onsite/Offsite Land Use	Water Use	Water Quality	Air Quality	Aquatic Ecology	Terrestrial Ecology	Threatened and Endangered Species	Radiological	Rad Accidents	Occ Issues	Cost	Socioeconomic	Env Justice	Cultural Impacts	Aesthetic Issues	Noise	Irretrievable Resources
Equipment into site				Decom Opt; Trans Prox							Trans Prox						
Backfill trucked into site				Size; Decom Opt							Size; Decom Opt; Land Mass; Trans Prox						X
Nonradioactive waste				Size; Loc; Env; Struct; Decom Opt, Trans Prox							Type; Size; Decom Opt						X

Table E-5. (contd)

16. License Termination Activities																	
Complete final radiation survey								X		X	Size; Type; Decom Opt; Land Mass						
Partial site release								X			Loc; Env; Struct, Land Mass; Culture						

"X" indicates that none of the variables change the analysis.

Appendix F

Summary Table of Permanently Shutdown and Currently Operating Commercial Nuclear Reactors

Table F-1. Permanently Shutdown Commercial Nuclear Plants

Nuclear Plant	Location	Reactor Type	Thermal Power	Decommissioning Option[a]	Total Site Area (ac)	Cooling System[b]	Cooling Water Source	Fuel Location	Operating License	Shutdown Date[c]
Reactors that are Currently in the Process of Decommissioning										
Big Rock Point	Michigan	BWR	240 MW	DECON	593	OT	Lake Michigan	Fuel in pool	05/01/1964	08/30/1997
Dresden, Unit 1	Illinois	BWR	700 MW	SAFSTOR	953+1274 cooling pond	Cooling lake and spray system	Kankakee River	Fuel in onsite ISFSI	09/28/1959	10/31/1978
Fermi, Unit 1	Michigan	FBR	200 MW	SAFSTOR	900[d]	OT	Lake Erie	No fuel onsite	05/01/1963	09/22/1972
GE-VBWR	California	BWR	50 MW	SAFSTOR	~1[e]	MDCI	Onsite cooling pond	No fuel onsite	05/14/1956	12/09/1963
Haddam Neck	Connecticut	PWR	1825 MW	DECON	524	OT	Connecticut River	Fuel in pool	12/27/1974	07/22/1996
Humboldt Bay, Unit 3	California	BWR	200 MW	SAFSTOR	143	OT	Humboldt Bay	Fuel in pool	08/28/1962	07/02/1976
Indian Point, Unit 1	New York	PWR	615 MW	SAFSTOR	239	OT	Hudson River	Fuel in pool	03/26/1962	10/31/1974
La Crosse	Wisconsin	BWR	165 MW	SAFSTOR	163[f]	FCDC	Mississippi River	Fuel in pool	07/03/1967	04/30/1987
Maine Yankee	Maine	PWR	2700 MW	DECON	820	OT	Montsweag Bay	Fuel in pool	06/29/1973	12/06/1996
Millstone, Unit 1	Connecticut	BWR	2011 MW	SAFSTOR	500	OT	Long Island Sound	Fuel in pool	10/07/1970	11/04/1995
Peach Bottom, Unit 1	Pennsylvania	HTGR	115 MW	SAFSTOR	620[g]	OT	NA	No fuel onsite	06/01/1967	10/31/1974

Table F-1. (contd)

Nuclear Plant	Location	Reactor Type	Thermal Power	Decommissioning Option[a]	Total Site Area (ac)	Cooling System[b]	Cooling Water Source	Fuel Location	Operating License	Shutdown Date[c]
Reactors that are Currently in the Process of Decommissioning (contd)										
Rancho Seco	California	PWR	2772 MW	SAFSTOR/ incremental decom	2480	NDCT	Folsom Canal	Fuel in onsite ISFSI/ DECON proposed in 1997	08/16/1974	06/07/1989
San Onofre, Unit 1	California	PWR	1347 MW	SAFSTOR	84	OT	Pacific Ocean	Fuel in pool	03/27/1967	11/30/1992
Saxton	Pennsylvania	PWR	28 MW	SAFSTOR	~1.1[h]	OT[i]	Juniata River	No fuel onsite/ currently in DECON	11/15/1961	05/01/1972
Three Mile Island, Unit 2	Pennsylvania	PWR	2772 MW	Accident cleanup followed by storage	472	NDCT	Susquehanna River	Approx 900 kg fuel onsite/ Post-Defueling Monitored Storage	02/08/1978	03/28/1979
Trojan	Oregon	PWR	3411 MW	DECON	635	NDCT	Columbia River	Fuel in pool	11/21/1975	11/09/1992
Yankee Rowe	Massachusetts	PWR	600 MW	DECON	1997	OT	Deerfield River	Fuel in pool[j]	12/24/1963	10/01/1991
Zion, Unit 1	Illinois	PWR	3250 MW	SAFSTOR	250	OT	Lake Michigan	Fuel in pool	10/19/1973	02/21/1997
Zion, Unit 2	Illinois	PWR	3250 MW	SAFSTOR	250	OT	Lake Michigan	Fuel in pool	11/14/1973	09/19/1996

Table F-1. (contd)

Nuclear Plant	Location	Reactor Type	Thermal Power	Decommissioning Option[a]	Total Site Area (ac)	Cooling System[b]	Cooling Water Source	Fuel Location	Operating License	Shutdown Date[c]
Reactors that have had their Licenses Terminated										
Fort St. Vrain	Colorado	HTGR	842 MW	DECON	2798	OT	NA	Fuel in ISFSI/ License terminated in 1997	12/01/1976	08/18/19891
Pathfinder	South Dakota	BWR	190 MW	SAFSTOR	1200	MDCT	Big Sioux River	No fuel onsite/ License terminated in 1992	01/01/1964	09/16/1967
Shoreham	New York	BWR	2436 MW	DECON	499	OT	Long Island Sound	No fuel onsite/ License terminated in 1995	06/01/1985	06/28/1989

(a) The option shown in the table for each plant is the option that has been officially provided to NRC. Plants in DECON may have had a short (1 to 4 yr) SAFSTOR period. Likewise, plants in SAFSTOR may have performed some DECON activities or may have transitioned from the storage phase into the decontamination and dismantlement phase of SAFSTOR.

(b) OT = once through; NDCT = natural draft cooling tower; FCDC = forced-circulation, direct cycle; MDCT - Mechanical Draft Cooling Tower; NA = not applicable.

(c) The shutdown date corresponds to the date of the last criticality.

(d) Originally licensed site area for Fermi, Unit 1. Currently, the facility occupies an area of less than 1.6 ha (4 ac) on the Fermi, Unit 2, site.

(e) The reactor building and associated structures occupy approximately 0 4 ha (1 ac) in the approximately 640 ha (1600 ac) Vallicitos Nuclear Center.

(f) The La Crosse site area is approximately 1 2 ha (3 ac) with the total utility-owned area being 66 ha (163 ac).

(g) Peach Bottom site area includes all units (1, 2, and 3).

(h) Originally licensed site area for the Saxton Plant was 0.4 ha (1.1 ac), wholly contained in a utility-owned property of approximately 61 ha (150 ac).

(i) Once-through cooling combined with a fossil steam electric generating facility also using spray pond during periods of high ambient temperatures.

(j) License is in process of transferring fuel to dry storage in onsite ISFSI.

Table F-2. Currently Operating Commercial Nuclear Plants

Nuclear Plant	Unit	Location	Reactor Type	Thermal Power[a]	Total Site Area, acres	Cooling System[b]	Cooling Water Source	Operating License	License Expiration[c]
Arkansas Nuclear One	1	Arkansas	PWR	2568 MW	1160	OT	Dardanelle Reservoir	05/21/1974	05/20/2034[d]
Arkansas Nuclear One	2	Arkansas	PWR	2815 MW	1160	NDCT	Dardanelle Reservoir	09/01/1978	07/17/2018
Beaver Valley	1	Pennsylvania	PWR	2652 MW	501	NDCT	Ohio River	07/02/1976	01/29/2016
Beaver Valley	2	Pennsylvania	PWR	2652 MW	501	NDCT	Ohio River	08/14/1987	05/27/2027
Braidwood	1	Illinois	PWR	3411 MW	4457	CCCP	Kankakee River	07/02/1987	10/17/2026
Braidwood	2	Illinois	PWR	3411 MW	4457	CCCP	Kankakee River	05/20/1988	12/18/2027
Browns Ferry	1	Alabama	BWR	3293 MW	840	OT with towers	Tennessee River	12/20/1973	12/20/2013
Browns Ferry	2	Alabama	BWR	3293 MW	840	OT with towers	Tennessee River	08/02/1974	06/28/2014
Browns Ferry	3	Alabama	BWR	3293 MW	840	OT with towers	Tennessee River	08/18/1976	07/02/2016
Brunswick	1	North Carolina	BWR	2558 MW	1210	OT	Cape Fear River	11/12/1976	09/08/2016
Brunswick	2	North Carolina	BWR	2436 MW	1210	OT	Cape Fear River	12/27/1974	12/27/2014
Byron	1	Illinois	PWR	3411 MW	1398	NDCT	Rock River	02/14/1985	10/31/2024
Byron	2	Illinois	PWR	3411 MW	1398	NDCT	Rock River	01/30/1987	11/06/2026
Callaway		Missouri	PWR	3565 MW	3188	NDCT	Missouri River	10/18/1984	10/18/2024
Calvert Cliffs	1	Maryland	PWR	2700 MW	1135	OT	Chesapeake Bay	07/31/1974	07/31/2034[d]
Calvert Cliffs	2	Maryland	PWR	2700 MW	1135	OT	Chesapeake Bay	11/30/1976	08/31/2036[d]
Catawba	1	South Carolina	PWR	3411 MW	391	MDCT	Lake Wylie	01/17/1985	12/06/2024
Catawba	2	South Carolina	PWR	3411 MW	391	MDCT	Lake Wylie	05/15/1986	02/24/2026
Clinton		Illinois	BWR	2894 MW	14090	OT	Salt Creek	04/17/1987	09/29/2026
Columbia Generating Station		Washington	BWR	3486 MW	DOE, Hanford Reservation	MDCT	Columbia River	04/13/1984	12/20/2023
Comanche Peak	1	Texas	PWR	3411 MW	7669	OT	Squaw Creek Reservoir	04/17/1990	02/08/2030
Comanche Peak	2	Texas	PWR	3411 MW	7669	OT	Squaw Creek Reservoir	04/06/1993	02/02/2033
Cooper		Nebraska	BWR	2381 MW	1090	OT	Missouri River	01/18/1974	01/18/2014
Crystal River	3	Florida	PWR	2544 MW	4738	OT	Gulf of Mexico	01/28/1977	12/03/2016
Davis Besse		Ohio	PWR	2772 MW	954	NDCT	Lake Erie	04/22/1977	04/22/2017
Diablo Canyon	1	California	PWR	3338 MW	741	OT	Pacific Ocean	11/02/1984	09/22/2021
Diablo Canyon	2	California	PWR	3411 MW	741	OT	Pacific Ocean	08/26/1985	04/26/2025
Donald C. Cook	1	Michigan	PWR	3250 MW	642	OT	Lake Michigan	10/25/1974	10/25/2014
Donald C. Cook	2	Michigan	PWR	3411 MW	642	OT	Lake Michigan	12/23/1977	12/23/2017
Dresden	2	Illinois	BWR	2527 MW	953+1274 Cooling pond	Cooling lake and spray canal	Kankakee	02/20/1991	01/10/2006
Dresden	3	Illinois	BWR	2527 MW	953+1274 Cooling pond	Cooling lake and spray canal	Kankakee	03/02/1971	01/12/2011
Edwin I Hatch	1	Georgia	BWR	2558 MW	2244	MDCT	Altamaha River	10/13/1974	08/06/2034
Edwin I Hatch	2	Georgia	BWR	2558 MW	2244	MDCT	Altamaha River	06/13/1978	06/13/2038
Fermi	2	Michigan	BWR	3430 MW	1120	NDCT	Lake Erie	07/15/1985	03/20/2025
Fort Calhoun	1	Nebraska	PWR	1500 MW	667	OT	Missouri River	08/09/1973	08/09/2013
Ginna	1	New York	PWR	1520 MW	338	OT	Lake Ontario	12/10/1984	09/18/2009
Grand Gulf	1	Mississippi	BWR	3833 MW	2100	NDCT	Mississippi River	11/01/1984	06/16/2022

Table F-2. (contd)

Nuclear Plant	Unit	Location	Reactor Type	Thermal Power[a]	Total Site Area, acres	Cooling System[b]	Cooling Water Source	Operating License	License Expiration[c]
H B. Robinson	2	South Carolina	PWR	2300 MW	4942	OT	Lake Robinson	09/23/1970	07/31/2010
Hope Creek	1	Delaware	BWR	3293 MW	740	NDCT	Delaware River	07/25/1986	04/11/2026
Indian Point	2	New York	PWR	3071 MW	239	OT	Hudson River	09/28/1973	09/28/2013
Indian Point	3	New York	PWR	3025 MW	239	OT	Hudson River	04/05/1976	12/15/2015
James A. Fitzpatrick		New York	BWR	2536 MW	702	OT	Lake Ontario	10/17/1974	10/17/2014
Joseph M. Farley	1	Alabama	PWR	2775 MW	1850	MDCT	Chattahochee River	06/25/1977	06/25/2017
Joseph M. Farley	2	Alabama	PWR	2775 MW	1850	MDCT	Chattahochee River	03/31/1981	03/31/2021
Kewaunee		Wisconsin	PWR	1650 MW	908	OT	Lake Michigan	12/21/1973	12/21/2013
La Salle	1	Illinois	BWR	3323 MW	3064	Cooling pond	Illinois River	08/13/1982	05/17/2022
La Salle	2	Illinois	BWR	3323 MW	3064	Cooling pond	Illinois River	03/23/1984	12/16/2023
Limerick	1	Pennsylvania	BWR	3458 MW	595	NDCT	Schuylkill River	08/08/1985	10/26/2024
Limerick	2	Pennsylvania	BWR	3458 MW	595	NDCT	Schuylkill River	08/25/1989	06/22/2029
McGuire	1	North Carolina	PWR	3411 MW	577	OT	Lake Norman	07/08/1981	06/12/2021
McGuire	2	North Carolina	PWR	3411 MW	577	OT	Lake Norman	05/27/1983	03/03/2023
Millstone	2	Connecticut	PWR	2700 MW	494	OT	Long Island Sound	09/26/1975	07/31/2015
Millstone	3	Connecticut	PWR	3411 MW	494	OT	Long Island Sound	01/31/1986	11/25/2025
Monticello		Minnesota	BWR	1670 MW	2125	OT with towers	Mississippi River	01/09/1981	09/08/2010
Nine Mile Point	1	New York	BWR	1850 MW	890	OT	Lake Ontario	12/26/1974	08/22/2009
Nine Mile Point	2	New York	BWR	3467 MW	890	NDCT	Lake Ontario	07/02/1987	10/31/2026
North Anna	1	Virginia	PWR	2893 MW	1043	OT	Lake Anna	04/01/1978	04/01/2018
North Anna	2	Virginia	PWR	2893 MW	1043	OT	Lake Anna	08/21/1980	08/21/2020
Oconee	1	South Carolina	PWR	2568 MW	519	OT	Lake Keowee	02/06/1973	02/06/2033[d]
Oconee	2	South Carolina	PWR	2568 MW	519	OT	Lake Keowee	10/06/1973	10/06/2033[d]
Oconee	3	South Carolina	PWR	2568 MW	519	OT	Lake Keowee	07/19/1974	07/19/2034[d]
Oyster Creek	1	New Jersey	BWR	1930 MW	1416	OT	Barnegat Bay	04/09/1969	12/15/2009
Palisades	1	Michigan	PWR	2530 MW	487	MDCT	Lake Michigan	03/24/1971	03/14/2007
Palo Verde	1	Arizona	PWR	3800 MW	4050	MDCT	Phoenix City Sewage and Treatment Plant	06/01/1985	12/31/2024
Palo Verde	2	Arizona	PWR	3876 MW	4050	MDCT	Phoenix City Sewage and Treatment Plant	04/24/1986	12/09/2025
Palo Verde	3	Arizona	PWR	3876 MW	4050	MDCT	Phoenix City Sewage and Treatment Plant	11/25/1987	03/25/2027
Peach Bottom	2	Pennsylvania	BWR	3458 MW	620	OT with towers	Conowingo Pond	12/14/1973	08/08/2013
Peach Bottom	3	Pennsylvania	BWR	3458 MW	620	OT with towers	Conowingo Pond	07/02/1974	07/02/2014
Perry	1	Ohio	BWR	3579 MW	1112	NDCT	Lake Erie	11/13/1986	03/18/2026
Pilgrim	1	Massachusetts	BWR	1998 MW	517	OT	Cape Cod Bay	09/15/1972	06/08/2012
Point Beach	1	Wisconsin	PWR	1519 MW	2065	OT	Lake Michigan	10/05/1970	10/05/2010
Point Beach	2	Wisconsin	PWR	1519 MW	2065	OT	Lake Michigan	03/08/1973	03/08/2013
Prairie Island	1	Minnesota	PWR	1650 MW	568	MDCT or OT	Mississippi River	04/05/1974	08/09/2013
Prairie Island	2	Minnesota	PWR	1650 MW	568	MDCT or OT	Mississippi River	10/29/1974	10/29/2014

Table F-2. (contd)

Nuclear Plant	Unit	Location	Reactor Type	Thermal Power[a]	Total Site Area, acres	Cooling System[b]	Cooling Water Source	Operating License	License Expiration[c]
Quad Cities	1	Illinois	BWR	2511 MW	784	OT	Mississippi River	12/14/1972	12/14/2012
Quad Cities	2	Illinois	BWR	2511 MW	784	OT	Mississippi River	12/14/1972	12/14/2012
River Bend	1	Louisiana	BWR	2894 MW	3342	MDCT	Mississippi River	11/20/1985	08/29/2025
Salem	1	New Jersey	PWR	3411 MW	691	OT	Delaware River	12/01/1976	08/13/2016
Salem	2	New Jersey	PWR	3411 MW	691	OT	Delaware River	05/20/1981	04/18/2020
San Onofre	2	California	PWR	3390 MW	84	OT	Pacific Ocean	09/07/1982	10/18/2013
San Onofre	3	California	PWR	3390 MW	84	OT	Pacific Ocean	09/16/1983	10/18/2013
Seabrook	1	New Hampshire	PWR	3411 MW	896	OT	Atlantic Ocean	03/15/1990	10/17/2026
Sequoyah	1	Tennessee	PWR	3411 MW	525	OT and/or NDCT	Chickamauga Lake	09/17/1980	09/17/2020
Sequoyah	2	Tennessee	PWR	3411 MW	525	OT and/or NDCT	Chickamauga Lake	09/15/1981	09/15/2021
Shearon Harris	1	North Carolina	PWR	2775 MW	10744	NDCT	Buckhorn Creek	01/12/1987	10/24/2026
South Texas	1	Texas	PWR	3800 MW	12350	CCCP	Colorado River	03/22/1988	08/20/2027
South Texas	2	Texas	PWR	3800 MW	12350	CCCP	Colorado River	03/28/1989	12/15/2028
St. Lucie	1	Florida	PWR	2700 MW	1132	OT	Atlantic Ocean	03/01/1976	03/01/2016
St. Lucie	2	Florida	PWR	2700 MW	1132	OT	Atlantic Ocean	06/10/1983	04/06/2023
Summer	1	South Carolina	PWR	2900 MW	2200	OT	Lake Monticello	11/12/1982	08/06/2022
Surry	1	Virginia	PWR	2546 MW	840	OT	James River	05/25/1972	05/25/2012
Surry	2	Virginia	PWR	2546 MW	840	OT	James River	01/29/1973	01/29/2013
Susquehanna	1	Pennsylvania	BWR	3441 MW	1075	NDCT	Susquehanna River	11/12/1982	07/17/2022
Susquehanna	2	Pennsylvania	BWR	3441 MW	1075	NDCT	Susquehanna River	06/27/1984	03/23/2024
Three Mile Island	1	Pennsylvania	PWR	2568 MW	472	NDCT	Susquehanna River	04/19/1974	04/19/2014
Turkey Point	3	Florida	PWR	2300 MW	23970	Closed cycle canal	Biscane Bay	07/19/1972	07/19/2032
Turkey Point	4	Florida	PWR	2300 MW	23970	Closed cycle canal	Biscane Bay	04/10/1973	04/10/2033
Vermont Yankee	1	Vermont	BWR	1593 MW	125	OT and towers	Connecticut River	02/28/1973	03/21/2012
Vogtle	1	Georgia	PWR	3565 MW	3169	NDCT	Savannah River	03/16/1987	01/16/2027
Vogtle	2	Georgia	PWR	3565 MW	3169	NDCT	Savannah River	03/31/1989	02/09/2029
Waterford	3	Louisiana	PWR	3390 MW	3561	OT	Mississippi	03/16/1985	12/18/2024
Watts Bar	1	Tennessee	PWR	3411 MW	1769	NDCT	Chickamauga Lake	02/07/1996	11/09/2035
Wolf Creek	1	Kansas	PWR	3565 MW	9818	CCCP	Wolf Creek	06/04/1985	03/11/2025

(a) Licensees may seek power uprates
(b) OT = once-through, NDCT = natural draft cooling towers; CCCP = closed-cycle cooling pond, MDCT = mechanical draft cooling towers.
(c) Licensees may seek a renewal of the license
(d) Includes 20-year license renewal period

Appendix G

Radiation Protection Considerations for Nuclear Power Facility Decommissioning

Appendix G

Radiation Protection Considerations for Nuclear Power Facility Decommissioning

Radiological issues are associated with the process of decommissioning nuclear reactor facilities, including power reactors, at the end of their operating lives. Both occupational workers and members of the public will be affected by these processes as a result of direct exposures to sources of radiation and as a result of small releases of radioactive materials in gaseous and liquid effluents. This appendix is intended to provide pertinent background information for analyses in this Generic Environmental Impact Statement Supplement.

G.1 Radiation Protection Standards

The primary U.S. Nuclear Regulatory Commission (NRC) standards for protection of workers and members of the public are found in 10 CFR Part 20. These standards are consistent with guidance to Federal agencies prepared by interagency committees and issued by the President. The Federal guidance is based on recommendations published by national and international organizations, such as the National Council on Radiation Protection and Measurements (NCRP), the International Commission on Radiological Protection (ICRP), and the United Nations Scientific Committee on the Effects of Atomic Radiation. Proposed changes to regulations are typically published in the Federal Register for public comment before enactment of the final rule. The most recent major revision to the NRC radiation protection regulations in 10 CFR Part 20 were enacted in 1991, with several amendments issued in the intervening years. Implementation of the regulations became mandatory for NRC licensees in 1994.

G.1.1 Concepts, Terminology, Quantities, and Units Used in Radiation Protection

Title 10 CFR Part 20 was first promulgated in 1957. In 1961, the regulation was amended to add an appendix containing maximum permissible concentrations and a new occupational dose limit structure for whole-body exposure to external radiation (1.25 rem/quarter, or 3 rem/quarter with 5 rem/yr average as a limit on the cumulative dose). The 1991 revision differs considerably from the previous regulations with respect to basic concepts, terminology, radiation dose quantities, and the associated dose units. This section is included to familiarize readers with these concepts.

G.1.1.1 Conventional Quantities and Units

In 10 CFR Part 20, the unit "rad" is usually used for the quantity "radiation absorbed dose" whenever early biological effects are the concern. When latent effects (e.g., cancer and genetic effects) are being considered, the unit "rem" is used for the dose equivalent (DE) quantity. The absorbed dose in rads is multiplied by an overall efficiency factor *Q* to obtain the DE in rem. Each type of radiation has its own value of *Q*, which in a very general way permits adding absorbed doses from different radiations to estimate the probability of stochastic effects. Values of Q in 10 CFR Part 20 are indicated in Table G-1.

Table G-1. Quality Factors and Absorbed Equivalents

Radiation	Absorbed Dose, rad	Q	Dose Equivalent, rem
x -, gamma or beta radiation	1	1	1
Alpha particles	1	20	20
Neutron (spectrum unknown)	1	10	10
Note: To convert rem to sievert, multiply by 0.01.			

These values of *Q* reflect the overall efficiency of a given type of radiation in causing latent effects and are not used for early effects such as acute radiation syndrome. The values were derived in consideration of the ability of the various radiations to ionize atoms in water as well as the relative biological effectiveness factors observed for specific effects.

G.1.1.2 International System of Units

The International System (SI) units of particular interest in radiation protection are the gray (Gy), sievert (Sv), and becquerel (Bq), as shown in Table G-2. The SI units are part of the metric system; however, they are not yet widely used in the United States.
Title 10 CFR 20.2101 requires the records to be reported in the units of curie, rad, and rem. The major concern of the NRC staff is that use of both the conventional and SI units would introduce confusion under emergency conditions.

Table G-2. Conventional and SI Units

Quantity	Conventional Unit	SI Unit	SI Unit Conversions
Absorbed dose	rad (100 ergs/gram)	gray (Gy) (10,000 ergs/gram)	100 rad = 1 Gy
Dose equivalent	rem (Q x rad)	sievert (Sv) (Q x gray)	100 rem = 1 Sv
Activity	curie (Ci) (3.7 x 10^{10} disintegrations per second)	becquerel (Bq) (1 disintegration per second)	1 Ci = 3.7 x $10^{(10)}$ Bq

G.1.1.3 Collective Dose

Previous revisions of 10 CFR Part 20 made no use of the collective DE (in person-rem). However, this quantity is used by the NRC in risk analyses and in its decision-making processes. The collective DE may be obtained as the sum of all individual doses or as the product of the average individual dose and the number of people exposed. The linear-nonthreshold hypothesis is accepted by the NRC for purposes of standards setting. Such acceptance means that standards based on the hypothesis, coupled with the "as low as reasonably achievable" (ALARA) concept, are believed to provide an adequate degree of protection.

G.1.1.4 Risks from Radiation Exposure

The current regulations in 10 CFR Part 20 are based on concepts first developed by the ICRP in Publication 26 (ICRP 1977). The ICRP system is based on the recognition of two basic types of radiation-induced health effects: stochastic and nonstochastic. Stochastic effects, such as cancer and hereditary effects, are considered to be probabilistic in nature. For stochastic effects, the probability of the effect, but not the severity, is dose-dependent (i.e., once a malignancy occurs). Its severity is no different if the dose that preceded it were 1 Sv (100 rem), 0.1 Sv (10 rem), or zero. The objective of radiation protection policies is to control the probability of these effects to acceptable levels. In contrast, the severity of nonstochastic effects, but not the probability of occurrence, depends on the radiation dose. Examples of radiation-induced nonstochastic effects include cataracts in the lens of the eye or burns on the skin surface. Nonstochastic effects typically do not occur unless the dose exceeds a threshold, which is specific to each type of effect. Once the threshold dose is exceeded, the effect occurs, and the severity of the effect depends on the dose received by the affected tissue or organ. For example, a radiation-induced cataract caused by a 4-Sv (400-rem) dose to the lens of the eye would impair vision to a greater extent than one following a dose of 1 Sv (100 rem). Therefore, radiation protection for nonstochastic effects is designed to keep radiological exposures to sensitive tissues below the threshold levels at which the effects would begin to appear.

In January 1990, the National Research Council (NAS 1990) published a report on the health effects of exposure to low levels of ionizing radiation. This report was prepared by the Committee on Biological Effects of Ionizing Radiation (BEIR) known as the BEIR-V Committee, organized by the Council for this purpose. The BEIR-V report concluded that the risk of radiation exposure was greater than estimates published by previous committees (NAS 1972, NAS 1980). In light of this data, the ICRP requested comment from a number of organizations on a draft of its revised recommendations on radiation protection. In 1991, the ICRP issued Publication 60 (ICRP 1991) recommending lower limits for occupational exposures. With regard to this Supplement, the primary importance of these developments lies in the selection of the most appropriate radiation risk coefficients to use for evaluating health effects. For a more complete history of the development of radiological risk estimates, see NRC (1996), Appendix E.

G.1.1.4.1 Stochastic Effects

Stochastic effects refer to health effects, such as cancer and inheritable genetic effects, for which the probability of occurrence is related to radiation dose. Based on the BEIR-V study (1990), the risks were estimated as 4 to 5 excess cancer deaths among 10,000 people receiving 100 person-Sv (10,000 person-rem). The following statement appears in the executive summary of the BEIR-V report (NAS 1990, p. 6):

> On the basis of the available evidence, the population-weighted average lifetime excess risk of death from cancer following an acute dose equivalent to all body organs of 0.1 Sv [0.1 Gy of low-linear energy transfer (LET) radiation] is estimated to be 0.8 percent, although the lifetime risk varies considerably with age at the time of exposure. For low-LET radiation, accumulation of the same dose over weeks or months, however, is expected to reduce the lifetime risk appreciably, possibly by a factor of 2 or more.

The 0.8-percent estimate is equivalent to 800 excess cancer fatalities among 100,000 people, each exposed to 0.1 Sv (10 rem). It is important to note that the risk values tabulated in the report are for a population size of 100,000 and that the 0.8-percent estimate is applicable to instantaneous, uniform irradiation of all organs. With regard to the lower extreme of the dose range over which the estimate is applicable, the Committee observes elsewhere in the BEIR-V report that "in general, the estimates of risk derived in this way for doses of less than 0.1 Gy (10 rem) are too small to be detectable by direct observation in epidemiological studies." The report does not provide a risk estimate for instantaneous doses of fewer than 0.1 Sv (10 rem). The Committee's estimate is considered useful for estimating fatalities among large populations, including all ages, that are irradiated instantaneously and uniformly to individual external radiation doses of 0.1 Sv (10 rem) or more. Risk assessments based on the Japanese experience are subject to substantially greater uncertainty when applied to conditions typically encountered in environmental exposures from normal facility operations, where

- exposures are protracted
- the exposed population is small
- individual doses are much lower than 0.1Sv (10 rem)
- irradiation is caused by internally deposited radionuclides and is not uniform throughout the body
- the exposed population differs significantly from the atomic bomb survivor study group or
- some combination of these conditions exists.

For stochastic effects, the ICRP adopted the risk associated with 0.05 Sv (5 rem) in a year, delivered to every organ, as the basis for its dose-limitation system (ICRP 1977). Therefore, the stochastic annual limit on intake (ALI) for each radionuclide is the quantity that, if inhaled, would cause the same stochastic risk as a uniform, whole-body dose of 0.05 Sv (5 rem) delivered by external sources in 1 year. To establish these ALIs, the ICRP considered the possibility that a given radionuclide taken into the body eventually reaches the bloodstream and is then distributed selectively to the various organs and tissues, where DE is delivered over a time course determined by the retention capabilities of the organ or tissue and the physical characteristics of the radionuclide. Using a radiation risk coefficient specific for each organ or tissue and the 50-year integrated dose equivalent to the tissue, the risk associated with each is estimated. The total risk to the worker per quantity of this radionuclide inhaled is the sum of the individual organ or tissue risks. The intake that will produce the same overall stochastic risk as 0.05 Sv/yr (5 rem/yr) of uniform external radiation can then be readily calculated as the ALI. Of course, a worker may be exposed to several airborne radionuclides and to external radiation as well. In that case, the total risk is still limited to that associated with 0.05 Sv (5 rem) in a year from uniform external radiation. Compliance is achieved if the fraction of the external dose limit that is received, added to the fraction of ALI inhaled for each radionuclide, does not exceed unity.

The risk of hereditary effects is included in a special way that, in the view of the ICRP, renders it additive to the cancer fatality risk. The ICRP considered only detrimental effects that the worker is likely to experience personally, so that effects manifested after the second generation are not included in the genetic risk coefficient used. The coefficient is also limited to very serious genetic effects (i.e., those comparable in severity to premature death).

Although all organs and tissues receive the same DE under uniform exposure conditions, the cancer risks for a given dose in each organ are not the same. Each organ or tissue contributes to the overall risk based on the relative sensitivity of tissue to radiation-induced cancer. This fraction is called the weighting factor, and the sum of the weighting factors for all tissues is unity. The product of the weighting factor and the DE is the effective dose equivalent (EDE). This quantity is used for both external and internal irradiation and may be used for individual organs and tissues or for the sum of all organs and tissues. The unit used for either quantity is the same as for the DE, namely, the sievert (or rem). In the unique case of uniform irradiation of all organs and tissues, the sum of their EDEs is by definition equal to the whole-body DE. The EDE may be determined irrespective of the degree of uniformity among the organ or tissue doses. The sum of the EDEs is not allowed to exceed 0.05 Sv/yr (5 rem/yr).

The committed dose equivalent (CDE) is a quantity defined as the 50-year integrated DE to a specific organ or tissue following the inhalation of a radionuclide. This quantity is still used, but only in connection with nonstochastic effects. The committed effective dose equivalent (CEDE) is the same quantity as the CDE, with the exception that, in the case of the CEDE, each dose equivalent is multiplied by the tissue or organ weighting factor. The rem (or sievert) is also the unit for both of these quantities.

The mathematical weighting method used by the ICRP is shown in Table G-3. The first column lists the organs, and the second column lists the risk coefficients from ICRP Publication 26 (1977) and their sum, namely, 1.65×10^{-4}. This sum is the total annual risk to the exposed person, assuming exposure to these organs at 0.01 Gy/yr (1 rad/yr).[a] The fraction of this risk per rad for each organ can be obtained by dividing its risk coefficient by 1.65×10^{-4}. These fractions represent the relative sensitivity of the organs; they are the weighting factors and are designated by the symbol w_T, where T represents the organ or tissue. The weighting factors appear in column three of the table. If T is the dose equivalent to tissue T, then $w_T H_T$ is the

(a) Multiplication by 5 gives the annual risk at 0.05 Gy/yr (5 rad/yr) (i.e., 8.25×10^{-4}/yr). This risk value means that if groups of 10,000 workers were to receive the dose limit every year for their entire careers, data as of the mid-1970s indicate that an average of 8.25 fatal occupational radiation-induced cancers per year would occur within each group. Assuming the approximate worst case of 45 years of exposure, the toll theoretically would be about 370 deaths per group, or almost 4 percent.

weighted DE. For example, w_T for the lung is 0.12. If a weighted lung dose of H rem is set equal to a highly penetrating, uniform whole-body dose of 5 rem, then

$0.12\ H = 0.05$ Sv (5 rem) and
$H = 4.17$ Sv (41.7 rem).

By hypothesis and analogy, an annual DE of 0.417 Sv (41.7 rem) to only the lung would have the same effect as 0.05 Sv (5 rem) to all of the organs combined. For this reason, $w_T H_T$ is called the EDE.

Nonstochastic effects have thresholds, and they become more severe as the dose gets larger. The ICRP believes that none of the thresholds will be exceeded if the annual dose to any tissue or organ does not exceed 0.5 Gy (50 rad). This nonstochastic limit is reflected in Table G-3, where it is evident that nonstochastic effects are controlling for all but four organs that have the largest weighting factors, the most sensitive organs with respect to stochastic effects.

Table G-3. ICRP Publication 26 Risk Weighting System

Organs	Risk Coefficients, Effects per Organ-rem	Weighting Factors	Organ DE Causing Same Risk as 5 rem to Whole Body, rem	Annual DE Permitted, Exposure of One Organ, rem/yr
Gonads	4×10^{-5}	0.25	20	20
Breasts	2.5×10^{-5}	0.15	33-1/3	33-1/3
Lung	2×10^{-5}	0.12	41-2/3	41-2/3
Red marrow	2×10^{-5}	0.12	41-2/3	41-2/3
Bone	5×10^{-6}	0.03	166-2/3	50
Thyroid	5×10^{-6}	0.03	166-2/3	50
1st RO[(a)]	1×10^{-5}	0.06	83-1/3	50
2nd RO	1×10^{-5}	0.06	83-1/3	50
3rd RO	1×10^{-5}	0.06	83-1/3	50
4th RO	1×10^{-5}	0.06	83-1/3	50
5th RO	1×10^{-5}	0.06	83-1/3	50
Totals	1.65×10^{-4}	1.0		

(a) The remainder organs (ROs) are the five organs that receive, from a given radionuclide, the highest EDE, integrated over 50 years.
Note: To convert rem to sievert, multiply by 0.01.

G.1.1.4.2 Nonstochastic Effects

Nonstochastic effects refer to those, such as radiation-induced cataracts, for which the severity of the effect depends on radiation dose. They typically are not observed unless the radiation dose exceeds a minimum threshold, whereas the probability of stochastic effects is assumed to be greater than zero, although very small, even at very low doses. Therefore, radiological protection for nonstochastic effects is based on limiting exposures to levels that prevent the effect, rather than on controlling the probability of occurrence, as discussed previously for stochastic effects. For tissues such as the lens of the eye, the skin, and the extremities, radiation protection standards are intended primarily to control the dose from external sources. For internal organs, it is necessary to control the dose from internally deposited radionuclides as well. Because radiation can damage or kill cells if the dose is sufficiently high, a nonstochastic dose limit must be established for all tissues, including tissues other than those mentioned above.

ICRP Publication 41 (1983) provides the technical justification supporting the position that, with the exception of the lens of the eye, nonstochastic effects will not be observed among adults if the DE from external and internal radiation combined to every organ and tissue is less than 0.5 Sv/yr (50 rem/yr). The NRC is not aware of later radiobiological information indicating that this dose limit should be changed and notes that the ICRP retained this value in the 1990 revision of its recommendations (ICRP 1991).

G.1.1.4.3 Risk Coefficient Selection for This Supplement

The BEIR-V risk estimate can be arithmetically converted to the more familiar terminology of 8 cancer fatalities among 10,000 people exposed to 10 person-Sv (10,000 person-rem), leading to a convenient risk coefficient of 8×10^{-4} fatalities per person-rem. This coefficient is considered useful for estimating fatalities among large populations irradiated instantaneously and uniformly to individual external radiation doses of 0.1 Sv (10 rem) or more. However, since no dose or dose rate effectiveness factor (DDREF) is included in this risk factor, the fatality estimates become speculative as the individual doses and the size of the exposed population become progressively smaller. A DDREF of 2 has been recommended by the ICRP (1991) for doses below 0.2 Gy (20 rad) and dose rates below 0.1 Gy/h (10 rad/h), which corresponds to a risk coefficient 4.0×10^{-4} cancer fatalities per person-rem.

The risk coefficients for fatal cancer and hereditary effects (listed in Table G-4) are taken from ICRP (1991). The coefficients are consistent with the risk factors reported in BEIR-V if a DDREF of 2 is applied. The somewhat higher risk coefficients for the general population as compared to workers reflects the fact that individuals under age 18 at the time of exposure are more susceptible to radiation-induced cancer. A person must be 18 years or older to be

Table G-4. Nominal Probability Coefficients Used in this Supplement[(a)]

Health Effect	Occupational	Public
Fatal cancer	4	5
Hereditary	0.6	1

(a) Estimated number of excess effects among 10,000 people receiving 100 person-Sv (10,000 person-rem).
Source: ICRP Publication 60 (1991).

employed as a radiological worker. Excess hereditary effects are listed separately because radiation-induced effects of this type have not been observed in any human population, as opposed to excess malignancies that have been identified among people receiving instantaneous and near-uniform exposures of 0.1 Sv (10 rem) or more. As applied to low-level environmental and occupational exposures, risk factors for radiological health effects are subject to substantial uncertainty. The lower limit of the range for these risk coefficients is assumed to be zero because there may be biological mechanisms that can repair damage caused by radiation at low doses and/or dose rates.

G.1.2 Occupational Protection Standards

Occupational radiation protection standards have been in effect since 1947, and have generally been revised downward over the years, from 1.0 roentgen/wk (or about 50 roentgen/yr) in 1947 to the current 0.05 Sv/yr (5 rem/yr) total effective dose equivalent (TEDE). For an historical overview of development of these regulations, see NRC (1996), Appendix E. The current regulation implements the concept of TEDE, as developed by ICRP Publication 26 (1977). This methodology accounts for both exposure to radiation from external sources and intakes of radionuclides into the body in assessing compliance with the standards. Standards that were previously in effect applied only to external dose and did not account for dose from intakes of radionuclides by workers, which were assessed separately. In practice, radionuclide intakes account for a small fraction of the total dose received by workers at nuclear power facilities.

Historical dose data for nuclear power plant workers are presented in Section G.2. Table G-5 presents a summary of the occupational standards in the 1991 revision of 10 CFR Part 20. On an annual basis, the whole-body limit has decreased from 12 roentgen (3 roentgen per quarter) in 1957 (external radiation only) to 0.05-Sv (5-rem) TEDE (external plus internal).

Regulatory control over the intake of radioactive materials in the workplace has always been a complex issue. Beginning in 1991, the NRC adopted the method published by the ICRP in Publication 26 (ICRP 1977). Under the ICRP method, the dose to each significantly irradiated organ is weighted according to its radiation sensitivity. The weighted doses are summed to produce an EDE that can be added to the dose from external sources.

The revised 10 CFR Part 20 provides additional flexibility for establishing more accurate dose controls. It allows the use of actual particle-size distribution and physiochemical characteristics of airborne particulates to define site-specific derived air concentration limits. With NRC approval, these modified concentration limits can be used in lieu of generic values provided in 10 CFR Part 20. Such adjustments result in more precise estimates that use actual exposure conditions, as compared to generic assumptions.

The 1991 revision to 10 CFR Part 20 codifies a requirement that licensees implement a program to maintain radiation doses ALARA. Compliance with the commitments is required through the licensing process in 10 CFR Part 50 and the technical specifications. Two Regulatory Guides have been issued to provide guidance on ALARA programs for nuclear power plants: one on ALARA philosophy in NRC Regulatory Guide 8.10, Rev. 1R (NRC 1977), and one on implementation in NRC Regulatory Guide 8.8, Rev. 3 (NRC 1978). Nuclear power plant licensees are required to maintain and implement adequate plant procedures that contain ALARA criteria. During plant licensing, applicants commit to implement ALARA programs consistent with Regulatory Guides 8.8 and 8.10.

Table G-5. Occupational Dose Limits for Adults in 10 CFR Part 20[(a)]

Tissue	External Radiation	Internal Plus External Radiation
Whole Body	0.05 Sv/y (5 rem/yr) total DE,[(b)] not to exceed 0.5 Sv/y (50 rem/yr) total DE to any individual organ or tissue other than the lens of the eye	0.05 Sv/yr (5 rem/year) TEDE,[(c)] not to exceed 0.5 Sv/yr (50 rem/yr) total DE to any individual organ or tissue other than the lens of the eye
Lens	0.15 Sv/yr (15 rem/yr)	
Extremities, Including Skin	0.5 Sv/yr (50 rem/yr)	
All Other Skin	0.5 Sv/yr (50 rem/yr)	

(a) These revised 10 CFR Part 20 standards became effective on January 1, 1994.
(b) The total DE is the sum of the EDE (at 1 cm [0.39 in] depth) and the CDE from nuclides deposited in the body.
(c) The TEDE is the sum of the EDE (at 1 cm depth [0.39 in]) and the CEDE from nuclides deposited in the body.

G.1.3 Public Radiation Protection Standards

For many years, the ICRP and NCRP recommended dose limits for the public that were 10 percent of those for workers. During the 1980s, both organizations adopted a more conservative value of 2 percent. In 1985, the ICRP released a statement that its principal limit for the whole body was 0.001 Sv/yr (0.1 rem/yr) EDE (ICRP 1985). However, a subsidiary limit of 0.005 Sv/yr (0.5 rem/yr) is authorized, provided that the average dose over a lifetime does not exceed 0.001 Sv/yr (0.1 rem/yr). The ICRP limit for the skin and lens of the eye is 0.05 Sv/yr (5 rem/yr). In 1987, the NCRP recommended limits of 0.001 Sv/yr (0.1 rem/yr) EDE for the whole body under conditions of continuous or frequent exposure and 0.005 Sv/yr (0.5/yr) for infrequent exposure (NCRP 1987). The NCRP limit for the lens of the eye, skin, and extremities is 0.05 Sv/yr (5 rem/yr).

The 1991 revision of 10 CFR Part 20 implements guidelines consistent with the recommended limit of 0.001 Sv/yr (0.1 rem/yr) EDE (see Table G-6). Provision is made for temporary increases to 0.005 Sv/yr (0.5 rem/yr) with prior authorization and justification. Hourly and annual dose rate limits for unrestricted areas are also included.

Licensees may also demonstrate compliance with the provisions of 10 CFR Part 20 by showing that annual average concentrations of radioactive material released in gaseous and liquid effluents at the boundary of an unrestricted area do not exceed the values specified in 10 CFR Part 20, Appendix B, Table 2.

Table G-6. Dose Limits for an Individual Member of the Public under 10 CFR Part 20[a]

Applicability by Pathway	Dose Limits
Annual dose, all pathways[b]	1 mSv/yr (0.1 rem/yr) TEDE[c]
External dose rate, unrestricted areas	0.02 mSv/h (0.002 rem/h) or 0.5 mSv/yr (0.05 rem/yr)
Temporary Annual Dose, all pathways[d]	5 mSv/yr (0.5 rem/yr) TEDE[c]
ALARA dose constraint, air emissions[e]	0.1 mSv/yr (0.01 rem/yr) TEDE[c]

(a) These revised 10 CFR Part 20 standards became effective on January 1, 1994.
(b) Excludes contribution from materials disposed to sanitary sewers.
(c) The TEDE is the sum of the EDE (at 1 cm depth) and the CEDE from nuclides deposited in the body.
(d) Temporary increases in the public dose limit are subject to prior authorization from the NRC and other constraints to ensure the increase is justified and controlled to be ALARA.
(e) This is not a 10 CFR Part 20 dose limit, but is given to ensure consistency with air emissions standards for Federal facilities in 40 CFR Part 61.

The NRC has not established standards for radiological exposures to biota other than humans on the basis that limits established for the maximally exposed members of the public would provide adequate protection for other species. In contrast to the regulatory approach applied to human exposures, the fate of individual nonhuman organisms is of less concern than the maintenance of the endemic population (NCRP 1991). Experience has shown that population stability is crucial to survival of most species. However, in many ecosystems individual members of a species may suffer relatively high mortality rates from natural causes without creating detrimental effects to the population as a whole. The exception might be for threatened or endangered species where protection of the individual may be required in order to avoid detrimental effects on a relatively small population.

Evaluations of radiation exposures to nonhuman biota at nuclear power facilities have not identified exposures that could be considered significant in terms of harm to the species, or which approach the public exposure limits in 10 CFR Part 20. Limiting exposure in humans to 1 mSv/yr (100 mrem/yr) will lead to dose rates to plants in animals in the same area of less than 1 mGy per day (100 mrad per day). The International Atomic Energy Agency (IAEA) concludes that there is no convincing evidence from scientific literature that chronic radiation dose rates below 1 mGy per day (100 mrad per day) will harm plant or animal populations (IAEA 1992). Because of the relatively lower sensitivity of nonhuman species to radiation, and the lack of evidence that nonhuman populations or ecosystems would experience detrimental effects at radiation levels found in the environment around nuclear power stations, effects on these biota are not evaluated in detail for the purposes of this Supplement.

In addition to the basic standards mentioned above, 10 CFR 50.36(a) contains license conditions that are imposed on licensees in the form of technical specifications applicable to effluents from nuclear power reactors. These specifications ensure that releases of radioactive materials to unrestricted areas during normal operations, including expected operational occurrences, remain ALARA. Appendix I to 10 CFR Part 50 provides numerical guidance on dose-design objectives and limiting conditions for operation for light-water reactors (LWRs) to meet the ALARA requirements. As a part of the licensing process, all licensees have provided reasonable assurance that the design objectives will be met for all unrestricted areas even during the decommissioning process. Title 10 CFR Part 20 requires compliance with the U.S. Environmental Protection Agency regulation 40 CFR Part 190, which also contains ALARA limits. The dose constraints are summarized in Tables G-7 and G-8.

Specific radiological criteria for license termination were added to 10 CFR Part 20 in 1997, and the basis for public health and safety considerations is discussed in NUREG-1496 (NRC 1997). These criteria limit the dose to members of the public to 0.25 mSv/yr (25 mrem/yr) from all

Table G-7. 10 CFR Part 50, Appendix I, Design Objectives and Annual Limits on Radiation Doses to the General Public from Nuclear Power Facilities[a]

Tissue	Gaseous	Liquid
Total body	0.05 mSv (5 mrem)	0.03 mSv (3 mrem)
Any organ, all pathways	--	0.01 mSv (10 mrem)
Ground-level air dose	0.1 mGy (10 mrad) gamma and 0.3 mGy (30 mrad) beta	--
Any organ,[b] all pathways	0.15 mSv (15 mrem)	--
Skin	0.15 mSv (15 mrem)	

(a) Calculated doses.
(b) Particulates, radioiodines.

Table G-8. 40 CFR 190, Subpart B, Annual Limits on Doses to the General Public from Nuclear Power Operations[a]

Tissue	Limit	Source
Total body	0.25 mSv (25 mrem)	All effluents and direct radiation from nuclear power operations
Thyroid	0.75 mSv (75 mrem)	"
Any other organ	0.25 mSv (25 mrem)	"

(a) Calculated doses.

pathways following unrestricted release of a property. In cases where unrestricted release is not feasible, the licensee must provide for institutional controls that would limit the dose to members of the public to 0.25 mSv/yr (25 mrem/yr) during the control period and to 1 mSv/yr (100 mrem/yr) after the end of institutional controls. These criteria will largely determine the types and extent of activities undertaken during the decommissioning process to reduce the radionuclide inventory remaining onsite.

G.2 Nuclear Power Plant Exposure Data

G.2.1 Occupational Dose Experience

Individual occupational doses are measured by NRC licensees as required by the basic NRC radiation protection standard, 10 CFR Part 20. The exposure pathway of primary interest is from sources that are external to the body. Measurements of the whole-body dose are normally derived from personal dosimeters worn by each worker, and they represent a relatively uniform dose to all organs of the body. Since 1984, many of the nuclear power plants have provided dosimetry programs accredited by the National Bureau of Standards (NBS, now National Institute of Standards and Technology [NIST]). In 1988, NBS/NIST accreditation became an NRC requirement.

Whole-body dose data from NRC-licensed LWRs are shown in Table G-9 for the years 1973 through 1999 (NRC 2000). For each year, the number of reactors, the number of workers receiving measurable exposures, the average annual dose per worker, the collective dose for all reactors combined, and the number of individuals exceeding 0.05 Sv (5 rem) are listed. Until 1991, the limit for exposure to workers was 0.03 Sv per quarter (3 rem per quarter), or a maximum of 0.12 Sv/yr (12 rem/yr), with an average of 0.05 Sv/yr (5 rem/yr). The collective dose is the sum of doses to workers at all plants. The collective doses to nuclear plant workers decreased from a peak of over 55 person-Sv/yr) (55,000 person-rem/yr) in 1983-1984 to less than 15 person-Sv/yr (15,000 person-rem/yr) in 1998-1999, although there are currently about 25 percent more operating plants than in the mid-1980s. Average annual doses to workers have likewise decreased from just under 0.01 Sv/yr (1 rem/yr) in the early 1970s to less than 0.25 mSv/yr (0.25 rem/yr) after 1997. Whole-body doses exceeding 0.05 Sv/yr (5 rem/yr) have been infrequent since 1985, and no doses at that level have been reported since 1989. Nuclear power plant workers may also be exposed to airborne radioactive material, primarily fission and corrosion products, but such exposures have historically been small in comparison with external doses. A study of intake data indicated that for cobalt-58 and cobalt-60, the most prevalent radionuclides, very few of the workers had organ burdens of more than 1 percent of the maximum permissible (see Baker 1996).

These data indicate that occupational exposures within the nuclear power industry have been significantly reduced since 1973. Individual doses are characteristically far below the regulatory limit, and the annual average is less than 5 percent of the 5 rem per year limit that is now in effect. Effective implementation of the ALARA concept is largely responsible. The range of risks associated with these exposures are discussed in Section G.1.

Occupational doses at reactors that are undergoing decommissioning are typically lower than those accumulated at operating facilities, as indicated in the Table G-9 data for reactors that are no longer operating. Between 1995 and 1999, the collective dose from shutdown facilities typically amounted to a few hundred person-rem per year, and the annual average dose per worker was comparable to, or lower than, that for operating facilities. A comparison in Table G-10 of the occupational doses at 12 facilities before and after they were shutdown confirms that decommissioning would not be expected to increase occupational doses on average, although some phases of the process may result in temporarily higher collective doses depending on the activities in progress and the number of workers involved.

Table G-9. Occupational Dose at Light Water Reactors (LWRs) - Comparison of Operating Reactors to Reactors No Longer in Operation[(a)]

Year	Number of Workers with Measurable Exposure[(b)]	Collective Dose, person-rem[(c)]	Average Dose per Worker with Measurable Exposure, rem[(c)]	Total Number with Dose > 5 rem[(d)]	Number of Reactors	Average Collective Dose per Reactor-Year, person-rem[(e)]
Operating Reactors						
1973	14,780	13,962	0.945	--	24	582
1974	18,139	13,650	0.753	--	33	414
1975	28,234	20,901	0.740	--	44	475
1976	34,515	26,105	0.756	--	52	502
1977	38,985	32,521	0.834	351	57	571
1978	42,777	31,785	0.743	159	64	497
1979	60,299	39,908	0.662	180	67	596
1980	74,629	53,739	0.720	391	68	790
1981	76,772	54,163	0.706	210	70	774
1982	79,309	52,201	0.658	135	74	705
1983	79,709	56,484	0.709	169	75	753
1984	90,520	55,251	0.610	74	78	708
1985	86,926	43,048	0.495	1	82	525
1986	93,979	42,386	0.451	0	90	471
1987	96,231	40,406	0.420	0	96	421
1988	96,013	40,772	0.425	1	102	400
1989	100,084	35,931	0.359	0	107	336
1990	98,567	36,602	0.371	0	110	333
1991	91,086	28,519	0.313	0	111	257
1992	94,172	29,297	0.311	0	110	266
1993	86,193	26,364	0.306	0	108	244
1994	71,613	21,704	0.303	0	109	199
1995	70,821	21,688	0.306	0	109	199
1996	68,305	18,883	0.276	0	109	173
1997	68,372	17,149	0.251	0	109	157
1998	57,466	13,187	0.229	0	105	126
1999	59,216	13,666	0.231	0	104	131
Average 1973-1999	69,545	32,603	0.514	73		430
Average 1995-1999	64,836	16,915	0.259	0		157
Permanently Shutdown Reactors[(f)]						
1995	699	262	0.375	0	6	44
1996	974	165	0.169	0	8	21
1997	1144	136	0.119	0	7	19
1998	2178	430	0.197	0	11	39
1999	2856	430	0.151	0	13	33
Average 1995-1999	1,570	285	0.202			31

(a) Data Source: NUREG-0713, Vol. 21 (NRC 2000)
(b) 1973-1976 data are not adjusted for multiple reporting of transient individuals
(c) To convert rem to sievert, multiply by 0.01.
(d) Number of workers by dose range not available for 1973-1976 The dose limit was 3 rem/quarter (12 rem/yr) before the 1991 revision of 10 CFR Part 20; thereafter, it was reduced to 5 rem/yr.
(e) To convert person-rem to person-sievert, multiply by 0 01.
(f) Includes plants not in operation for a full year as of December 31 of the reporting year.

Table G-10. Occupational Whole-Body Dose at Decommissioning Reactors, Comparison of Dose During Operations to Dose During Decommissioning

						Average Annual Occupational Dose, person-rem/yr			Maximum Annual Occupational Dose, person-rem/yr		
Nuclear Plant	Reactor Type	Capacity, MWe	Years in Operation	Years Post Shutdown	D&D Method	Normal Power Operations	Post Shutdown	Post Shutdown as % of Operations	Operations	Post Shutdown	Post Shutdown as % of Operations
Ft. St. Vrain	HTGR[a]	330	10	12	DECON	3	106	4076.9	6	210	3500
Big Rock Point	BWR[b]	67	34	2	DECON	166	116	69.7	277	144	52.0
La Crosse	BWR	48	17	13	SAFSTOR	247	19	7.8	313	105	33.5
Humboldt Bay, Unit 3	BWR	63	13	25	SAFSTOR	294	183	62.4	339	1905	561.9
Yankee Rowe	PWR[c]	175	30	8	DECON	159	75	47	246	156	63.4
Haddam Neck	PWR	560	28	3	DECON	355	137	38.5	590	261	44.2
Maine Yankee	PWR	860	25	3	DECON	326	154	47.1	653	173	26.5
Trojan	PWR	1080	17	7	DECON	346	38	11	567	52	9.2
San Onofre, Unit 1	PWR	436	25	8	SAFSTOR	512	16	3.1	880	16	1.8
Rancho Seco	PWR	873	14	10	SAFSTOR	385	9	2.3	787	41	5.2
Zion, Units 1 and 2	PWRs	2080	24	2	DECON	645	8	1.2	1043	12	1.2
Average All LWR						343	75	29	570	287	79.9
Average BWR						235	106	46.6	310	718	215.8
Average PWR						390	62	21.5	681	102	21.6
Average DECON						333	88	35.8	563	133	32.7
Average SAFSTOR						359	57	18.9	580	517	150.6

(a) High-temperature gas-cooled reactor.
(b) Boiling water reactor.
(c) Pressurized water reactor.

Table G-11. Occupational Dose by Activity During Decommissioning

Nuclear Plant	Reactor Type	Capacity, MWe	D&D Method	Cumulative Dose Post Shutdown, person-rem[a]	Percent of Total Cumulative Dose to Completion by Activity: Large Component Removal, %	Systems, Structures, and Components Removal, %	Other Decon Activities, %	SNF Management, %	Transportation, %	SAFSTOR Activities, %
Fort St. Vrain	HTGR[b]	330	DECON	433	45.1	25.6	13.8		15.5	
Big Rock Point	BWR[c]	67	DECON	700						
Haddam Neck	PWR[d]	560	DECON	996	37	28.7	19.3	8.7	6.1	
Maine Yankee	PWR	860	DECON	946	9.9	12.8	74.2	3		
Trojan	PWR	1080	DECON	556	22.7	50.7	5.4	21.2		
Zion, Units 1 and 2	PWRs	2080	SAFSTOR	637						
Humboldt Bay, Unit 3	BWR	63	SAFSTOR	354			50.8		3.7	45.5
Rancho Seco	PWR	873	SAFSTOR	483	39.1	47.6	5.8			7.5
San Onofre, Unit 1	PWR	436	SAFSTOR	1100						
Average All Plants				689	26.9	28	36.9	8.3	8.4	18.1
Number of Plants				9	6	6	7	4	3	3
Occupational Dose in Decommissioning BWRs										
Average BWR				527			50.8		3.7	45.5
Number of Plants				2			1		1	1
BWR SAFSTOR				354			50.8		3.7	45.5
BWR DECON				700						
Occupational Dose in Decommissioning PWRs										
Average PWR				786	23.2	28.4	38.7	8.3	6.1	4.4
Number of Plants				6	5	5	5	4	1	2
PWR SAFSTOR				792	23.3	25	47.2	0.3		4.4
PWR DECON				784	23.2	30.8	33	11	6.1	

(a) Dose is estimated for activities during decommissioning at plants that have not reached license termination.
(b) High-temperature gas-cooled reactor.
(c) Boiling water reactor.
(d) Pressurized water reactor.

Table G-12. Reactor Vessel Removal Information and Data

Nuclear Plant	Total Bequerels (Curies) Removed	Personnel Exposure person-sievert (person-rem)	Segmented components/ Lineal inches cut	Cutting Methods	Considerations for Planning and Implementation
Haddam Neck (in progress)	2.8 x 10^{16} (750,000)	1.77 (177)	• Core baffle • Core former plates • Core barrel in active fuel region • Lower core support plate • Lineal inches cut - 23,251	• Abrasive water • MDM cutting	• Worker exposure • Airborne contamination • Waste form and disposal costs • Cavity cleanup requirements • Schedule
San Onofre, Unit 1 (in progress)	1 2 x 10^{16} (330,000)	0.73 (73)	• Core region of the core barrel • Core baffles/formers • Lower core support plates • Lineal inches cut - 10,821	• Abrasive water • MDM cutting	
Maine Yankee (in progress)	Not available	(actual to date) 0 24 (24)	• Upper guide structure • Upper core barrel • Core support barrel • Mid-core region • Thermal shield • Lineal inches cut - 14,000	• Abrasive water jet (AWJ) • Conventional machining	• Avoid thermal processing • Use AWJ and conventional machining vs. plasma arc and MDM/EDM to reduce the occupational dose • Modeled all the cuts in a 3D CAD system before actually performing any of the dismantlement • Segregating, capturing, and confining AWJ cutting waste • Solid waste collection system • Cavity water treatment system • Much Maine Yankee dismantlement done under water and remotely, which cut down the worker dose • Abrasive Feed Assist System (patent pending) • Underwater AWJ Vision Enhancement - remote operability (patent pending) • Minimized amount of secondary waste • For underwater equipment, a maintenance and reliability issue • Sequence of cuts (low to high activity) reduced occupational exposure
Big Rock Point (in progress)	Not available	Not available	N/A	N/A	

Table G-12. (contd)

Nuclear Plant	Total Bequerels (Curies) Removed	Personnel Exposure (person-rem)	Segmented components/ Lineal inches cut	Cutting Methods	Considerations for Planning and Implementation
Trojan (completed)	74,000 (2,000,000)[a]	0.72 (72)	N/A	N/A	• Used the fuel transfer crane to lift the reactor vessel and place in the container • Removed reactor vessel with internals intact • The internals were grouted in place with low-density cellular concrete • Placed the reactor vessel on a heavy haul trailer for road transport to the rail • Shipped the reactor vessel with internals to U.S. Ecology, Richland, WA • Eliminated 74,000 Bq (2 million curies) from the Trojan nuclear facility site

(a) The Trojan plant reactor vessel was removed and shipped intact to the disposal facility; reactor vessel internals were not removed as in the other plants listed in this table.

Tables G-11 and G-12 list available data regarding the distribution of the cumulative collective worker dose among the major types of activities that would occur during a typical decommissioning process. The lack of resolution in much of the data and the small number of facilities involved (10) precludes a detailed analysis. However, it appears that the largest share of occupational doses might be expected for three general classes of activities: (1) large component removal (reactor vessel, steam generators), (2) removal of other plant systems, structures, and components, and (3) the remaining general decontamination activities. Data for removal of the reactor vessel (Table G-12) indicate that the choice of removal method (i.e., intact or segmented) may influence the collective dose associated with the operation. Data for plants electing the SAFSTOR alternative were not substantially different from plants undergoing more immediate DECON. The one exception was at Humboldt Bay, where the plant was maintained in a shutdown condition over an extended period of time. In that case, SAFSTOR activities accounted for a relatively large fraction of the total estimated occupational dose. In all cases, the estimated cumulative doses through the end of decommissioning for these plants were within the estimates presented in the 1988 GEIS (NRC 1988).

G.2.2 Dose to Members of the Public

Doses to members of the public from power reactor effluents were summarized in a series of NRC reports entitled *Dose Commitments Due to Radioactive Releases from Nuclear Power Plant Sites*. The last volume published covers reactor operations during 1992 (NUREG/CR-2850, Baker 1996). Radioactive material is released in gaseous (airborne, and may contain particulates, such as radioiodine) and liquid (aqueous) effluents under stringently controlled conditions in accordance with technical specifications and NRC regulations. The term "dose commitment" indicates that the reported doses come from the inhalation and ingestion of radionuclides, as well as from external radiation from noble gases. The population dose caused by direct radiation from plant facilities is negligible. Table G-13 presents results obtained for the 18-year period ending in 1992. The public doses represent collective person-rem received by those who live within an 80-km (50-mi) radius of a site; data for individual sites also appear in this report. The population dose within 80 km (50 mi) of each plant is calculated for each operating reactor in the United States. The total collective dose is then obtained by combining the doses received by these populations. As with the occupational doses, collective dose to the public from reactor effluents has been decreasing steadily since the mid-1980s. The collective dose to members of the public is smaller by several orders of magnitude than the dose to plant workers.

Data on maximally exposed individuals from gaseous effluents is also reported annually to the NRC by each nuclear utility. Data for the period 1985-1987 were compiled in NUMARC (1989) and summarized in NRC (1996). A summary of the data is presented in Table G-14.

Inspection of this table reveals that the maximum doses to individuals via gaseous effluents are on the order of a few mrem per year, and the dose to an individual is orders of magnitude lower for most plants.

Table G-13. Summary of Collective Public and Occupational Doses for All Operating Nuclear Power Facilities Combined[(a)]

		Collective Public Dose, person-rem			
Year	Number of Operating Reactors[(b)]	Liquid Effluents	Gaseous Effluents	Total	Average per reactor-yr, person-rem
1975	44	76	1300	1300	30
1976	52	82	390	470	9.0
1977	57	160	540	700	12
1978	64	110	530	640	10
1979	67	220	1600	1800	27
1980	68	120	57	180	2.6
1981	70	87	63	150	2.1
1982	74	50	87	140	1.9
1983	75	95	76	170	2.3
1984	78	160	120	280	3.6
1985	82	91	110	200	2.4
1986	90	71	44	110	1.2
1987	96	56	22	78	0.81
1988	102	65	9.6	75	0.74
1989	107	68	16	84	0.79
1990	110	63	15	78	0.71
1991	111	70	17	88	0.79
1992	110	32	15	47	0.43

(a) Collective public dose calculated for those living within an 80-km (50-mi) radius of a nuclear plant site.

(b) Includes plants in operation at least 1 full year at the end of the reporting year.

Source: NUREG/CR-2850 (Baker 1996).

Note: To convert person-rem to person-sievert, multiply by 0.01.

Table G-14. Estimated Doses to the Maximally Exposed Individual from Routine Gaseous Effluents from Operating Facilities, mrem[a]

	1985	1986	1987
Average	2.8E-01	2.6E-01	9.1E-02
Minimum	7.8E-04	4.9E-04	1.0E-06
Maximum	1.8E+00	4.3E+00	8.9E-01
Number of plants reporting	26	33	34

(a) Data compiled from reports submitted to the NRC by each nuclear utility.
Adapted from NUMARC (1989).
Note: To convert millirem to millisievert, multiply by 0.01.

A comparison of more recent effluent release rates from both operating and decommissioning facilities (Table G-15) indicates that the gaseous release rates for many types of effluents are similar. Decommissioning facilities reported no emissions of radioiodine in their gaseous effluents, which would be as expected after the plants are shut down and defueled. Most of the iodine isotopes are short-lived and are not present in plants that have been out of operation for any length of time. Releases of longer-lived fission gases and particulate materials in gaseous effluents continue after the end of operation because of the need to maintain plant ventilation systems during activities associated with the decommissioning process. Radionuclide emissions in liquid effluents were typically lower in the shutdown facilities because the reactor core cooling systems were not operating, and the levels of radionuclides in circulating water systems needed to maintain the spent fuel pool are lower than in primary coolant for an operating plant.

Recent DEs to members of the public from emissions at operating and decommissioning facilities were similar, and the doses from gaseous effluents were within the ranges published in NRC (1996) for operating facilities. Both individual and collective doses were very low for liquid and gaseous effluents. Although information was available for a relatively small sample of facilities, there does not appear to be any reason to project substantial increases in emissions or public doses from reactors undergoing decommissioning compared to the levels experienced during normal operation of those facilities.

Table G-15. Summary of Effluent Releases Comparison of Operating Facilities and Decommissioning Facilities

Operating Reactors						
Reactor Type	**PWR**			**BWR**		
	Average	**Max**	**Min**	**Average**	**Max**	**Min**
Capacity (MWe)	829	912	760	972	1154	786
Gaseous Effluents - Total (Ci)	5.8E+01	1.5E+02	4.0E-01	9.3E+01	1.7E+02	1.2E+01
Fission and Activation Gases (Ci)	4.4E+01	1.4E+02	7.5E-02	8.3E+01	1.6E+02	1.5E+00
Iodines (Ci)	6.4E-07	1.3E-06	0	2.3E-03	5.1E-03	0
Particulates (Ci)	1.9E-05	3.8E-05	3.3E-07	8.9E-04	1.6E-03	3 0E-04
Gross Alpha (Ci)	--	--	--	--	--	--
Tritium (Ci)	1.4E+01	3.7E+01	3.2E-01	1.0E+01	1.2E+01	6.2E+00
Liquid Effluents - Total (Ci)	5.2E+02	6.7E+02	4.2E+02	1.2E+01	1.9E+01	6.9E+00
Fission and Activation Products (Ci)	1.6E-01	3.7E-01	8.5E-02	6.2E-02	9.4E-02	1.2E-02
Tritium (Ci)	5.2E+02	6.7E+02	4.2E+02	1.2E+01	1.9E+01	6.9E+00
Dissolved and Entrained Gases (Ci)	1.0E-01	3.8E-01	2.2E-04	4.3E-03	6.7E-03	1.8E-03
Gross Alpha (Ci)	1.2E-03	1.9E-03	4 4E-04	2.4E-06	3 8E-06	0

Decommissioning Reactors						
Reactor Type	**PWR**			**BWR**		
	Average	**Max**	**Min**	**Average**	**Max**	**Min**
Capacity, MWe	970	1080	860	65	67	63
Gaseous Effluents - Total (Ci)	2.1E+01	4.0E+01	2.6E+00	1.1E+02	2.1E+02	1.2E+00
Fission and Activation Gases (Ci)[(a)]	1.6E+01	1.6E+01	1.6E+01	2.1E+02	2.1E+02	2.1E+02
Iodines (Ci)	--	--	--	--	--	--
Particulates (Ci)	0	0	0	1.0E-04	2.0E-04	0
Gross Alpha (Ci)	--	--	--	0	0	0
Tritium (Ci)	1.3E+01	2.4E+01	2.6E+00	1.2E+00	1.2E+00	1.2E+00
Liquid Effluents - Total (Ci)	7.8E-01	1.4E+00	1.2E-01	3.3E-01	1.3E+00	1.0E-03
Fission and Activation Products (Ci)	3.5E-02	6.7E-02	2.6E-03	3.3E-01	1.3E+00	2.0E-04
Tritium (Ci)	7.4E-01	1.4E+00	1.2E-01	9.5E-04	1.1E-03	8.0E-04
Dissolved and Entrained Gases (Ci)	--	--	--	--	--	--
Gross Alpha (Ci)	0	3.0E-05	0	0	0	0

(a) The average, maximum, and minimum values for this radionuclide category are identical within each reactor type because only one facility of each type reported detectable emissions. Other facilities either did not report emissions for this category or indicated that emissions were below detection limits and, therefore, were not included in the calculation.

G.3 References

10 CFR 20. Code of Federal Regulations, Title 10, *Energy*, Part 20, "Standards for protection against radiation."

10 CFR 50. Code of Federal Regulations, Title 10, *Energy*, Part 50, "Domestic licensing of production and utilization facilities."

40 CFR 61. Code of Federal Regulations, Title 40, Protection of Environment, Part 61, "National emissions standards for hazardous air pollutants; regulations of radionuclides."

40 CFR 190. Code of Federal Regulations, Title 40, *Protection of Environment*, Part 190, "Environmental radiation protection standards for nuclear power operations."

Baker, D.A. 1996. *Dose Commitments Due to Radioactive Releases from Nuclear Power Plant Sites in 1992.* NUREG/CR-2850, vol. 14, NRC, Washington, D.C.

International Atomic Energy Agency (IAEA). 1992. *Effects of Ionizing Radiation on Plants and Animals at Levels Implied by Current Radiation Protection Standards.* Technical Reports Series No. 332. IAEA, Vienna, Austria.

International Council on Radiation Protection (ICRP). 1977. "Recommendations of the International Commission on Radiological Protection," *Annals of the ICRP* 1(3), ICRP Publication 26, Pergamon Press, New York.

International Council on Radiation Protection (ICRP). 1983. "Nonstochastic Effects of Ionizing Radiation," *Annals of the ICRP* 14(3), ICRP Publication 41, Pergamon Press, New York.

International Council on Radiation Protection (ICRP). 1985. "Statement from the 1985 Paris Meeting of the ICRP." *Health Physics* 48: 828.

International Council on Radiation Protection (ICRP). 1991. "Recommendations of the International Commission on Radiological Protection," *Annals of the ICRP* 21(1-3), ICRP Publication 60, Pergamon Press, New York.

National Academy of Sciences (NAS), National Research Council, Advisory Committee on the Biological Effects of Ionizing Radiation. 1972. *The Effects on Populations of Exposure to Low Levels of Ionizing Radiations* (BEIR-I). NAS, Washington, D.C.

National Academy of Sciences (NAS), National Research Council, Advisory Committee on the Biological Effects of Ionizing Radiation. 1980. *The Effects on Populations of Exposure to Low Levels of Ionizing Radiation: 1980* (BEIR-III). NAS, Washington, D.C.

National Academy of Sciences (NAS), National Research Council, Advisory Committee on the Biological Effects of Ionizing Radiation. 1990. *Health Effects of Exposure to Low Levels of Ionizing Radiation* (BEIR-V). NAS, Washington, D.C.

National Council on Radiation Protection and Measurements (NCRP). 1987. *Recommendations on Limits for Exposure to Ionizing Radiation.* Report No. 91, NCRP, Bethesda, Maryland.

National Council on Radiation Protection and Measurements (NCRP). 1991. *Effects of Ionizing Radiation on Aquatic Organisms.* Report No. 109, NCRP, Bethesda, Maryland.

Nuclear Management and Resources Council (NUMARC). 1989. *Study of Generic Environmental Issues Related to License Renewal.* NUMARC, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 1977. *Operating Philosophy for Maintaining Occupational Radiation Exposures As Low As Reasonably Achievable.* NRC Regulatory Guide 8.10, Rev. 1R, NRC, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 1978. *Information Relevant to Ensuring That Occupational Radiation Exposures at Nuclear Power Stations Will Be As Low As Reasonably Achievable.* NRC Regulatory Guide 8.8, Rev. 3, NRC, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 1988. *Final Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities.* NUREG-0586, NRC, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 1996. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants.* NUREG-1437, NRC, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 1997. *Final Generic Environmental Impact Statement in Support of Rulemaking on Radiological Criteria for License Termination of NRC-Licensed Facilities.* NUREG-1496, Vol. 1, NRC, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 2000. *Occupational Radiation Exposure at Commercial Nuclear Power Reactors and Other Facilities, 1999.* NUREG-0713, vol. 21, NRC, Washington, D.C.

G.4 Related Documents

Connecticut Yankee Atomic Power Company, Docket No. 50-213, CY-01-076. Letter from Noah W. Fetherston, Connecticut Yankee Atomic Power Company, to U.S. Nuclear Regulatory Commission. "Response to NRC Request for Additional Information to Support GEIS Supplement." April 25, 2001.

Entergy. 2000. Entergy, Arkansas Nuclear One - Units 1 and 2 - Annual Radioactive Effluent Release Report for 1999.

Maine Yankee, MN-01-009, RA-01-033. Letter from Thomas L. Williamson to Dino Scaletti, U.S. Nuclear Regulatory Commission. "Request for Information to Support GEIS Supplement." March 21, 2001.

Sacramento Municipal Utility District, Docket 50-312. Letter from Sacramento Municipal Utility District to Dino Scaletti, U.S. Nuclear Regulatory Commission. "Request for Information to Support GEIS Supplement." January 31, 2001.

Southern California Edison. Letter from A. Edward Scher to Dino Scaletti, U.S. Nuclear Regulatory Commission. "Request for Information to Support GEIS Supplement." February 5, 2001.

Southern Company. 2000. Southern Company, E.I. Hatch Nuclear Plant Units 1 & 2, Annual Report - Plant Radioactive Effluent Releases, January 1, 1999 - December 31, 1999.

Appendix H

Summary of Environmental Impacts from Decommissioning Activities

Appendix H

Summary of Environmental Impacts from Decommissioning Activities

This appendix provides two tables that summarize findings from the analysis of the environmental impacts from decommissioning of permanently shutdown nuclear reactors. Table H-1 shows those issues and decommissioning activities that have no environmental impacts. Licensees may conduct these activities without further consideration of the potential environmental impacts. Table H-2 presents each environmental issue that was evaluated, provides the activities that were determined potentially to have environmental impacts, and then states whether the impacts related to the issue's associated activities were determined to be generic or site-specific for all variables. The significance level is identified and a short discussion of the finding is provided on the right-hand side of the table. Section 4.1 defines the significance levels and explains the distinction between generic or site-specific issues.

Table H-1. Issues and Activities with No Environmental Impacts

Issue	Activity
Onsite/Offsite Land Use	Remove fuel Organizational changes Stabilization Post-shutdown surveys Create nuclear island Chemical decontamination of primary loop Storage preparation activities for SAFSTOR Storage (SAFSTOR) Decontamination and dismantlment phases of DECON, SAFSTOR, and ENTOMB1 System dismantlement Entombment Transportation License termination activities
Water Use	Remove fuel • Drain primary system • Process liquid Organizational changes • Adjust site training • Changes to licensing basis - site-specific Stabilization Post-shutdown surveys Create nuclear island Chemical decontamination of primary loop Large component removal • Steam generator and other large components intact or cut up Storage preparation activities for SAFSTOR Storage (SAFSTOR) Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 • Chemical decontamination (surface/specific components) • Decontaminate piping inside walls • Remove contaminated soil from specific areas • Do preventive and corrective maintenance on SSCs • Maintain the security system • Maintain effluent and environmental monitoring programs

Table H-1. (contd)

Issue	Activity
Water Use (contd)	System dismantlement Entombment • Install engineered barriers • Disconnect operational systems (e.g. electrical and fire protection) • Remove all radioactive material that is outside of containment • Place material inside containment LLW packaging and storage Transportation License termination activities
Water Quality	Organizational changes Stabilization • Isolate SSCs that are no longer required • Rewire site to eliminate unneeded electrical circuits Post-shutdown surveys Create nuclear island Chemical decontamination of primary loop Large Component Removal Storage preparation activities for SAFSTOR Storage (SAFSTOR) Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 • Chemical decontamination (surface/specific components) • Decontamination of piping inside walls • Remove contaminated soil from specific areas • Do preventive and corrective maintenance on SSCs • Maintain the security system • Maintain effluent and environmental monitoring programs System dismantlement Structure dismantlement • Removal of structures Entombment LLW packaging and storage Transportation License termination activities

Table H-1. (contd)

Issue	Activity
Air Quality	Remove fuel Organizational changes • Reduce staff • Adjust site training • Change licensing basis - site-specific Stabilization Rewire site to eliminate unneeded electrical circuits Post-shutdown surveys Create nuclear island Chemical decontamination of primary loop Large component removal Storage preparation activities for SAFSTOR • De-energize systems, put in monitors where they are needed • Perform a radiological assessment Storage (SAFSTOR) • Monitor systems and radiation levels etc. • Do preventive and corrective maintenance on SSCs • Maintain the security system Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 • Chemical decontamination (surface/specific components) • Decontamination of piping inside walls • High-pressure water sprays of surface • Remove contaminated soil from specific areas • Do preventive and corrective maintenance on SSCs • Maintain the security system System dismantlement Entombment • Disconnect operational systems (e.g., electrical and fire protection) • Remove all radioactive material that is outside of containment • Place material inside containment LLW packaging and storage License termination activities

Table H-1. (contd)

Issue	Activity
Aquatic Ecology	Remove fuel Organizational changes Stabilization Post-shutdown surveys Create nuclear island Chemical decontamination of primary loop Large Component Removal Storage preparation activities for SAFSTOR Storage (SAFSTOR) Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 System dismantlement Structure dismantlement • Rubblization Entombment LLW packaging and storage Transportation License termination activities
Terrestrial Ecology	Remove fuel Organizational changes Stabilization • Drain and flush system • Isolate SSCs that are no longer required Post-shutdown surveys Create nuclear island Chemical decontamination of primary loop Storage preparation activities for SAFSTOR Storage (SAFSTOR) Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 • Chemical decontamination (surface/specific components) • Decontamination of piping inside walls • High-pressure water sprays of surface • Do preventive and corrective maintenance on SSCs • Maintain the security system • Maintain effluent and environmental monitoring programs

Table H-1. (contd)

Issue	Activity
Terrestrial Ecology (contd)	System dismantlement Structure dismantlement • Rubblization Entombment LLW packaging and storage Transportation License termination activities
Threatened and Endangered Species	Remove fuel Organizational changes Stabilization • Drain and flush system • Isolate SSCs that are no longer required Post-shutdown surveys Create nuclear island Chemical decontamination of primary loop Storage preparation activities for SAFSTOR Storage (SAFSTOR) Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 • Chemical decontamination (surface/specific components) • Decontamination of piping inside walls • High-pressure water sprays of surface • Do preventive and corrective maintenance on SSCs • Maintain the security system • Maintain effluent and environmental monitoring programs System dismantlement Structure dismantlement • Rubbliztion Entombment LLW packaging and storage Transportation License termination activities
Radiological	Organizational changes • Changes to licensing basis - site-specific Create nuclear island • Reduce the security area to that around the fuel • Change security function • Install or modify chemistry controls

Table H-1. (contd)

Issue	Activity
Radiological (contd)	Storage (SAFSTOR) • Maintain the security system • Maintain effluent and environmental monitoring programs Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 • Maintain the security system • Maintain effluent and environmental monitoring programs Entombment • Entomb facility in concrete Transportation • Equipment into site • Backfill trucked into site • Nonradioactive waste
Radiological Accidents	Organizational changes • Reduce staff • Employ contractor or other additional staff Stabilization • Isolate SSCs that are no longer required • Rewire site to eliminate unneeded electrical circuits Post-shutdown surveys Create nuclear island Storage preparation activities for SAFSTOR Storage (SAFSTOR) Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 • Remove contaminated soil from specific areas • Do preventive and corrective maintenance on SSCs • Maintain the security system • Maintain effluent and environmental monitoring programs Structure dismantlement • Rubblization Entombment • Install engineered barriers • Disconnect operational systems (e.g. electrical and fire protection) • Remove all radioactive material that is outside of containment

Table H-1. (contd)

Issue	Activity
Radiological Accidents (contd)	• Place material inside containment • Entomb facility in concrete Transportation • Equipment into site • Backfill trucked into site • Nonradioactive waste License termination activities
Occupational Issues	Organizational changes • Reduce staff • Employ contractor or other additional staff • Changes to licensing basis Post-shutdown surveys Create nuclear island • Reduce the security area to that around the fuel • Change security function Storage preparation activities for SAFSTOR • Perform a radiological assessment Storage (SAFSTOR) • Monitor system and radiation levels • Maintain security system • Maintain efficient and environmental monitoring programs Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 • Maintain the security system • Maintain effluent and environmental monitoring programs Transportation • Equipment into site • Backfill trucked into site • Nonradioactive waste License termination activities • Partial site release

Table H-1. (contd)

Issue	Activity
Cost	Remove fuel • Transfer fuel to spent fuel pool Create nuclear island • Install or modify chemistry controls
Socioeconomic	Remove fuel Organizational changes • Adjust site training • Change licensing basis - site-specific Stabilization Post-shutdown surveys Create nuclear island Chemical decontamination of primary loop Large component removal Storage preparation activities for SAFSTOR Storage (SAFSTOR) Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 System dismantlement Structure dismantlement Entombment LLW packaging and storage Transportation License termination activities
Environmental Justice	Remove fuel Organizational changes • Adjust site training • Change licensing basis - site-specific Stabilization Post-shutdown surveys Create nuclear island Chemical decontamination of primary loop Large components removal Storage preparation activities for SAFSTOR Storage (SAFSTOR)

Table H-1. (contd)

Issue	Activity
Environmental Justice (contd)	Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 System dismantlement Structure dismantlement Entombment LLW packaging storage Transportation • Move equipment into site • Backfill trucked into site • Nonradioactive waste License termination activities
Cultural Impacts	Remove fuel Organizational changes Stabilization • Drain and flush system • Isolate SSCs that are no longer required Post-shutdown surveys Create nuclear island Chemical decontamination of primary loop Storage preparation activities for SAFSTOR Storage (SAFSTOR) Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 • Chemical decontamination (surface/specific components) • Decontamination of piping inside walls • High pressure water spray of surface • Do preventative and corrective maintenance on SSCs • Maintain security system • Maintain effluent and environmental monitoring programs System dismantlement Structure dismantlement Entombment LLW packaging and storage Transportation • Equipment into site • Backfill trucked into site • Nonradioactive waste License termination activities

Table H-1. (contd)

Issue	Activity
Aesthetic Issues	Remove fuel Organizational changes Stabilization Post-shutdown surveys Create nuclear island Chemical decontamination of primary loop Large component removal Storage preparation activities for SAFSTOR Storage (SAFSTOR) Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 System dismantlement Entombment • Disconnect operational systems (e.g. electrical and fire protection) • Remove all radioactive material that is outside of containment • Place material inside containment • Lower ceiling (optional) LLW packaging and storage Transportation License termination activities
Noise	Remove fuel Organizational changes Stabilization Post-shutdown surveys Create nuclear island Chemical decontamination of primary loop Large components removal Storage preparation activities for SAFSTOR Storage (SAFSTOR) Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 System dismantlement

Table H-1. (contd)

Issue	Activity
Noise (contd)	Entombment • Disconnect operational systems (e.g. electrical and fire protection) • Place material inside containment • Lower ceiling (optional) LLW packaging and storage Transportation License termination activities
Irretrievable Resources	Remove fuel Organizational changes Stabilization Post-shutdown surveys Create nuclear island Chemical decontamination of primary loop Large components removal Storage preparation activities for SAFSTOR Storage (SAFSTOR) Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 Entombment Transportation • Equipment into site License termination activities

Table H-2. Summary of Environmental Impacts

Onsite/Offsite Land Use (4.3.1)
Activities that Could Impact Onsite/Offsite Land Uses
Large Component Removal Structure dismantlement (Laydown yards) LLW packaging and storage
Generic
Yes - For onsite activities for all reactor types No - For offsite activities for all reactor types
Impact and Summary of Findings
• Onsite land use activities - SMALL • Offsite land use activities - site specific

Table H-2. (contd)

Water Use (4.3.2)
Activities that Could Impact Water Use
Remove Fuel • Transfer fuel to spent fuel pool Organizational changes (affects potable water use) • Reduce staff • Employ contractor staff or other additional staff Large Component Removal • Remove reactor vessel and internals Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 • High-pressure water spray Structure dismantlement (dust control) Entombment • Lower containment ceiling (dust control) • Entomb facility in concrete
Generic
Yes - For all activities and reactor types
Impact and Summary of Findings
All activities related to water use that are identified in this Supplement - SMALL The amount of water used during decommissioning is much less than the amount of water used during operations except for possible short periods of time when potable water use may temporarily increase with staffing levels.

Table H-2. (contd)

Water Quality (4.3.3)
Activities that Could Impact Water Quality
Remove Fuel Stabilization • Drain and flush system Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 • High-pressure water spray Structure dismantlement (pH concerns) • Rubblization
Generic
Yes - For surface water and groundwater for all reactor types
Impact and Summary of Findings
All activities related to water quality (surface and groundwater) that are identified in this Supplement except for onsite disposal of demolition debris - SMALL The releases during decommissioning are within the NPDES guidelines.

Table H-2. (contd)

Air Quality (4.3.4)
Activities that Could Impact Air Quality
Organizational changes (additional worker vehicle traffic) • Employ contractor staff or other additional staff Stabilization • Drain and flush system • Isolate system structures and components Preparation for Storage (SAFSTOR) • Reactor coolant system ventilation pathways • Containment ventilation pathways Storage (SAFSTOR) • Maintain effluent and environmental monitoring programs Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 • Maintain effluent and environmental monitoring programs Structural dismantlement (dust control) Entombment • Install engineered barriers (dust control) • Lower containment ceiling (dust control) • Entomb facility in concrete (vehicle traffic) Transportation
Generic
Yes - For all activities and reactor types
Impact and Summary of Findings
All activities related to air quality that are identified in this Supplement - SMALL Any fugitive dust from decommissioning activities are temporary and can be controlled by mitigative measures. Air quality impacts from workers' vehicles and for movement of materials to and from the site are expected to be negligible.

Table H-2. (contd)

Aquatic Ecology (4.3.5)
Activities that Could Impact Aquatic Ecology
Structure dismantlement • Remove structures that were necessary for plant operation (intake structure)
Generic
Yes - For activities within the operational area and reactor types No - Requires site-specific analysis if the activities are outside the boundaries of the operational area.
Impact and Summary of Findings
Activities within the boundaries of the operational areas - SMALL Activities outside the boundaries of the operational areas - site-specific

Table H-2. (contd)

Terrestrial Ecology (4.3.6)
Activities that Could Impact Terrestrial Ecology
Stabilization • Rewiring of site to eliminate unneeded electrical circuits (includes repowering from the outside) Large Component Removal Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 • Remove contaminated soil from specific areas Structure dismantlement • Remove structures that were necessary for plant operation
Generic
Yes - For activities within the operational area and for all reactor types No - Requires a site-specific analysis if the activities are outside the boundaries of the operational areas.
Impact and Summary of Findings
Activities within the boundaries of the operational areas - SMALL Activities outside the boundaries of the operational areas - site-specific

Table H-2. (contd)

Threatened and Endangered Species (4.3.7)
Activities that Could Impact Threatened and Endangered Species
Stabilization • Rewiring of site to eliminate unneeded electrical circuits (includes repowering from the outside) Large component removal Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 • Remove contaminated soil Structure dismantlement • Remove structures that were necessary for plant operation
Generic
No - Requires a site-specific analysis and continued monitoring of site activities concerning the presence of threatened and endangered species.
Impact and Summary of Findings
A site-specific analysis is required. The appropriate Federal agency (either U.S. Fish and Wildlife Service or the National Marine Fisheries Service) must be consulted about the presence of threatened or endangered species.

Table H-2. (contd)

Radiological (4.3.8)
Activities that Could Have Radiological Impacts
Remove Fuel Organizational changes • Reduce staff • Employ contractor or additional staff • Adjust site training Stabilization Post-shutdown surveys Create nuclear island • Install electrical power to SFP • Move old or install new security-related power Chemical decontamination of primary loop Large component removal SAFSTOR preparation SAFSTOR • Monitor systems and radiation levels • Preventive and corrective measures on SSCs

Table H-2. (contd)

Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 • Chemical decontamination • Decontaminate pipes in walls • High-pressure water sprays • Remove contaminated soil • Preventive and corrective maintenance on SSCs System dismantlement Structure dismantlement Entombment • Install engineered barriers • Disconnect operational systems • Remove radioactive material from outside of containment • Place material inside containment • Lower containment ceiling (optional) LLW packaging and storage Transportation • Large components • LLW License Termination Activities
Generic
Yes - For all activities and reactor types
Impact and Summary of Findings
Activities resulting in occupational doses to workers - SMALL Activities resulting in dose to the public - SMALL The long-term radiological aspects of Rubblization or onsite disposal of slightly contaminated material would require a site-specific analysis and would be addressed at the time the license termination plan is submitted.

Table H-2. (contd)

Radiological Accidents (4.3.9)
Activities that Could Impact Radiological Accidents
Remove Fuel Organizational changes • Adjust site training Stabilization • Drain and flush system Chemical decontamination of primary loop Large component removal Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 • Chemical decontamination • Decontamination inside pipe walls • High-pressure water sprays System dismantlement Structure dismantlement • Remove structures necessary for plant operations Entombment • Lower containment ceiling (optional) LLW packaging and storage Transportation • Large components • LLW
Generic
Yes - For all activities and reactor types
Impact and Summary of Findings
Activities resulting in accidents with offsite dose consequences - SMALL

Table H-2. (contd)

Occupational Issues (4.3.10)
Activities that Could Have Occupational Impacts
Remove fuel Organizational changes • Adjust site training Stabilization Create nuclear island • Install electrical power supply • Install or modify chemistry controls • Move old or install new security-related power Chemical decontamination of the primary loop Large component removal SAFSTOR preparation Storage (SAFSTOR) • Do preventive and corrective maintenance on SSCs Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 • Chemical decontamination • Decontaminate piping inside walls • High-pressure water sprays of surface • Remove contaminated soil System dismantlement • Do preventive and corrective maintenance on SSCs Structure dismantlement Entombment Low-level waste packaging and storage Transportation • Large components • LLW License termination activities • Complete final radiation survey
Generic
Yes - For all activities and reactor types
Impact and Summary of Findings
All activities related to occupational noise, temperature, ergonomic, and biological hazards if proper ES&H procedures are followed - SMALL

Table H-2. (contd)

Cost (4.3.11)
Activities that Could Have Socioeconomics Impacts
Removal Fuel • Drain primary system • Process liquid Organizational changes Stabilization Post-shutdown surveys Create nuclear island • Install electrical power to SFP • Reduce security area • Change security function • Move old or install new security-related power Chemical decontamination of primary loop Large component removal SAFSTOR preparation SAFSTOR Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 System dismantlement Structure dismantlement Entombment LLW packaging and storage Transportation License Termination Activities
Generic
No - Decommissioning costs are site specific
Impact and Summary of Findings
NA – Evaluation of decommissioning cost is not a NEPA requirement. This information is presented as a summary of actual and predicted decommissioning costs based on available data.

Table H-2. (contd)

Socioeconomics (4.3.12)
Activities that Could Have Socioeconomics Impacts
Organizational changes • Reduce staff • Employ contractor or other additional staff
Generic
Yes - For all activities and reactor types
Impact and Summary of Findings
All activities and reactor types - SMALL

Table H-2. (contd)

Environmental Justice (4.3.13)
Activities that Could Impact Environmental Justice
Organizational changes • Reduce staff • Employ contractor or other additional staff Transportation • Large components • LLW
Generic
No - Requires a site-specific analysis. The impacts depend on the location of and circumstances of minority and low-income populations in the vicinity of the plant.
Impact and Summary of Findings
A site-specific analysis is required. The licensee must provide, in their PSDAR submittal, appropriate information related to the issue of environmental justice.

Table H-2. (contd)

Cultural and Historic Impacts (4.3.14)
Activities that Could Have Cultural Impacts
Stabilization Large Component Removal Decontamination and dismantlement phases of DECON, SAFSTOR, and ENTOMB1 • Remove contaminated soil from specific areas
Generic
Yes - For activities within the operational area and reactor types
No - Requires a site-specific analysis if the activities are outside the boundaries of operational areas.
Impact and Summary of Findings
Activities are within the boundaries of the operational areas - SMALL
Activities are outside the boundaries of the operational areas - site specific

Table H-2. (contd)

Aesthetic Issues (4.3.15)
Activities that Could Have Aesthetic Impacts
Structure dismantlement Entombment • Install engineered barriers • Entomb facility in concrete
Generic
Yes - For all decommissioning activities
Impact and Summary of Findings
Visual intrusion would be temporary and would serve to reduce the aesthetic impact of the site for most decommissioning activities - SMALL

Table H-2. (contd)

Noise (4.3.16)
Activities that Could Have Noise Impacts
Structure dismantlement Entombment • Install engineered barriers • Remove radioactive structures outside containment • Entomb facility in concrete
Generic
Yes - For all activities and reactor types
Impact and Summary of Findings
Noise levels are easily controlled during most decommissioning activities - SMALL

Table H-2. (contd)

Transportation (4.3.17)
Issues that Could be Impacted by Transportation Activities
Air Quality Radiological Radiological accidents Cost Environmental justice Irretrievable resources
Generic
Yes - For all activities and reactor types
Impact and Summary of Findings
All activities, both radiological and nonradiological, related to transportation that are identified in this Supplement - SMALL

Table H-2. (contd)

Irretrievable Resources (4.3.18)
Activities that Could Impact Irretrievable Resources
System dismantlement Structure dismantlement LLW packaging and storage Transportation • Large components • LLW • Backfill trucked into site • Nonradioactive waste
Generic
Yes - For all decommissioning activities
Impact and Summary of Findings
All activities and options related to irretrievable resources - SMALL

Appendix I

Radiological Accidents

Appendix I

Radiological Accidents

The information below summarizes the review of existing information on accidents at decommissioning nuclear power facilities using the DECON or SAFSTOR option. The ENTOMB option was not included in this review because of the lack of available information; however, accidents would likely be similar to the DECON option during preparation of the facility for entombment. The purpose of this review was to determine the potential accidents that could occur at nuclear power facilities that have permanently ceased operations. When available, the potential offsite doses from these accidents were analyzed to determine which accidents could have the greatest offsite impact. This appendix provides an assessment of the activities conducted during decommissioning and determines whether accidents of greater consequence may occur during those activities.

As indicated in the Introduction to this Supplement, although the staff relies on the Commission's Waste Confidence Proceeding Finding, which states, in part, that there is, "reasonable assurance that, if necessary, spent fuel generated in any reactor can be stored safely and without significant impact for at least 30 yrs beyond the licensed life for operation...of that reactor at its spent fuel storage basin..." (54 Federal Register 39767),[a] the staff has elected to include in this Supplement a discussion of potential accidents related to the storage and maintenance of fuel in a spent fuel pool.

Three sources of information were reviewed to obtain a list of potential accidents and their consequences: (1) U.S. Nuclear Regulatory Commission (NRC) research efforts, including NUREGs, NUREG/CRs, and the 1988 GEIS (NRC 1988), (2) industry-related publications and documents, and (3) licensing-basis documents for the individual plants, such as post-shutdown decommissioning activity reports (PSDARs), decommissioning plans, final safety analysis reports (FSARs) or FSAR-equivalent documents, or environmental reports (ERs) developed by the licensee. A list of documents used for this analysis is provided in Section I.5. Included as well were environmental assessments (EAs), environmental impact statements (EISs), safety evaluations, or emergency exemptions that were written by NRC. Twenty of the 22 plants listed in Chapter 3 were included in the analysis, which was completed in late 1999. Zion, Units 1 and 2, the most recent plants to permanently cease operations, were not included.

(a) The Commission reaffirmed this finding of insignificant environmental impacts in 1999. This finding is codified in the Commission's regulations in 10 CFR 51.23(a).

I.1 Potential Accidents Considered During Decommissioning

Table I-1 contains a list of the accidents that were considered for both pressurized water reactors (PWRs) and boiling water reactors (BWRs) during decommissioning in early studies on safety and the cost of decommissioning PWRs and BWRs (Smith et al. 1978 and Oak et al. 1980, respectively). Both documents also considered several other types of accidents that were determined to be either of low probability or to result in very small releases, as shown in Table I-2. These accidents are listed along with a brief description or discussion of the accidents, as given in Smith et al. (1978) and Oak et al. (1980). The discussion in this section does not evaluate whether the accidents described in Smith et al. (1978) or Oak et al. (1980) should still be considered appropriate to the decommissioning process. As a result of improvements in the technology used for decommissioning, several of the accidents listed in Table I-2 may now be considered to be of a much lower probability or, at the least, to result in much-reduced consequences. For example, the use of a single failure-proof crane significantly reduces the potential for certain postulated spent fuel cask drops or heavy load accidents. Table I-3 provides a comprehensive list of accidents of potential accidents at facilities undergoing decommissioning, including HTGRs and FBRs.

The 1988 GEIS (NRC 1988) also considered accidents that could potentially occur during decommissioning. The list of postulated accidents was developed from the lists given in Smith et al. (1978) and Oak et al. (1980). However, not all accidents contained in these two documents were included in the 1988 GEIS, as shown by the footnote in Table I-1.

The staff conducted a study of spent fuel pool accident risk at decommissioning nuclear power facilities to support development of a risk-informed technical basis for reviewing exemption requests and a regulatory framework for integrated rulemaking (NRC 2001). Earlier analyses in NUREG/CR-4982, *Severe Accidents in Spent Fuel Pools in Support of Generic Issue 82*, (Sailor et al. 1987) and NUREG/CR-6451, *A Safety and Regulatory Assessment of Generic BWR and PWR Permanently Shutdown Nuclear Power Plants* (Travis et al. 1997) included a limited analysis of the offsite consequences of a severe spent fuel pool accident. As part of its effort to develop generic, risk-informed requirements for decommissioning, the staff performed a further, analysis of the offsite radiological consequences of beyond-design-basis spent fuel pool accidents. The external event initiators included:

- seismic events (earthquakes)
- aircraft crashes
- tornadoes and high winds

Table I-1. Summary of Accidents for PWR and BWR Plants Undergoing Decommissioning Operations[a]

Pressurized Water Reactors	Boiling Water Reactors
Explosion of liquid propane gas leaked from a front-end loader – Explosion ruptures filters and prefilters in the purge exhaust filter banks in containment.	**Explosion of liquid propane gas leaked from a front-end loader** – Used to load concrete rubble in the reactor building Assumed to occur in building ventilation ductwork and to cause failure of filters and blowers as well as to release radioactive contamination that is deposited on the high-efficiency particulate air (HEPA) filters and in the ductwork
Explosion of oxyacetylene during segmentation of the reactor pressure vessel – Postulated during segmenting of the reactor pressure vessel in the reactor cavity. Explosion is sufficient to cause failure of the HEPA filter in the contamination control envelope.	**Oxyacetylene explosion** – During use of oxyacetylene cutting torch to remove the activated portion of the reactor vessel in air before segmenting the removed sections under water.
Explosion and/or fire in the ion exchange resin – Explosive release of an ion exchange column in a nuclear waste facility.	--
Detonation of Unused Explosives in the Reactor Cavity[b] – A charge used to scarf the bioshield is detonated when the water spray is turned off, and the blasting mat and contamination control envelope are not in place.	**Detonation of unused explosives** – Assumes that a charge positioned to remove the sacrificial shield explodes when the water sprays are off and the contamination control envelope has been removed.
Fire in contaminated sweeping compound[b] – Sweeping compound is composed of sawdust treated with oil or other additives to enhance pickup of contamination. Postulated to catch fire spontaneously. Contains contamination from the floor surfaces	**Contaminated sweeping compound fire** – Sweeping compound is composed of sawdust treated with oil or other additives to enhance collection of loose surface contamination. A fire is postulated to occur in used sweeping compound contaminated with radioactive material.
Gross leak during *in situ* decontamination – Leak of 10 times the magnitude of the routine *in situ* decontamination leak for 30 minutes.	**Gross leak during loop chemical decontamination** – A massive failure of reactor piping during loop chemical decontamination is assumed to be low. This accident involves a gross leak about 10 times larger than the spray lead. A total of 1% of the liquid in the system is assumed to be made airborne.
Segmentation of reactor coolant system (RCS) piping with unremoved contamination – Released to the reactor containment building since no contamination-control envelope is assumed to be used.	–

Table I-1. (contd)

Pressurized Water Reactors	Boiling Water Reactors
Loss of contamination control envelope during oxyacetylene cutting of the reactor vessel shell – Molten metal particles penetrate the plastic sheet walls. Release lasts 5 minutes.	**Contamination control envelope rupture** – During oxyacetylene cutting. Molten metal particles penetrate the plastic sheet walls and increase leakage into the reactor building. Assumed to occur during the removal of the reactor vessel. Assumed large leak occurs for 1 hour of cutting before it is detected.
Pressure surge damage to filters during blasting of activated concrete bioshield[b]	**Filter damage from blasting surges** – During removal of activated concrete in the sacrificial shield.
Loss of blasting mat during removal of activated concrete[b] – Protective blasting mat is lost during blasting, and confinement barriers could be breached.	--
Temporary loss of local airborne contamination control during blasting[a] – A contamination control envelope is required in the reactor containment building during the explosive removal of the contaminated concrete in the biological shield. Loss of fine fog spray and contamination control increases the dust made airborne.	--
Loss of integrity of portable filtered ventilation enclosure during segmentation of the steam generators[b] – Substantial breach occurs and is readily apparent. Segmenting is promptly terminated. Air flow continues for 10 minutes.	--
Vacuum bag rupture – Metal shards rupture the filter bag and puncture the vacuum cleaner, releasing all the collected material into the air.	**Vacuum filter-bag rupture** – From metal shard, releasing all collected material to the reactor building.
Fire involving contaminated clothing or combustible waste[b] – Assumed 1 m^3 (35 ft^3) of combustible waste (absorbent materials such as rags or paper wipes).	**Combustible waste fire** – Assumed 1 m^3 (35 ft^3) of combustible waste (absorbent materials such as rags or paper wipes).
Accidental cutting of contaminated piping – Caused by human error. Assumed pipe is 25 cm (10 in.) or smaller.	--
Accidental spraying of concentrated contamination with the high-pressure spray – Postulated to be in the thermal insulation that has hidden a slow leak for a number of years. Results in an airborne release.	-

Table I-1. (contd)

Pressurized Water Reactors	Boiling Water Reactors
Accidental break of contaminated piping during inspection[b] – Occurs during SAFSTOR in reactor building. Pipe is weakened by corrosion and becomes damaged by incidental jostling or hitting of pipe. Assumed not to have been decontaminated *in situ*. Ventilation system is not operating.	--
Minor accidents with closed van	**Minor transportation accident** – Truck collision or overturn with waste containers that may rupture, or a collision and overturn with a minor fire (½ hour or less) involving one Type A waste container.
Moderate accidents with closed van	--
Severe accidents with closed van	**Severe transportation accidents** – Truck collision or overturn and a major fire (1 hour or longer) involving 40 Type A waste containers.

(a) All accidents listed are from Smith et al. (1978) and Oak et al. (1980).
(b) These accidents were not included in the 1988 GEIS (NRC 1988).

- compression or buckling of stored assemblies from the impact of a dropped heavy load (such as a fuel cask)

- loss of neutron absorber plates that separate the stored assemblies.

The results of the staff's analysis is presented in Section I.2.

The accidents and malfunctions considered in licensing documents were divided into subgroupings within five main categories:

- fuel-related accidents, which center around the storage of fuel in the spent fuel pool

- other radiological, non-fuel-related accidents, which include onsite accidents related to decontamination or dismantlement activities (e.g., material-handling accidents or accidental cutting of contaminated piping), or storage activities (e.g., fires or ruptures of liquid waste tanks)

- external events, which include aircraft crashes, floods, tornadoes and extreme winds, earthquakes, volcanic activity, forest fires, lightning storms, freezing, and intruder events

Table I-2. Accidents Considered but Not Evaluated in Smith et al. (1978) and Oak et al. (1980)

Pressurized Water Reactors	Boiling Water Reactors
Accidents involving fuel – Extensively studied and considered in other references. Not unique to or amplified by decommissioning.	--
Temporary loss of local airborne containment control during jackhammer scarfing of concrete surfaces – Manual operation, so the loss of local airborne containment is readily apparent to operator. Operation is suspended before significant release occurs.	--
Dropping of contaminated concrete rubble – Causing fine particles to become suspended in air. Quantity of such material is assumed to be small since most of the readily suspendible particles are removed during routine operations.	--
Dropping a concrete slab during placement in onsite retrievable waste storage – Precast concrete slab used for top shield and sealing surface is dropped 6 m (20 ft) while it is being placed. Surface particles become airborne, but do not increase routine release significantly and are not considered further in this study.	--
--	**Ion-exchange resin accidents** – Assumes no danger of combustion. Handling accidents appear likely, but would lead to little airborne release because of liquid nature of wastes involved.
Temporary loss of services, such as water, power, or airflow – Constitutes a lesser hazard for airborne releases than other postulated accidents.	**Loss of services, such as water supply, electrical power, or air flow** – Constitutes a lesser magnitude release than other postulated accidents, so no further analysis was made.
Natural phenomena – Reference PWR is designed to withstand effects of natural phenomena. It is assumed that this structural integrity is preserved during decommissioning as long as required for safety. These are low-probability events, e.g., floods, earthquakes, tornadoes, and high winds.	**Natural phenomena** – Reference BWR is designed to withstand the most severe natural phenomena recorded for the site with appropriate margins for uncertainties. Events are of low probability, and impact is less than the impacts calculated for operating BWRs. Includes floods, earthquakes, tornadoes, and high winds.
Aircraft crashes – Probability is low, risk is not escalated by dismantlement operations.	**Aircraft crashes** – Probability is low and risk of damage is low and not escalated by dismantlement operations.
--	**Man-caused events** – Covers wide spectrum of magnitude, ranging from releases induced by casual trespassers to releases induced by armed terrorists. Detailed analysis beyond scope of study.

- offsite events, which consist solely of transportation accidents that occur offsite
- hazardous, nonradiological, chemical-related accidents, with the potential for injury to the offsite public either directly from the accident, or as a result of further actions initiated by the accident.

Table I-3 contains the list of accidents as described in the licensing documentation for each of the 20 plants reviewed. The accidents are organized under the five category headings shown above and under subgroup headings that describe a specific type of accident, e.g.,"cask or heavy load handling accidents" or "spent resin accidents." Each of the plants described the accidents they evaluated in a specific way, which may or may not be identical to the subgroup headings. For example, Big Rock Point considered a "loss of spent fuel pool cooling," while the Trojan Nuclear Plant described a similar accident as a "loss of spent fuel decay heat removal without concurrent spent fuel pool inventory loss." The exact descriptions given by the plants were used when available. In some cases, however, a short description was not available, and it was necessary to paraphrase or summarize from a longer discussion of the accident.

Categorizing accidents is not a straightforward process. Frequently, an initiating event causes more than one type of accident. For example, the loss of electric power could cause the loss of spent fuel cooling, resulting in the potential for fuel failure and subsequent offsite release. The same loss of electric power could result in a crane or hoist failure, resulting in a heavy object being dropped either into the spent fuel pool with subsequent failure of fuel cladding, or in a highly contaminated object other than fuel being dropped onto an unyielding surface, causing the release of contamination. The same loss of electric power could affect the ventilation system and result in the loss of high-efficiency particulate air (HEPA) filtration and subsequent release of contamination. Alternatively, a single accident could be caused by multiple types of initiating events. For example, the loss of spent fuel pool coolant could be caused by the loss of offsite power, a break in a pipe (resulting from cutting the wrong pipe), or an external event (such as damage to the pipes from freezing or rupture of the pool during an earthquake) causing the release of the water. Because an effort was made to categorize the accidents as they were described by the licensing documents for each plant, a "loss of offsite power accident" may be the same thing as a "loss of spent fuel cooling accident." In some cases, a single plant would analyze both the loss of offsite power and the loss of spent fuel pool cooling as separate accidents, whereas they both concluded with the same result.

Table I-3. Comprehensive Accident List

Fuel-Related Accidents	Nuclear Plant
Cask or Heavy Load Handling Accident	
Cask drop into spent fuel pool	Haddam Neck
Spent fuel shipping cask drop in the spent fuel pool	Maine Yankee
Spent fuel cask drop	San Onofre, Unit 1
Shipping cask or heavy load drop in fuel element storage well	La Crosse
Heavy load drop (equivalent to spent fuel cask drop) into pool	Big Rock Point
Drop of heavy object (cask) into spent fuel pool	Indian Point, Unit 1
Heavy load drop (equivalent to spent fuel cask drop) into spent fuel pool	Humboldt Bay, Unit 3
Heavy load drop	Fort St. Vrain
Spent Fuel-Handling Accident	
Fuel assembly drop	Haddam Neck
Fuel-handling accident	Trojan
Fuel-handling accident	San Onofre, Unit 1
Fuel-handling accident	Rancho Seco
Spent fuel handling accident	Humboldt Bay, Unit 3
Spent fuel handling event	Yankee Rowe
Fuel-assembly handling accident in the spent fuel pool	Maine Yankee
Spent fuel handling accident in fuel element storage well	La Crosse
Loss of Spent Fuel Pool Cooling	
Loss of spent fuel pool cooling water (caused by loss of offsite power)	Big Rock Point
Loss of fuel pool cooling	Indian Point, Unit 1
Loss of spent fuel pool cooling water	Yankee Rowe
Loss of fuel element storage well cooling	La Crosse
Loss of prestressed concrete reactor vessel shielding water (after fuel has been removed)	Fort St. Vrain
Loss of spent fuel pool decay heat-removal capability	Maine Yankee
Loss of spent fuel decay heat-removal without concurrent spent fuel pool inventory loss	Trojan
Failure of auxiliary electrical systems related to fuel pool cooling	Dresden, Unit 1
Loss of offsite power; limited loss of spent fuel pool cooling	San Onofre, Unit 1
Nonmechanistic loss of cooling and airborne release	Humboldt Bay, Unit 3
Loss of Water from the Spent Fuel Pool	
Loss of spent fuel pool water level	Big Rock Point
Loss of spent fuel pool water (nonmechanistic; earthquake beyond design basis)	Haddam Neck
Loss of spent fuel pool water	Indian Point, Unit 1
Loss of spent fuel pool inventory (loss of heat sink or by inadvertent siphoning)	Maine Yankee
Loss of spent fuel pool water from pool rupture of unknown origin	Humboldt Bay, Unit 3
Loss of cooling water	Yankee Rowe
Fuel pool drain-down	Dresden, Unit 1

Table I-3. (contd)

Fuel-Related Accidents (contd)	Nuclear Plant
Fuel element storage well system pipe break	La Crosse
Loss of spent fuel pool decay heat-removal capability with concurrent spent fuel pool inventory loss	Trojan
Loss of Offsite Power	
Loss of offsite power (resulting in loss of spent fuel cooling)	Big Rock Point
Loss of offsite power (resulting in loss of water from the pool)	La Crosse
Loss of offsite power (resulting in loss of spent fuel pool cooling)	Rancho Seco
Loss of power	Fort St. Vrain
Temporary loss of offsite power (crane or hoist failure)	Trojan
100% Fuel Failure	
100% fuel failure	Indian Point, Unit 1
100% fuel failure	Shoreham
Simultaneous failure of fuel assemblies	Dresden, Unit 1
Criticality	
Inadvertent criticality (misplaced assembly in pool)	Maine Yankee
Criticality, stored spent fuel rearranged from seismic or other events	Humboldt Bay, Unit 3
Accidents Involving Radioactive Materials (Non-Fuel-Related)	
Decontamination-Related Accidents	
Spray release during in situ decontamination of systems	Saxton
Gross leak or accident during in situ decontamination (spray and liquid)	Trojan
Decontamination of liquid spill	Three Mile Island, Unit 2
Decontamination events	Yankee Rowe
Accidental spraying of concentrated contamination with high-pressure spray	Three Mile Island, Unit 2
Concentrated contamination spray	Three Mile Island, Unit 2
Radioactive Material (Non-fuel) Handling Accidents	
Waste container drop	Pathfinder
Waste container drop and rupture (containing activated concrete rubble)	Shoreham
Dropping of filters or packages of particulate material	Trojan
Dropping of contaminated components	Trojan
Dropping of concrete rubble	Fort St. Vrain
Dropping of concrete rubble	Trojan
Packaging events	Yankee Rowe
Materials-handling event	Yankee Rowe
Steam generator load drop inside containment	Trojan
Dropping the reactor pressure vessel	Pathfinder
Dropping steam generator primary module	Fort St. Vrain
Steam generator load drop outside of containment	Trojan

Table I-3. (contd)

Accidents Involving Radioactive Materials (Non-Fuel-Related) (contd)	Nuclear Plant
Dismantlement-Related Accidents	
Contamination release during accidental cutting of contaminated piping	Three Mile Island, Unit 2
Contamination release during accidental break of contaminated piping	Three Mile Island, Unit 2
Loss of engineering controls during dismantlement of reactor cavity	Big Rock Point
Contamination release during dismantlement of main coolant system loop	Yankee
Dismantlement of RCS and safety injection piping without or with loss of local engineering controls	Saxton
Absence of blasting mat during removal of activated concrete	Trojan
Loss of HEPA Filters	
Rupture of contamination-control envelope; release of contamination on HEPA filter	Shoreham
HEPA filter failure	Three Mile Island, Unit 2
Loss of integrity of portable filtered ventilation enclosure	Trojan
Pressure-surge damage to filters during blasting of activated concrete bioshield	Trojan
Temporary loss of local airborne contamination control during blasting	Trojan
Temporary loss of local airborne contamination control during scarfing of contaminated concrete surfaces with jackhammer	Trojan
Loss of contamination-control envelope during oxyacetylene cutting of the reactor-vessel shell	Trojan
Radioactive Gas Waste System Leaks	
Leaks and failures in radioactive waste gas system in radwaste decay tanks	Maine Yankee
Leak or failure in radioactive waste gas system	Trojan
Radioactive Liquid Waste Releases	
Liquid waste tanks rupture	Fermi, Unit 1
Storage tank rupture	Three Mile Island, Unit 2
Liquid waste storage vessel failure	Saxton
Postulated radioactive releases due to liquid tank failures	Trojan
Liquid radioactive tank release	Humboldt Bay, Unit 3
Liquid radioactive waste release to lake through cracks in building, earthquake-induced	Fermi, Unit 1
Rupture of spent fuel pool, contents released to bay	Humboldt Bay, Unit 3
Liquid waste discharge pumped to river without sampling	La Crosse
Leaks and failures in radioactive liquid waste system	Maine Yankee
Condensate storage tank contents pumped into ground during in-service leak test (actual event report)	Dresden, Unit 1
Containment Breach (Open Penetration to Containment)	
Containment vessel breach, subsequent loss of contents to air/water	Saxton
Open penetration – unfiltered pathway from containment	Three Mile Island, Unit 2

Table I-3. (contd)

Accidents Involving Radioactive Materials (Non-Fuel-Related) (contd)	Nuclear Plant
Release of helium coolant	Peach Bottom 1
Spent Resin Accidents	
Spent resin handling accident (exothermic reaction during dewatering)	Haddam Neck
Dropped resin vessel during removal from containment building	Saxton
Low-level waste storage accident (resin liner drop)	Maine Yankee
Release of resins from makeup and purification demineralizer	Three Mile Island, Unit 2
Storage of spent resins	Big Rock Point
Explosion and/or fire in ion exchange resins	Trojan
Vacuum Filter Bag Ruptures	
Vacuum filter bag rupture during decontamination of spent fuel pool floor	Saxton
Vacuum filter bag rupture during cleaning of the Reactor Building floor	Shoreham
Vacuum canister failure	Three Mile Island, Unit 2
Loss of Electric Power	
Loss of offsite power	Yankee Rowe
Loss of offsite power	Trojan
Loss of electric power with unknown scenario	Pathfinder
Loss of offsite power affecting HEPA filters, etc.	Saxton
Loss of Compressed Air	
Temporary loss of compressed air	Trojan
Loss of compressed air	Yankee Rowe
Fire	
Fire	Dresden, Unit 1
Fire	San Onofre, Unit 1
Fire	Fort St. Vrain
Fire	Indian Point, Unit 1
Fire events (primarily those that could impact SFP cooling)	Big Rock Point
Fire inside of containment	Three Mile Island, Unit 2
Fire inside reactor vessel	Peach Bottom 1
Fire inside stairwell	Three Mile Island, Unit 2
Fire in D-rings	Three Mile Island, Unit 2
Fire in reactor building or fuel handling building	Pathfinder
Fire in boiler building	Pathfinder
Fire in storage facilities	Yankee Rowe
Fire in intermodel container of waste	Yankee Rowe
Fire in combustible waste stored in yard	Saxton
Fire in low-level radioactive waste storage building	Trojan
Combustible waste fire in 208-L (55-gal) drum container	Shoreham
Contaminated clothing or combustible waste fire	Trojan

Table I-3. (contd)

Accidents Involving Radioactive Materials (Non-Fuel-Related) (contd)	Nuclear Plant
Contaminated sweeping compound fire (sawdust with oil and other additives, used to enhance collection of loose surface contaminants)	Shoreham
Fire or other catastrophic event, initiator for residual sodium release	Fermi, Unit 1
Explosion	
Explosion of liquid propane gas leaked from front-end loader in containment	Trojan
Liquid propane gas explosion on front-end loader	Shoreham
Liquid propane gas explosion caused by an accidental leak on front-end loader used in containment building	Saxton
Oxyacetylene explosion in the containment building while cutting reactor coolant system piping and release of HEPA filter contents within portable enclosure	Saxton
Oxyacetylene explosion and release of HEPA filter contents	Shoreham
Explosion of oxyacetylene during segmenting of reactor vessel shell	Trojan
Explosion event inside vapor container	Yankee Rowe
Explosion inside area warehouse	Yankee Rowe
Explosion of large fuel-oil storage tanks	Humboldt Bay, Unit 3
Detonation of unused explosives in reactor cavity	Trojan
Sodium interaction with water caused by water inflow through a crack in a tank	Fermi, Unit 1
Onsite Transportation Accidents	
Onsite transportation accident	Yankee Rowe
Accidents Initiated in External Events	
Aircraft Crashes	
Aircraft hazards	Big Rock Point
Aircraft crashes	Trojan
Aircraft impact	Yankee Rowe
Floods	
Flood	San Onofre, Unit 1
Flood	Yankee Rowe
Flood	Pathfinder
Flooding	Saxton
External flooding	Big Rock Point
External flooding	Trojan
Site flooding	Dresden, Unit 1
Site flooding	Indian Point, Unit 1
Site flooding	Peach Bottom, Unit 1
Flood, seiches, and tsunamis	Shoreham
Low Water	
Probable minimum water level, from negative lake surge or sieche	Big Rock Point

Table I-3. (contd)

Accidents Initiated in External Events (contd)	Nuclear Plant
Wind	
Tornadoes and extreme winds	Pathfinder
Tornadoes and extreme winds	Trojan
Tornadoes and extreme wind	Yankee Rowe
Tornadoes and extreme wind	Saxton
Tornadoes and wind	Big Rock Point
Wind and tornadoes	La Crosse
Wind and tornado missiles	San Onofre, Unit 1
Tornados and hurricanes	Shoreham
Natural disaster, tornado	Fort St. Vrain
Earthquakes	
Earthquake	Big Rock Point
Earthquake	Indian Point, Unit 1
Earthquake	Pathfinder
Earthquake	Trojan
Earthquake	Saxton
Earthquake	San Onofre, Unit 1
Earthquake	Shoreham
Earthquakes	Yankee Rowe
Seismic events	Dresden, Unit 1
Seismic event	La Crosse
Volcanoes	
Volcanic activity	Trojan
Lightning	
Lightning	Trojan
Lightning	Saxton
Lightning	Yankee Rowe
Forest Fire	
Forest fires	Yankee Rowe
Forest or brush fire	Saxton
Freezing Temperatures	
Freezing temperatures, loss of plant heating	Big Rock Point
Freezing temperatures (actual accident)	Dresden, Unit 1
Physical Security	
Intruder event	Saxton
Physical security breach	Shoreham
Physical security breach	Pathfinder

Table I-3. (contd)

Offsite Transportation-Related Accidents	
Offsite transportation accident	Shoreham
Offsite transportation accident	Yankee Rowe
Transportation accident	Three Mile Island, Unit 2
Truck carrying radwaste – fire	Pathfinder
Truck and two intermodel containers, transportation accident with fire	Saxton
Reactor pressure vessel railroad accident and fire	Pathfinder
Reactor pressure vessel in the river during transportation by rail	Pathfinder
Offsite radiological event (shipment of radioactive materials)	Saxton
Hazardous Nonradiological Chemical Events	
Toxic chemical event (initiation for material handling event)	Saxton
Toxic chemical event	Trojan
Chemical combustion (from sodium-water interaction) and dispersal	Fermi, Unit 1
Toxic chemical event, initiator for fuel-handling event	Trojan

All accidents identified by licensees were included in Table I-3, even if they were just considered without a detailed discussion or analysis of the consequences. A number of accidents were initially considered, but were determined without further analysis to fall under one of the following categories:

- an accident that is not possible or probable – For example, a licensee might consider an aircraft impact as an accident, but state in their documentation that the probability of occurrence is low and, therefore, the accident is not analyzed further.

- an accident may occur, but not result in any type of consequence – For example, during consideration of a flood, the licensee might state that "flooding events do not result in significant radiological release; therefore, public health and safety are not adversely affected," or in the case of a material-handling event, make a statement such as, "compliance with management programs and quality assurance plan ensure that the probability of occurrence and the consequences do not significantly affect the public health and safety."

- an accident may occur, but mitigative actions can be taken before any radioactive material is released offsite – For example, during consideration of a seismic event, a statement is made that the facility was designed to accommodate the initiating event, and no damage resulting in a release would occur.

- an accident may occur, but with minimal offsite dose consequences – For example, loss of cooling for a spent fuel pool where the fuel has cooled to a level that would not result in the release of activity for a number of days and where mitigative actions could be taken to ensure that there would be no release of radioactive materials.

Although these accidents were not analyzed in depth, they were considered and, therefore, are included in Table I-3.
Most licensees did not describe the entire scenario that would cause the accident. For example, most documents that discussed the analysis of the release of liquid radioactive waste did not provide an indication of the event that caused the rupture of a liquid waste tank or storage tank. Therefore, it was a simple decision to place this accident in the group of "Liquid Radwaste Releases." However, some licensees did provide a complete scenario, such as a description that the tanks located in the basement were assumed to have been cracked during an earthquake, allowing fluid to leak into the earth and then into an aquifer, finally settling in a nearby lake. This accident could have been grouped by the initiating event (an earthquake) or the consequence (a release of liquid radioactive waste). In such cases, the initiators (or the consequences) are also shown in Table I-3.

In other cases, the accident could easily be placed under more than one heading. For example, one licensee (Trojan Nuclear Plant) analyzed an explosion and/or fire in the ion exchange resins. This accident could have been included under "Explosions," "Fires," or "Spent Resin Accidents." In this case, the last choice was selected. Another example would be the "oxyacetylene explosion and release of HEPA filter contents," which was analyzed by the licensees for the Saxton, Shoreham, and Trojan Nuclear Plants. This accident could have been included under either "Explosions" or "Loss of HEPA filters." In this case, the first choice was selected.

In some cases, the descriptions provide much more information regarding the accident than they do in other cases. For instance, under the heading "Fire," five of the licensees did not give any more detailed description other than they were analyzing a "fire" or "fire events." Other licensees described the location of the fire (inside stairwells, inside boiler buildings, etc.), and the remainder discussed the items that were combusted (contaminated clothing or waste, or contaminated sweeping compound).

Some of the descriptions of the accidents did not give any details regarding the scenario that resulted in offsite dose consequences. These accidents were described as nonmechanistic, i.e., they had no associated scenarios or initiators. For example, three licensees evaluated the simultaneous failure of 100% of the fuel assemblies in the spent fuel pool but gave no reason for the simultaneous failure.

The fuel-related accidents centered around the storage of the spent fuel in the spent fuel pool. The most common fuel-related accidents analyzed include the loss of spent fuel pool cooling (10 facilities), the loss of water in the spent fuel pool (9 facilities), cask or heavy handling (8 facilities), and the spent fuel handling (8 facilities). The accidents listed under "Loss of Offsite Power Accidents" also result in the loss of cooling, the loss of water from the pool, or a handling accident.

The non-fuel-related accidents center around decontamination, dismantlement, or storage-type activities. Decontamination-related activities include *in situ* decontamination and rupture of vacuum-filter bags. Accidents from these activities could include fires that occur in contaminated clothing or sweeping compounds. Dismantlement-related activities include accidental cutting or breaking of contaminated piping or breaching of containment, loss of HEPA filters during cutting or blasting operations, and material-handling accidents, such as dropping of contaminated components, concrete rubble, or spent resins. Dismantlement activities also include the potential for explosions either from front-end loaders or while using oxyacetylene during dismantlement activities. Storage-type activities include storage of non-fuel wastes that could result in liquid waste tank ruptures and explosive gas buildup in ion exchange resins. There is also the potential for fires in buildings or in waste stored inside the facility.

The most common non-fuel-related accidents that involved radioactive material were the fires (20 total accidents from 12 different plants). A fire may be one of the more important accidents to consider for a plant in decommissioning because of the large loading of combustible material resulting from the amount of low-level radioactive waste in the form of wipes, clothing, etc. Fire events included generic listings of "fire," specific listings of locations where the fire might occur (in the boiler building or low-level waste storage buildings) or the material the fire involves (contaminated clothing or contaminated sweeping compounds).

The second most common non-fuel-related accident related to the handling of radioactive (non-fuel) material such as waste containers, filters, concrete rubble, contaminated components, or larger items such as reactor pressure vessels or steam generators (13 accidents identified from 5 separate plants). The third most common radiation-related (non-fuel) accident was from explosions, which comprise 11 accidents from 5 separate plants. These accidents included explosion of liquid propane gas from front-end loaders being used for dismantlement activities and oxyacetylene explosions during dismantlement, which released HEPA filter contents, or during the reactor vessel shell. The fourth most common non-fuel-related accident is the release of liquid radioactive waste from storage tanks. The majority of these accidents resulted from the rupture or failure of a tank storing liquid radioactive waste. However, one of the postulated accidents occurs during the inadvertent pumping or transfer of the liquid radioactive waste to the river without sampling. Another of the postulated accidents in this group was the rupture of the spent fuel pool, with the contents released to a nearby body of water. This accident looked at the offsite dose consequences of the contaminated water being released to the environment and did not consider the resultant effect on the spent fuel remaining in the now-drained pool (considered a separate accident).

The licensees considered external events, including aircraft crashes into the facility's buildings, floods, low water levels, wind, earthquakes, volcanoes, lightning, forest fires, freezing temperatures, and physical security (intruder-initiated events). Earthquakes or seismic events (11 accidents from 10 plants), site flooding (10 accidents from 10 plants) and tornado or extreme wind (10 accidents from 9 plants) were the most commonly cited.
There is only one subgrouping of transportation-related accidents. Eight potential transportation-related accidents were discussed, ranging from transportation of low-level waste to transportation of large components, such as the reactor pressure vessel.

There were four accidents related to nonradiological, chemical releases that were found in the licensing-basis documentation. Three of the four accidents would result in an offsite release of toxic chemicals, and the fourth would result in a chemical event that would incapacitate the operator of a crane inside the plant, thus initiating a material-handling event.

I.2 Consequences of Potential Accidents

In addition to compiling a comprehensive list of accidents and malfunctions at permanently shutdown facilities, the potential offsite dose consequences were evaluated. The evaluation of dose consequences is necessary for understanding the risk to the public from these accidents. Compared to the potential consequences from an accident at an operating facility, most of the accident consequences for a permanently shutdown facility are small. This section addresses accident consequences both from the accidents obtained from NRC-sponsored research and the accidents found in the licensing documentation.

Table I-4 presents the highest doses in each of four categories of radiological accidents as obtained from licensing-basis documents. The highest doses result from postulated fuel-related accidents and radioactive-material-related accidents. All accidents that were reviewed used conservative assumptions to calculate the offsite dose. For example, some licensees analyzed accidents that considered the 100% failure of fuel by using assumptions that were non-mechanistic to determine the estimated dose.

Information obtained from licensing-basis documents for the fuel-related accidents showed that the highest doses were from the cask or heavy load handling accidents, the accidents that assumed a 100% fuel failure, and the spent fuel handling accidents. Although some of the licensing-basis documents gave calculated doses to the offsite population from the loss of water in the spent fuel pool (Maine Yankee, 2.3 mSv [0.23 rem]; Fort St. Vrain, 0.35 mSv [0.035 rem]) and from the loss of cooling capability to the spent fuel pool (Maine Yankee, 2.2E-5 mSv [0.002 mrem]), the majority of the documents stated that these accidents would result in no appreciable offsite dose because the accident could be mitigated before offsite-dose consequences could occur.

Table I-4. Highest Offsite Doses Calculated for Postulated Accidents in Licensing-Basis Documents

Accident Description	Nuclear Plant	Offsite Whole-Body Dose, rem
Fuel-Related Accidents		
Cask drop into spent fuel pool	Haddam Neck	0 418
Loss of spent fuel pool inventory (loss of heat sink or by inadvertent siphoning)	Maine Yankee	0.23
Shipping cask or heavy load drop into fuel element storage well	La Crosse	0.186
Loss of prestressed concrete reactor vessel shielding water (after fuel has been removed)	Fort St. Vrain	0.035
100% fuel failure	Indian Point, Unit 1	0.027
Simultaneous failure of fuel assemblies	Dresden, Unit 1	0.016
Spent fuel handling accident	Humboldt Bay, Unit 3	0 013
Fuel-handling accident	Rancho Seco	0.01
Heavy load drop	Fort St. Vrain	0 007
Fuel assembly drop	Haddam Neck	0 0026
Radioactive Material-Related Accidents (Non-Fuel)		
Spent resin handling accident (exothermic reaction during dewatering)	Haddam Neck	0 96
Explosion inside vapor container	Yankee Rowe	0.44
Radioactive liquid waste system leaks and failure	Maine Yankee	0.23
Materials-handling event	Yankee Rowe	0.16
Fire	Fort St. Vrain	0.12
Fire in intermodal container of waste	Yankee Rowe	0.1
Fire in D-rings	Three Mile Island, Unit 2	0 049
Decontamination events	Yankee Rowe	0 039
Liquid radioactive waste released to lake through cracks in building (earthquake-induced)	Fermi, Unit 1	0 02364
Release of resins from makeup and purification demineralizer	Three Mile Island, Unit 2	0 02
External-Events Initiated Accidents		
Natural disaster, tornado	Fort St. Vrain	0.001
Physical security breach	Pathfinder	<0 000001
Offsite Transportation Accidents		
Reactor pressure vessel railroad accident and fire	Pathfinder	0.00014
Truck carrying radioactive waste – fire	Pathfinder	0.000005
Reactor pressure vessel drop into river during transportation by rail	Pathfinder	0.000001
Transportation accident	Three Mile Island, Unit 2	<0.000001

To convert from rem to sievert, multiply by 0 01.

In addition to the licensing-basis documents reviewed, the staff's report *Technical Study of Spent Fuel Pool Accident Risk at Decommissioning Nuclear Power Plants* report (NRC 2001) provides an analysis of the consequences of the spent fuel pool accident risk. As discussed previously, earlier analyses in NUREG/CR-4982, *Severe Accidents in Spent Fuel Pools in Support of Generic Issue 82*, (Sailor et al. 1987) and NUREG/CR-6451, *A Safety and Regulatory Assessment of Generic BWR and PWR Permanently Shutdown Nuclear Power Plants* (Travis et al. 1997) included a limited analysis of the offsite consequences of a severe spent fuel pool accident occurring up to 90 days after the last discharge of spent fuel into the spent fuel pool. These analyses showed that the likelihood of an accident that drains the spent fuel pool is very low, although the consequences of such accidents could be comparable to those for a severe reactor accident. As part of its effort to develop generic, risk-informed requirements for decommissioning, the staff performed a further analysis of the offsite radiological consequences of beyond-design-basis spent fuel pool accidents using fission product inventories at 30 and 90 days and 2, 5, and 10 years. The accident progression scenarios that lead to large radiological releases following the drainage of a spent fuel pool require many nonmechanistic assumptions. This is because the geometry of the fuel assemblies, and the air cooling flow paths, cannot be known following a major dynamic event that might drain the water from the spent fuel pool. In addition, no credit is taken for preventative or mitigative actions and large uncertainties exist in the source term and consequence calculations. Because of these uncertainties, the staff developed bounding risk curves in NUREG-1738 (NRC 2001) that capture both the frequency and consequences of a beyond-design-basis spent fuel pool drainage event. The risk curves are provided in Figures I-1 and I-2. The results of the study indicate that the risk at spent fuel pools is low and well within the Commission's Quantitative Health Objectives. The risk is low because of the very low likelihood of a zirconium fire even though the consequences from a zirconium fire could be serious.

For the "Other Radioactive Material-Related" accidents (nonfuel), the accident subgroup with the highest estimated offsite dose was 0.96-rem total effective dose equivalent (TEDE) for a spent resin handling accident. The spent resin handling accident is only slightly below the U.S. Environmental Protection Agency's Protective Action Guide (PAGs). Other associated accident scenarios included handling accidents occurring during dewatering, releases from makeup and purification demineralizers, and the dropping of liners. Other categories with significant estimated doses include accidental releases of radioactive liquid wastes, radioactive material (nonfuel) handling accidents, explosions, and fires. However, there was a significant variation in doses within each subcategory. For example, for the radioactive liquid waste release accidents, the estimated doses range from a high of 2.3 mSv (0.23 rem) TEDE for a leak in the radioactive liquid waste system (Maine Yankee) to an estimate of "no dose" for the uncontrolled liquid waste discharge via a tank pumped directly to the river (Humboldt Bay 3).

The external event accidents (aircraft crashes, forest fires, floods, freezing temperatures, low water levels, lightning, earthquakes, volcanoes, and extreme winds and tornadoes) were in all but one case determined by the licensee's analyses either to be of a very low probability of occurrence, to have no dose consequences, to have doses that were bounded by other accidents, or to have doses that were below the U.S. Environmental Protection Agency (EPA) PAGs (EPA 1991). Most of the time, it was indicated that the doses would be significantly less than the EPA PAGs. The one case where an offsite dose was calculated was a tornado event (Fort St. Vrain), which was estimated to result in a whole body, 2-hour dose of 0.0058 mSv (0.0058 rem) and an organ dose (lung) of 0.17 mSv (0.017 rem).

Doses from offsite transportation accidents were very small, ranging from a "no dose" estimate to an estimated 0.0014 mSv (0.00014 rem) for a reactor pressure vessel that was involved in a railroad accident (Pathfinder).

The accident consequences during decommissioning are somewhat time-dependent since some of the radionuclide inventory significantly decreases shortly following shutdown, and then continues to decrease at a slower rate during the entire decommissioning period. This is most pronounced for the fuel-related accidents since some of the radionuclides present in the fuel, such as iodine-131, have a significant impact on the severity of the dose, but have a short half-life and will decay to negligible amounts within a few months following shutdown.

I.3 Correlation of Activities with Potential Accidents During Decommissioning

Activities and hazards at reactor sites following permanent shutdown and defueling may be different from those routinely experienced at an operating reactor; however, there are similarities in decommissioning activities and the activities that take place during refueling and maintenance outages.
Table I-5 lists the activities that characterize the type of actions that are being taken at sites both in DECON and SAFSTOR and compares the activities to the accidents listed in Table I-3, "Comprehensive Accident List." This list of activities was obtained from documentation from the

sites that have recently completed, or have recently started, the decommissioning process. The list is divided into activities performed during DECON and SAFSTOR. The decontamination and dismantlement activities were included for those sites that are in SAFSTOR but are performing incremental decontamination and dismantlement. Under DECON, the activities are categorized as having to do with construction; decontamination; contamination control; dismantlement; removal of the vessel, internals, and other large components and systems; radioactive waste management; spent fuel pool; soil remediation;

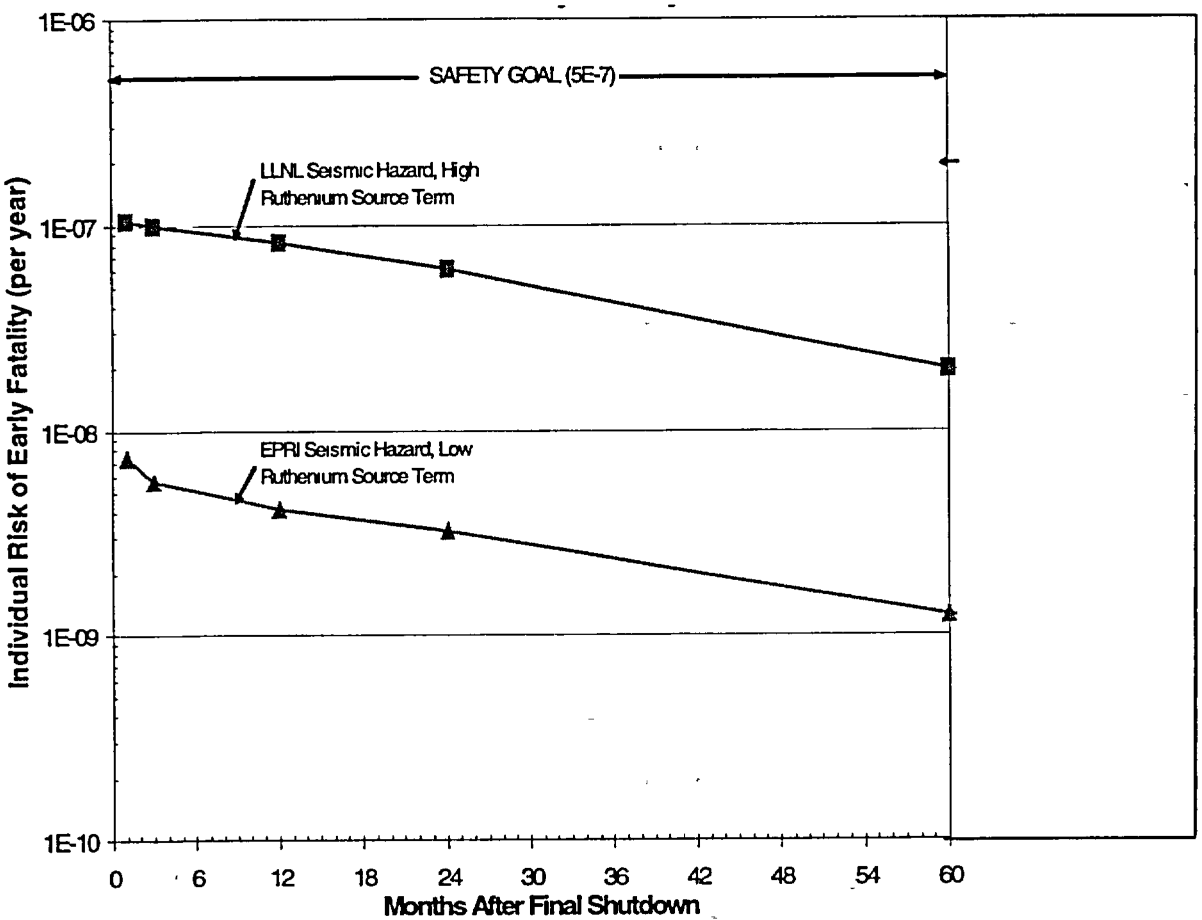

Figure I-1. Individual Early Fatality Risk Within 1 Mile of the Plant After a Beyond-Design-Basis Spent Fuel Pool Drainage Event.

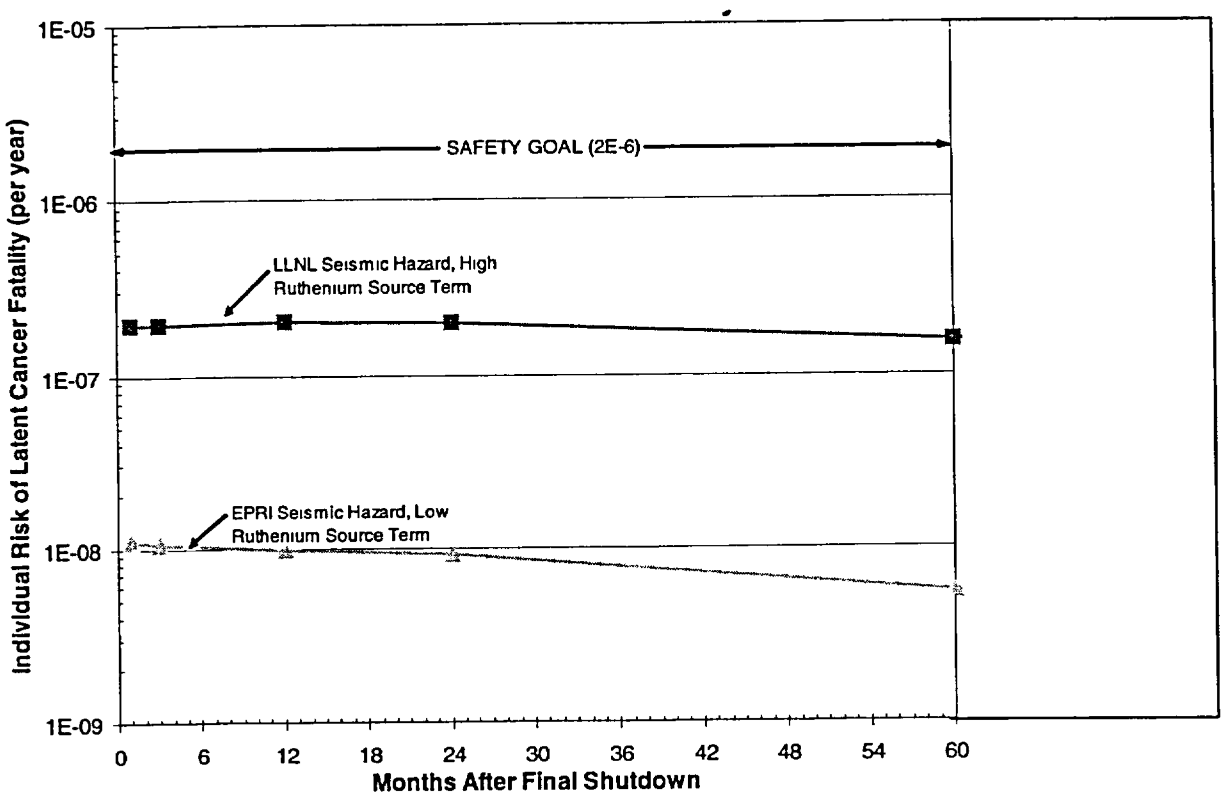

Figure I-2. Individual Latent Cancer Fatality Risk Within 10 Miles of the Plant After a Beyond-Design-Basis Spent Fuel Pool Drainage Event.

and the final radiation survey. For activities that take place during SAFSTOR, activities are simply listed as taking place in preparation for or during SAFSTOR.

For each activity, an assessment was made to determine the accident type that might occur during that activity. In the right-hand column of Table I-5, an associated accident is given, using the subgroup heading used in Table I-3. If an activity was determined not to have the potential for an accident, then it is described as "no accident." From the comparison of activities to accidents, it was determined that there would be no accident of greater consequence than the accidents already identified.

Table I-5. Comparison of Activities and Accidents During DECON and SAFSTOR

Activities	Associated Accidents
DECON	
Construction and Establishment	
Possible establishment of site construction power site	No accident
Possible establishment of monitoring stations separate from the control room	No accident
Possible construction of independent spent fuel storage installation (ISFSI)	Cask or heavy load handling
Possible establishment of spent fuel pool cooling system that is independent of existing plant systems	Loss of spent fuel cooling
Possible construction of decommissioning support building and utilities	No accident
Possible establishment of radioanalytical facilities	No accident
Possible design and fabrication of special shielding and contamination-control envelopes	No accident
Possible establishment of radiological monitoring stations	No accident
In situ chemical decontamination of primary coolant system	Decontamination-related accidents
Decontamination of outside of large components, facility surfaces, components, and piping surfaces	Decontamination-related accidents
Vacuuming	Vacuum filter bag ruptures
Ultra-high-pressure water lancing	Decontamination-related accidents
Abrasive grit blasting	Decontamination-related accidents
Manual decontamination techniques (handwriting), wet mopping, scrubbing	Decontamination-related accidents
Painting or applying coatings to stabilize contamination	No accident
Contamination Control	
Bag items to prohibit contamination spread	Fire
Dismantlement	
Remove contaminated piping and tubing - cut and install covers and plugs	Dismantlement-related accidents; fire; hazardous materials accidents
Remove walls	Radioactive material (nonfuel) handling accidents
Demolish buildings	Radioactive material (nonfuel) handling accidents
Concrete removal with impact hammers, saw cutting, and diamond wire cutting	Radioactive material (nonfuel) handling accidents
Abrasive water jet cutting (scabbier) for concrete.	Decontamination-related accidents
CO_2 blasters for concrete	Decontamination-related accidents

Table I-5. (contd)

Activities	Associated Accidents
DECON (contd)	
Metal component dismantlement - saw cutting - power band saws - diamond wire saws - machining - mechanical shearing - manual disassembly - abrasive shell cutting - OD milling machines - torch cutting (thermal methods melt or vaporize surfaces of materials being cut)	Radioactive material (nonfuel) related accidents; dismantlement-related accidents; fire; hazardous materials accidents
Rigging used to remove heavy or awkward sections Small-diameter piping	Radioactive material (nonfuel) related accidents; dismantlement-related accidents
Filings collected in catch basins and vacuumed, as needed	Radioactive material (nonfuel) related accidents; vacuum filter bag rupture
Removal of Reactor Pressure Vessel and Internals	
Piping and instrumentation lines cut; interferences removed	Radioactive material (nonfuel) related accidents; dismantlement-related accidents; fire; hazardous materials accidents
Decontaminated, segmented, packaged, and shipped offsite – segmenting included underwater semi-automatic plasma arc and metal disintegration machining equipment	Decontamination-related accidents; radioactive material (nonfuel) related accidents; dismantlement-related accidents; fire; hazardous materials accidents
Remove intact or segment	Radioactive material (nonfuel) related accidents; dismantlement-related accidents; fire; hazardous materials accidents
Intact removal requires - opening in building - grouting of openings created by cutting operations - removal from containment and placement in lay down area - removal of internals - injection of grout into reactor vessel - installation of welded closure caps on all openings - installation of structural members, as necessary - potential welding around reactor vessel.	Radioactive material (nonfuel) related accidents; dismantlement-related accidents; containment breach accidents

Table I-5. (contd)

Activities	Associated Accidents
DECON (contd)	
Removal of Other Large Components (Steam Generators and Pressurize)	
Intact removal or partial segmentation	Dismantlement-related accidents; radioactive material (nonfuel) handling accidents
Cut piping attachments	Dismantlement-related accidents; radioactive material (nonfuel) handling accidents; fire; hazardous materials accidents
Install temporary supports, cut hanger rods	No accidents given
Decontaminate external surfaces	Decontamination-related accidents
Seal-weld openings	
Move vessels horizontally for lifting through removable hatch or new opening in concrete building	Radioactive material (nonfuel) related accidents
Grout if required or segment greater than class C (GTCC) components for storage with the spent fuel	Dismantlement-related accidents; radioactive material (fuel- and nonfuel-related accidents)
Reactor Coolant System	
Decontaminate, segment, and dispose of RCS and other larger-bore piping	Radioactive material (nonfuel) related accidents; dismantlement-related accidents; fire; hazardous materials accidents
Remove and package asbestos insulation	Nonradioactive hazardous materials accidents
Remove turbine control oil	Fire
Remove nonradioactive materials, including fuel oil, lubricating oil, 1,1,1-tricholorethane, laboratory chemicals, lead, mercury, paint, battery acid, asbestos	Fire; nonradioactive hazardous materials accidents
Radwaste Management	
Ship radioactive materials	Transportation accidents
Ship mixed wastes to approved disposal sites	Transportation accidents
Spent Fuel Pool	
Remove spent fuel and GTCC waste	Cask or heavy load handling accidents; spent fuel pool handling accidents
Decontaminate and dismantle spent fuel facility after all spent fuel has been removed	Decontamination-related accidents; dismantlement-related accidents; radioactive material (nonfuel) related accidents

Table I-5. (contd)

Activities	Associated Accidents
DECON (contd)	
Soil remediation	Radioactive material (non-fuel) related accidents
Final radiation survey	No accidents
SAFSTOR	
Preparation for SAFSTOR	
Assess functional requirements for all plant systems, structures, and components for all phases of decommissioning	None
Deactivate systems; dispose of nonessential structures and systems	Radioactive material (nonfuel) related accidents; fire; hazardous materials accidents
Drain and flush plant systems	Decontamination-related accidents; hazardous materials accidents
Decontaminate, as necessary	Decontamination-related accidents
Either lay-up or isolate plant systems, structures, and components no longer required	No accidents
Remove filter elements and demineralizer resin beds	Spent resin accidents
Wet-mopping of clean areas	No accidents
Process, package, and ship liquid and solid radioactive waste generated during plant closure activities	Radioactive material (nonfuel) related accidents; radioactive liquid waste-release accidents; transportation accidents; hazardous materials accidents
Install permanent safety-related electrical power supply to spent fuel pool cooling system	Spent fuel pool cooling accidents
Establish a permanent reactor coolant system vent path (permanent passive venting of RCS to containment atmosphere)	Loss of HEPA filters; fire
Establish a permanent containment vent path	Loss of HEPA filters; fire
Removal of nitrogen gas cylinders	No accidents
Reconfigure the instrument/service air system	No accidents
Make electrical modifications required to de-energize equipment	No accidents
Remove dedicated safe-shutdown diesel and generator	Fire; hazardous materials accidents
Perform an assessment of current radiological conditions	No accidents
SAFSTOR Activities and Tasks	
24-hour guard force	No accidents
Maintain environmental and radiation monitoring program	No accidents
Preventative and corrective maintenance on operating/functional plant systems, structures, and components	No accidents
Maintain structural integrity	No accidents
Process liquid radwaste	Radioactive liquid waste releases
Provide for safe spent fuel storage	Loss of spent fuel cooling accidents

Table I-5. (contd)

Activities	Associated Accidents
SAFSTOR (contd)	
Maintain security systems	No accidents
Maintain radwaste systems	Radioactive gas waste system leaks radioactive liquid waste releases
Maintain heating and ventilation, where necessary	No accidents
Maintain lighting, fire protection, heating, ventilation, and air conditioning, and alarm systems, as required	No accidents
Dispose of nonradioactive hazardous waste	Hazardous materials accidents
Remove unused equipment during SAFSTOR	No accidents
Operate and monitor required systems	No accidents
Limited decontamination of selected structures and systems	Decontamination accidents; hazardous materials accidents
Perform general inspections during annual containment entry	No accidents

I.4 References

10 CFR 51. Code of Federal Regulations, Title 10, *Energy*, Part 51, "Environmental protection regulations for domestic licensing and related regulatory functions."

54 FR 39767. "10 CFR Part 51 Waste Confidence Decision Review." *Federal Register*. September 28, 1989.

64 FR 68005. "Waste Confidence Decision Review." *Federal Register*. December 6, 1999.

Oak, H. D., G. M. Holter, W. E. Kennedy, Jr., and G. J. Konzek. 1980. *Technology, Safety and Cost of Decommissioning a Reference Boiling Water Reactor Power Station*. NUREG/CR-0672, NRC, Washington, D.C.

Sailor, V. L., et al. 1987. *Severe Accidents in Spent Fuel Pools in Support of Generic Safety Issue 82*, NUREG/CR-4982, NRC, Washington, D.C.

Smith, R. I., G. J. Konzek, and W. E. Kennedy, Jr. 1978. *Technology, Safety and Costs of Decommissioning a Reference Pressurized Water Reactor Power Station*. NUREG/CR-0130, NRC, Washington, D.C.

Travis, R. J., R. E. Davis, E. J. Grove, and M. A. Azarm. 1997. *A Safety and Regulatory Assessment of Generic BWR and PWR Permanently Shutdown Nuclear Power Plants.* NUREG/CR-6451, NRC, Washington, D.C.

U.S. Environmental Protection Agency (EPA). 1991. *Manual of Protective Action Guides and Protective Actions for Nuclear Incidents,* 400-R-92-001, EPA, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 1988. *Final Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities.* NUREG-0583, NRC, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 1989. *Regulatory Analysis for the Resolution of Generic Issue 82, "Beyond Design Basis Accidents in Spent Nuclear Fuel Pools."* NUREG-1353, NRC, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 2001. *Technical Study of Spent Fuel Pool Accident Risk at Decommissioning Nuclear Power Plants.* NUREG-1738, NRC, Washington, D.C.

I.5 Licensing Basis Documents

One of the sources of information used in this report was licensing basis documents. The sources of information listed below by nuclear facility were consulted. The documents that are listed have been docketed by the NRC and are publicly available. The docket numbers for the facilities are noted below next to the facility name.

The documents can be obtained one of three ways. First, by accessing the NRC's website the reader can obtain most of the Post-Shutdown Defueling Activities Reports (PSDARs) and License Termination Plans (LTPs) that are cited in this chapter. The address for the decommissioning page on the NRC's website is http://www.nrc.gov/OPA/reports/dcmmssng.htm.

Second, the documents can be obtained from the Public Electronic Reading Room, which provides access to the NRC's new records-management system of publicly available information the Agency wide Documents Access and Management System (ADAMS). Within this system you can access two libraries: the Publicly Available Records System, and that Public Legacy Library.

This system, which was implemented on October 12, 1999, marks a change in the previous practice where records were available only in paper or microfiche copies at either the main NRC Public Document Room in Washington, DC or at 86 local public document rooms at libraries near nuclear power plants and other regulated facilities throughout the United States. Access to the NRC Public Electronic Reading Room will now be possible from personal computers, including those located in most public libraries.

ADAMS is an electronic information system that allows access to NRC's publicly available documents via the Internet. It permits full text searching and the ability to view document images, download files, and print locally. It also provides a more timely release of information by the NRC and faster access to documents by the public, than before. The reader can obtain the documents cited in this Appendix by providing the facility name (e.g., Trojan) or the docket number cited for each facility as shown at the end of this section, and the name or date of the document.

ADAMS can be accessed via the Internet at the NRC's website using the following URL: http://www.nrc.gov/NRC/ADAMS/index.html. This site contains instructions for installing and running ADAMS as well as information on obtaining assistance during installation or use.

The Public Electronic Reading Room on the NRC Web site at: www.nrc.gov, allows the public to use the Internet to search for any of the records that NRC has already released to the public. This site uses NRC's Agency wide Documents Access and Management System (ADAMS) to search two electronic libraries: the Public Legacy Library and the Publicly Available Records System (PARS) Library. The Public Legacy Library currently has a selection of bibliographic descriptions and some full text files of NRC records released to the public, prior to Fall 1999. Records in this library were copied from the NRC Bibliographic Retrieval System (BRS) and the Nuclear Document System (NUDOCS), the two systems previously used by the public to search for NRC records. Both BRS and NUDOCS will remain available for searching until all the records are in the Legacy Library. The other library, the Publicly Available Records System (PARS) Library, contains all NRC publicly available records released since Fall 1999. The records in the PARS Library are in, both, full text and image and the public can perform full text searches of the database, as well as view, download, and print the files from there.

Third, the NRC Public Document Room (PDR) at NRC Headquarters in Rockville, Maryland (One White Flint North, 20555 Rockville Pike, Washington DC 20555-0001 (1-800-397-4209), has a complete collection of over two million NRC documents released prior to the Fall of 1999 that are still retained as agency documents. The public may view documents at the PDR and there are reference librarians available to help in identifying, retrieving, organizing, and evaluating NRC documents from various resources and formats, including the Public Electronic Reading Room. Members of the public may also access the Electronic Reading Room libraries from computer terminals in the PDR. The PDR also provides reproduction services and, for a fee, the public can order copies of any of the records in the PDR, the Legacy, and the PARS libraries.

Big Rock Point (NRC Docket Number 50-155)

U.S. Nuclear Regulatory Commission (NRC). Undated. Transmittal of Safety Evaluation, Environmental Assessment and Notice of Issuance.

Consumers Energy. February 27, 1995. Big Rock Point Plant Decommissioning Plan.

U.S. Nuclear Regulatory Commission (NRC). 1995. Environmental Assessment by the U.S. Nuclear Regulatory Commission Related to the Request to Authorize Facility Decommissioning of Big Rock Point Nuclear Power Company, Consumers Energy.

U.S. Nuclear Regulatory Commission (NRC). 1995. Safety Evaluation Report by the U.S. Nuclear Regulatory Commission Related to the Request to Authorize Facility Decommissioning of Big Rock Point Nuclear Plant, Consumers Energy.

Consumers Energy. September 19, 1997. Big Rock Point Post-Shutdown Decommissioning Activities Report, Rev. 1.

Consumers Energy. September 19, 1997. Letter from Kenneth P. Powers, Consumers Energy, to the U.S. Nuclear Regulatory Commission. "Big Rock Point Plant - Request for Exemption from 10 CFR 50 Requirements for Emergency Planning."

U.S. Nuclear Regulatory Commission (NRC). February 23, 1998. Letter from NRC to Kenneth P. Powers, Big Rock Nuclear Plant, Consumers Energy Company. "Request for Additional Information Request for Exemption from Offsite Emergency Planning Requirements."

Consumers Energy. February 23, 1998. Request for Addition Information: Request for exemption from offsite emergency planning requirements.

U.S. Nuclear Regulatory Commission (NRC). September 30, 1998. Letter from NRC to Consumers Energy, "Exemption from Certain Requirements of 10 CFR 50.54(q) Regarding Offsite Emergency Planning Activities at Big Rock Point Nuclear Plant and Approval of Defueled Emergency Plan."

Dresden, Unit 1 (NRC Docket Number 50-010)

Commonwealth Edison Company. April 10, 1989. "Dresden Nuclear Power Station, Unit 1, Emergency Plan Response to Request for Additional Information."

U.S. Nuclear Regulatory Commission (NRC). September 3, 1993. Letter from Office of Nuclear Reactor Regulation, NRC, to D.L. Farrar, Commonwealth Edison Company. "Order to Authorize Decommissioning of Dresden Nuclear Power Station, Unit 1, and Amendment No. 37 to License No. DPR-2."

U.S. Nuclear Regulatory Commission (NRC). April 15, 1994. Letter from NRC to M.J. Wallace, Commonwealth Edison Company, "Special Inspection of a Potential Loss of Water from the Dresden Unit 1 Spent Fuel Storage Pool and the Plant's Compliance to the SAFSTOR Decommissioning Plan (Inspection Report No. 50-010/94001)."

U.S. Nuclear Regulatory Commission (NRC). October 20, 1995. Letter from Office of Nuclear Reactor Regulation, NRC, to D.L. Farrar, Commonwealth Edison Company. "Issuance of Amendments."

Commonwealth Edison Company. December 1996. Decommissioning Program Plan for the Dresden Nuclear Power Station Unit 1: Commonwealth Edison Company. Rev. 5.

Commonwealth Edison Company. December 19, 1996. Letter from J. Stephen Perry, Dresden Station, Commonwealth Edison Company, to U.S. Nuclear Regulatory Commission. "Dresden Nuclear Power Station Unit 1 Decommissioning Program Plan, vision 5, NRC Docket Number 50-010." JSPLTR #960245.

U.S. Nuclear Regulatory Commission (NRC). July 8, 1997. "Issuance of Amendment 39." [Includes Technical Specifications and Safety Evaluation.]

Fermi, Unit 1 (NRC Docket Number 50-016)

Detroit Edison Company. September 15, 1986. Letter from Detroit Edison to U.S. Nuclear Regulatory Commission. "Request for Additional Information as Outlined in 10CFR51.45(b) for Fermi 1." VP-86-0118.

U.S. Nuclear Regulatory Commission (NRC). April 1989. The Office of Nuclear Reactor Regulation Safety Evaluation Supporting Amendment No. 9 to Possession-Only License No. DRP-9: Fermi Unit No. 1.

U.S. Nuclear Regulatory Commission (NRC). April 28, 1989. Letter from Office of Nuclear Reactor Regulation, NRC, to W.S. Orser, Detroit Edison Company. "Issuance of Amendment No. 9 to Renew Possession-Only License No. DPR-9 for Fermi Unit 1.

U.S. Nuclear Regulatory Commission (NRC). April 2, 1996. "Inspection Results - Fermi 1."

Detroit Edison Company. August 23, 1996. Letter from Douglas R. Gipson, Detroit Edison Company, to U.S. Nuclear Regulatory Commission. "Enrico Fermi Atomic Power Plant, Unit 1: Annual Report Year Ending June 30, 1996." #NRC-96-0110.

U.S. Nuclear Regulatory Commission (NRC). November 21, 1996. Meeting Summary by U.S. Nuclear Regulatory Commission. "Summary of September 27, 1996, Meeting Regarding Status of Detroit Edison Company's Plans to Decommission its Fermi 1 Facility."

Detroit Edison Company. October 2, 1997. Letter from Douglas R. Gipson, Detroit Edison Company, to U.S. Nuclear Regulatory Commission. "Notification of Changes in Fermi 1 Schedule and Activities." #NRC-97-0110.

Detroit Edison Company. December 15, 1997. Letter from Douglas R. Gipson, Detroit Edison Company, to U.S. Nuclear Regulatory Commission. "Application for a License Amendment – Fermi Safety Analysis Report." #NRC-97-0115.

Fort St. Vrain (NRC Docket Number 50-267)

U.S. Nuclear Regulatory Commission (NRC). October 3, 1991. "Natural Gas Hazards at Fort St. Vrain." NRC Information Notice 91-63.

U.S. Nuclear Regulatory Commission (NRC). November 20, 1992. Letter from NRC to Public Service Company of Colorado. "Environmental Assessment and Finding of No Significant Impact regarding exemption from emergency preparedness requirements of 10 CFR 50.54(q)."

U.S. Nuclear Regulatory Commission (NRC). November 23, 1992. Letter from Office of Nuclear Reactor Regulation, NRC, to A. Clegg Crawford, Public Service Company of Colorado. "Order to Authorize Decommissioning of Fort St. Vrain and Amendment No. 85 to Possession Only License No. DPR-34."

Haddam Neck (NRC Docket Number 50-213)

Haddam Neck Plant Updated Final Safety Analysis Report. October 1995. Section 15.1, pp. 15.1-1 – 15.5-4; Table 15.5-1 (May 1987), 15.5-2 (May 1996), and 15.5-3 May 1987).

Connecticut Yankee Atomic Power Company. August 31, 1996. "Licensee Event Report: Pinhole Leak on Inlet Valve to "A" Residual Heat Removal Heat Exchanger."

Connecticut Yankee Atomic Power Company. August 22, 1997. Cover letter from Connecticut Yankee Atomic Power Company to U.S. Nuclear Regulatory Commission re "Haddam Neck Plant Post Shutdown Decommissioning Activities Report." CY-97-075.

Connecticut Yankee Atomic Power Company. December 18, 1997. Letter from R.A. Mellor, Connecticut Yankee Atomic Power Company, to U.S. Nuclear Regulatory Commission. "Haddam Neck Plant: Additional Information for the Proposed Defueled Emergency Plan." CY-97-121.

U.S. Nuclear Regulatory Commission (NRC). August 28, 1998. Letter from NRC to Connecticut Yankee Atomic Power Company, "Exemption from a Portion of 10 CFR 50.54(q) and Approval of Defueled Emergency Plan at Haddam Neck Plant."

Humboldt Bay, Unit 3 (NRC Docket Number 50-133)

U.S. Nuclear Regulatory Commission (NRC). April 1987. Final Environmental Statement for Decommissioning Humboldt Bay Power Plant, Unit No. 3. NUREG-1166, U.S. Nuclear Regulatory Commission, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). July 1994. SAFSTOR: Decommissioning Plan for the Humboldt Bay Power Plant, Unit 3. Revision 1.

Pacific Gas and Electric. February 27, 1998. Humboldt Bay Power Plant, Unit 3, Post-Shutdown Decommissioning Activities Report.

Indian Point, Unit 1 (NRC Docket Number 50-003)

U.S. Nuclear Regulatory Commission (NRC). October 17, 1980. "USNRC Order to Authorize Decommissioning and Amendment No. 45."

Consolidated Edison Company of New York, Inc. March 28, 1988. Supplemental Environmental Information in Support of Indian Point Unit 1.

Consolidated Edison Company of New York, Inc. August 10, 1989. Letter from A. Clegg Crawford, Consolidated Edison Company of New York, Inc., to Office of Nuclear Reactor Regulation, NRC. "Response to NRC Request for Additional Information on Indian Point Unit 1 Decommissioning."

U.S. Nuclear Regulatory Commission (NRC). June 18, 1993. Letter from Office of Nuclear Reactor Regulation, NRC, to Stephen B. Bram, Consolidated Edison Company of New York, Inc.. "Indian Point Unit 1 Decommissioning Plan Request for Additional Information."

Consolidated Edison Company of New York, Inc. September 20, 1993. Indian Point Unit 1 Decommissioning Plan. Request for Additional Information.

U.S. Nuclear Regulatory Commission (NRC). January 2, 1996. "Approval of Decommissioning Plan and Amendment of License for Indian Point Unit 1, Consolidated Edison Company of New York, Inc."

Consolidated Edison Company of New York, Inc. January 31, 1996. Appendix A to Provisional Operating License DPR-5 for the Consolidated Edison Company of New York, Inc. Amendment No. 45, Indian Point Station Unit No. 1.

U.S. Nuclear Regulatory Commission (NRC). January 31, 1996. Order to Authorize Decommissioning and Amendment No. 45 to License No. DPR-5 for Indian Point Unit No. 1.

U.S. Nuclear Regulatory Commission (NRC). January 31, 1996. Cover letter from Office of Nuclear Reactor Regulation, NRC, to the Consolidated Edison Company of New York, Inc. Indian Point Unit No. 1. "Amendment to Provisional Operating License."

La Crosse (NRC Docket Number 50-409)

U.S. Nuclear Regulatory Commission (NRC). December 23, 1987. Letter from NRC to Dairyland Power Cooperative. "Exempted from Requirement to Conduct 1987 Exercise and Exempted from Requirement to Produce and Distribute Annual Information Brochure to Public."

U.S. Nuclear Regulatory Commission (NRC). April 1, 1988. "Notice of Consolidation of Issuance of Amendment to Facility License."

La Crosse Boiling Water Reactor (LACBWR). May 1991. Decommissioning Plan. Prepared by the LACBWR staff, La Crosse, Wisconsin.

U.S. Nuclear Regulatory Commission (NRC). September 15, 1994. Letter from Office of Nuclear Materials Safety and Safeguards, NRC, to William L. Berg, La Crosse Boiling Water Reactor, Dairyland Power Cooperative. "Confirmatory Order Modifying the August 7, 1991, Decommissioning Order for the La Crosse Boiling Water Reactor."

Dairyland Power Cooperative. December 10, 1996. Letter from William L. Berg, Dairyland Power Cooperative, La Crosse Boiling Water Reactor, to U.S. Nuclear Regulatory Commission. Dairyland Power Cooperative, La Crosse Boiling Water Reactor (LACBWR), Possession-Only License DPR-45, "Annual Decommissioning Plan Revision." LAC-13570.

Pathfinder (NRC Docket Number 50-130)

Northern States Power Company. August 31, 1988. Pathfinder Plant Decommissioning Plan. Northern States Power Company, Minneapolis, Minnesota.

U.S. Nuclear Regulatory Commission (NRC). June 1990. Environmental Assessment of Proposed Final Decommissioning of the Fuel Handling Building and Reactor Building at the Pathfinder Generating Plant.

U.S. Nuclear Regulatory Commission (NRC). June 1990. Safety Evaluation Report on Proposed Final Decommissioning of the Fuel Handling Building and Reactor Building at the Pathfinder Generating Plant.

Peach Bottom, Unit 1 (NRC Docket Number 50-171)

Philadelphia Electric Company. July 1974. Decommissioning Plan and Safety Analysis Report: Peach Bottom Atomic Power Station Unit 1. Docket No. 50-171.

Philadelphia Electric Company. May, 1975. Decommissioning Plan and Safety Analysis Report Revision. Peach Bottom Atomic Power Station, Unit 1.

Rancho Seco (NRC Docket Number 50-312)

Sacramento Municipal Utility District. "Supplement to Applicant's Environmental Report – Post Operating License Stage. Rancho Seco Nuclear Generating Station."

Sacramento Municipal Utility District. Undated. "Technical Specifications to Defueled Rancho Seco Facility - Proposed Amendment 182, Rev. 2."

U.S. Nuclear Regulatory Commission (NRC). February 22, 1991. Letter from Office of Nuclear Reactor Regulation, NRC, to Dan R. Keuter, Rancho Seco Nuclear Generating Station. "Issuance of Exemption to 10 CFR 50.54(q) for the Rancho Seco Nuclear Generating Station and Approval of the Rancho Seco Emergency Plan, Change 4, 'Long Term Defueled Condition'."

Rancho Seco Decommissioning Plan. April 1991. Pp. 3-1 – 10-1, and Glossary, pp. G-1 – G-8; Decommissioning Cost Study for the Rancho Seco Nuclear Generating Station. Prepared by TLG Engineering, Inc. for the Sacramento Municipal Utility District (SMUD), Sacramento, California.

Sacramento Municipal Utility District. May 20, 1991. Letter from Dan R. Keuter, SMUD, to U.S. Nuclear Regulatory Commission. "Proposed Decommissioning Plan." #AGM/NUC 91-081.

Sacramento Municipal Utility District. April 15, 1992. Letter from James R. Shetler, SMUD, to U.S. Nuclear Regulatory Commission. "Response to the Request for Additional Information in Support of the Rancho Seco Decommissioning Plan and Associated Environmental Report." #DAGM/NUC 92-086.

U.S. Nuclear Regulatory Commission (NRC). June 16, 1993. Letter from Office of Nuclear Reactor Regulation, NRC, to James R. Shetler, Rancho Seco Nuclear Generating Station. "Environmental Assessment, Notice of Issuance of Environmental Assessment and Finding of No Significant Impact, Safety Evaluation, and Evaluation of the Decommissioning Funding Plan Related to Request to Decommission Rancho Seco Nuclear Generating Station."

U.S. Nuclear Regulatory Commission (NRC). March 20, 1995. Letter from Office of Nuclear Reactor Regulation, NRC, to James R. Shetler, Rancho Seco Nuclear Generating Station. "Order Approving the Decommissioning Plan and Authorizing Decommissioning of Rancho Seco Nuclear Generating Station and Approval of the Decommissioning Funding Plan."

Sacramento Municipal Utility District. March 18, 1996. Letter from Steve J. Redeker, SMUD, to U.S. Nuclear Regulatory Commission. "Proposed License Amendment No. 192, Updated Cask Drop Design Basis Analysis and Editorial Changes to Load Handling Limit Specification D3/4.3." MPC&D 96-034.

Sacramento Municipal Utility District. October 14, 1996. "Amendment 2 to the Rancho Seco Defueled Safety Analysis Report."

Sacramento Municipal Utility District. January 29, 1997. Letter from Steve J. Redeker, SMUD, to U.S. Nuclear Regulatory Commission. "Rancho Seco Decommissioning Schedule Change." MPC&D 97-006.

Sacramento Municipal Utility District. March 20, 1997. Rancho Seco Post-Shutdown Decommissioning Activities Report, Docket No. 50-312. Rancho Seco Nuclear Generating Station, License No. DPR-54.

San Onofre, Unit 1 (NRC Docket Number 50-206)

San Onofre Nuclear Generating Station, Unit 1. Decommissioning Plan. Vision 0. Southern California Edison Company, Irvine, California, and San Diego Gas and Electric Company, San Diego, California.

San Onofre Nuclear Generating Station, Unit 1. December 1988. San Onofre 1 Final Safety Analysis Report, Updated. Section 15.17, pp. 15.17-1 – 15.18-4, Tables 15.18-1 – 15.18-3, and Figures 15.18-1 – 15.18-4.

Southern California Edison Company. November 23, 1993. Letter from Walter Marsh, Southern California Edison Company, to U.S. Nuclear Regulatory Commission. "Docket No. 50-206, Amendment Application No. 211, Supplement 2, Permanently Defueled Technical specifications, San Onofre Nuclear Generating Station, Unit 1."

Southern California Edison Company. May 12, 1993. Letter from Harold B. Ray, Southern California Edison Company, to U.S. Nuclear Regulatory Commission. "Docket No. 50-206. Amendment Application No. 211, Permanently Defueled Technical Specifications, San Onofre Nuclear Generating Station, Unit 1."

U.S. Nuclear Regulatory Commission (NRC). December 28, 1993. Letter from Office of Nuclear Reactor Regulation, NRC, to Harold B. Ray, Southern California Edison Company. "Issuance of Amendment No. 155 to Facility Operating License No. DPR-13, San Onofre Nuclear Generating Station, Unit No. 1, Permanently Defueled Technical Specifications."

U.S. Nuclear Regulatory Commission (NRC). December 28, 1993. Safety Evaluation by the Office of Nuclear Reactor Regulation Related to Amendment No. 155 to Facility Operating License No. DPR-13. Southern California Edison Company, San Diego Gas and Electric Company, San Onofre Nuclear Generating Station, Unit No. 1, Docket No. 50-206.

Southern California Edison Company. March 7, 1994. "Revision 6.0 to the Site Emergency Plan."

Southern California Edison Company. November 3, 1994. "Proposed Decommissioning Plan, San Onofre Nuclear Generating Station, Unit 1."

Southern California Edison Company. November 29, 1994. "Application for Termination of License."

Southern California Edison Company. August 16, 1996. Letter from Gregory T. Gibson, Southern California Edison Company, to U.S. Nuclear Regulatory Commission. "Unit 1 Spent Fuel Pool Information: San Onofre Nuclear Generating Station, Unit 1."

Saxton (NRC Docket Number 50-146)

GPU Nuclear, Inc. February 16, 1996. "Decommissioning Plan for Saxton Nuclear Experimental Facility." 0301-96-2006.

GPU Nuclear, Inc. February 1998. Updated Safety Analysis Report for Decommissioning the SNEC Facility. Revision 2. Saxton Nuclear Experimental Corporation/GPU Nuclear, Inc., Middletown, Pennsylvania.

GPU Nuclear, Inc. March 3, 1998. Letter from G.A. Kuehn, GPU Nuclear, Inc. to U.S. Nuclear Regulatory Commission. "SNEC Facility Response to Question 7 of the Fourth Request for Additional Information." 6L20-98-20105.

U.S. Nuclear Regulatory Commission (NRC). March 1998. Letter from Office of Nuclear Reactor Regulation, NRC, to G.A. Kuehn, Jr., GPU Nuclear, Inc.. "Environmental Assessment and Finding of No Significant Impact Related to Request to Authorize Facility Decommissioning, Saxton Nuclear Experimental Facility."

U.S. Nuclear Regulatory Commission (NRC). March 1998. Letter from Office of Nuclear Reactor Regulation, NRC, to G.A. Kuehn, Jr., GPU Nuclear, Inc.. "Issuance of Amendment No. 15 to Amended Facility License No. DPR-4 – GPU Nuclear, Inc. and Saxton Nuclear Experimental Corporation."

Shoreham (NRC Docket Number 50-322)

Shoreham Nuclear Power Station. January 15, 1994. Letter from A.J. Bortz, Shoreham Nuclear Power Station, to U.S. Nuclear Regulatory Commission. "Request for Approval of Decommissioning Plan Change: Spent Fuel Storage Pool (SFSP) Decommissioning Shoreham Nuclear Power Station – Unit 1, Docket No. 50-322."

Shoreham Nuclear Power Station. January 1994. Licensee Event Report 93-002, Shoreham Nuclear Power Station – Unit 1, Docket No. 50-322. LSNRC-2143, Shoreham Nuclear Power Station, Wading River, New York.

U.S. Nuclear Regulatory Commission (NRC). February 1993. Updated Decommissioning Plan, Long Island Power Authority, Shoreham Nuclear Power Station. U.S. Nuclear Regulatory Commission, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). September 30, 1993. Letter from NRC to Long Island Power Authority, "Issuance of Exemption from the Emergency Preparedness Requirements of 10 CFR 50.54(q) for the Shoreham Nuclear Power Station, Unit 1. Emergency Assessment and Finding of No Significant Impact."

Shoreham Nuclear Power Station. October 1993. Decommissioning Plan Change Notification: Removal of Reactor Pressure Vessel Bioshield Wall: Shoreham Nuclear Power Station – Unit 1. Docket No. 50-332, Shoreham Nuclear Power Station, Wading River, New York.

Trojan Nuclear Plant (NRC Docket Number 50-344)

Portland General Electric Company. June 18, 1997. Letter from Stephen M. Quennoz, Portland General Electric Company, Trojan Nuclear Plant, to U.S. Nuclear Regulatory Commission. "Response to NRC Request for Additional Information – Reactor Vessel Package."

Portland General Electric Company. June 18, 1997. Trojan Reactor Vessel Dose Analysis. VPN-048-97, Portland General Electric Company, Portland, Oregon.

Portland General Electric Company. March 31, 1997. Trojan Reactor Vessel Package: Safety Analysis Report. PGE-1076, Portland General Electric Company, Portland, Oregon.

Vallecitos Nuclear Center, GE-VBWR (NRC Docket Number 50-018)

Kornblith, L., Jr., E. Strain, and L. Welsh. February 1, 1957. The General Electric Developmental Boiling Water Reactor: Description. SG-VAL 1, General Electric Company, Portland, Oregon.

U.S. Atomic Energy Commission. July 25, 1966. Order Authorizing Dismantling of Facility General Electric Company/Vallecitos Boiling Water Reactor. U.S. Atomic Energy Commission, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). September 30, 1992. Letter from Office of Nuclear Reactor Regulation, NRC, to Gary L. Stimmell, General Electric Company. "Issuance of Amendment No. 16 to Facility License No. TR-1 for the General Electric Test Reactor License."

General Electric Company. August 21, 1995. Letter from G.E. Cunningham, General Electric Company, to U.S. Nuclear Regulatory Commission. "License R-33, Docket No. 50-73, VNC Reactor Facilities Radiological Emergency Plan; October, 1981 (as Revised)."

U.S. Nuclear Regulatory Commission (NRC). April 22, 1996. Letter from Thomas P. Bwynn, Division of Reactor Safety, NRC, to Gary L. Stimmell, General Electric Company, Vallecitos Nuclear Center. "NRC Inspection Report 50-073/96/01; 50-070/96-01; 50-018/96/01; 50-183/96-01.

Yankee Rowe (NRC Docket Number 50-029)

U.S. Nuclear Regulatory Commission (NRC). October 30, 1992. Letter from NRC to Yankee Atomic Electric Company, "Exemption from the Emergency Preparedness Rule 10 CFR 50.54(q) and Approval of the Defueled Emergency Plan at the Yankee Nuclear Power Station."

U.S. Nuclear Regulatory Commission (NRC). August 19, 1993. Letter from Division of Reactor Projects, NRC, to Mr. Jay K. Thayer, Yankee Atomic Electric Company. "Yankee Rowe Inspection 93-05."

Yankee Atomic Electric Company. December 20, 1993. "Decommissioning Plan for Yankee Nuclear Power Station." BYR 93-087.

U.S. Nuclear Regulatory Commission (NRC). December 14, 1994. Environmental Assessment Related to the Request to Authorize Facility Decommissioning: Yankee Nuclear Power Station, Yankee Atomic Electric Company.

U.S. Nuclear Regulatory Commission (NRC). February 2, 1995. "Issuance of Decommissioning Order to Yankee Atomic Electric Company Approving Yankee Nuclear Power Station Decommissioning Plan."

U.S. Nuclear Regulatory Commission (NRC). February 14, 1995. Letter from Office of Nuclear Reactor Regulation, NRC, to James A. Kay, Yankee Atomic Electric Company. "Order Approving the Decommissioning Plan and Authorizing Decommissioning of the Yankee Nuclear Power Station."

U.S. Nuclear Regulatory Commission (NRC). November 5, 1995. Letter from Division of Reactor Safety, NRC, to Russell Mellor, Yankee Atomic Electric Company. "Yankee Rowe Inspection 95-04." NRC Inspection Report 50-029/95-04.

Appendix J

Socioeconomics and Environmental Justice Impacts Related to the Decision to Permanently Cease Operations

Appendix J

Socioeconomics and Environmental Justice Impacts Related to the Decision to Permanently Cease Operations

This appendix presents information on the socioeconomic and environmental justice aspects of selected nuclear power facilities currently in the decommissioning process or that have recently completed the process. This Appendix provides a discussion of the impacts related to the decision to permanently cease operations that are outside the scope of this Supplement (See Section 1.3). The NRC staff reviewed this information to provide additional information related to concerns raised during scoping and Supplement development about Socioeconomic Impacts (Section 4.3.12) and Environmental Justice (Section 4.3.13).

Impact significance is assigned to specific issues as described in 10 CFR Part 51 Subpart A, Appendix B, Table B-1. The impacts are based on the definitions of three significance levels. Unless the significance level is identified as beneficial, the impact is adverse, or in the case of "small," may be negligible. The definitions of significance follow:

SMALL -- For the issue, environmental effects are not detectable or are so minor that they will neither destabilize nor noticeably alter any important attribute of the resource. For the purposes of assessing radiological impacts, the Commission has concluded that those impacts that do not exceed permissible levels in the Commission's regulations are considered small.

MODERATE -- For the issue, environmental effects are sufficient to alter noticeably, but not to destabilize, important attributes of the resource.

LARGE -- For the issue, environmental effects are clearly noticeable and are sufficient to destabilize important attributes of the resource.

J.1 Socioeconomic Impacts

There are two primary pathways through which the decision to permanently cease operations at a nuclear power plant creates socioeconomic impacts on the area surrounding the plant. The first is through direct expenditures in a local community by the plant work force, plus any purchases of goods and services required for plant activities. The second pathway for socioeconomic impact is through the effects on local government tax revenues and services. The impact pathways (direct expenditures and tax revenues) relate specifically to changes in the workforce and population, local tax revenues, housing availability, and public services.

Socioeconomic changes related to direct expenditures in the local community are considered not detectable if there is little or no impact on housing values, education, and other public services, and local government finances are not distinguishable from normal background variation due to other causes. Impacts on housing are considered not detectable when no discernable change in housing availability occurs, changes in rental rates and housing values are similar to those occurring statewide, and little or no housing construction or conversion occurs. Detectable impacts result when there is a discernable increase or reduction in housing availability, rental rates and housing values exceed the inflation rate elsewhere in the State, or more than minor housing conversions and additions or abandonments occur. Destabilizing impacts occur when project-related demand results in a very large excess of housing or very limited housing availability, there are considerable increases or decreases in rental rates and housing values, and there is substantial conversion or abandonment of housing units.

Socioeconomic changes related to tax revenues and services (education, transportation, public safety, social services, public utilities, and tourism and recreation) are considered not detectable if the existing infrastructure (facilities, programs, and staff) could accommodate any changes in demand related to plant closure without a noticeable effect on the level of service. Detectable impacts arise when the changes in demand for service or use of the infrastructure is sizeable and would noticeably decrease the level of service or require additional resources to maintain the level of service. Destabilizing impacts would result when new local government programs, upgraded or new facilities, or substantial numbers of additional staff and unsupportable levels of resources are required because of facility-related demand.

The information provided here is based, in part, on data obtained from or about facilities that have completed decommissioning and facilities that are currently being decommissioned. This data was obtained in the areas of workforce and population, local tax revenues, housing availability, and public services. The time period used for was the mid-1960s to 2001.

J.1.1 Changes in Work Force and Population

The size of the work force varies considerably among operating U.S. nuclear power facilities, with the onsite staff generally consisting of 600 to 800 personnel per reactor unit. The average permanent staff size at a nuclear power facility site ranges from 800 to 2400 people, depending on the number of operating reactors at the site. In rural or low-population communities, this number of permanent jobs can provide employment for a substantial portion of the local work force. In addition to the work force needed for normal operations, many nonpermanent personnel are required for various tasks that occur during outages. Between 200 and 900 additional workers may be employed during these outages to perform the normal outage maintenance work. These are work force personnel who will be in the local community only a short time, but during these periods of extensive maintenance activities, the additional personnel will have a substantial effect on the locality. If the local economy is stable or declining, the result of the reduction in work force related to plant closure could be economic hardships, including declining property values and business activity, and problems for local government as it adjusts to lower levels of tax revenues.

If there is a net reduction in the community work force but the economy is growing, the adverse impacts of this ongoing growth (e.g., housing shortages and school overcrowding) could be reduced. Changes of over 3 percent to a local population in a single year are expected to have detectable effects, while changes of over 5 percent are expected to result in destabilizing impacts. These negative impacts include reduction of school system enrollments, weakened housing markets, and loss of demand for goods and services provided by local business.

The impact from facility closure depends on the rate and amount of population change. If post-closure work begins shortly after shutdown with a large work force, then the impact of facility closure is mitigated. Facilities where layoffs are sudden and there is a long delay before post-closure work begins are likelier to experience negative population-related socioeconomic impacts. Thus, large plants located in rural areas that permanently shut down early and choose the SAFSTOR option are the likeliest to have negative impacts. Considering all variables such as plant size and community size as the same, plants that go into immediate DECON have fewer negative impacts that are less immediate than those of SAFSTOR. The impacts from the ENTOMB option, assuming those preparations were made immediately after shutdown, would also be less significant than those of SAFSTOR.

In only two cases did the corresponding county populations decline around the time of the closure (Indian Point, Unit 1, in Westchester, New York, and Millstone, Unit 1, in New London, Connecticut). However, during the same time period that the host counties experienced population declines, the hosting States also experienced population declines. This suggests that the decline in the county population was most likely part of an overall State population trend. Observing population trends over a decade may not capture small population declines or reductions in the rate of growth from one year to the next; however, longer trends should indicate whether or not the county had any large destabilizing population or housing impacts from the facility closure.

In 18 out of the 20 facility case studies where populations grew, the populations of the counties where the facilities are located increased more rapidly or at the same rate as the State population. The two cases where the populations of the counties grew at a slower rate include relatively rural counties in California (Humboldt and Alameda) during time periods when California as a whole experienced very high urban population growth.

Data was gathered on the changes in workforce at facilities that are currently being decommissioned (i.e., where operations have ceased), where information on operational and decommissioning workforces was available. This information is shown in Table J-1. The table also shows the total population in the host county at the time of plant shutdown, to indicate the potential importance of the facility closure.

U.S. Census population estimates for the counties that house the closed plants are used to assess population changes around the time of shutdown by comparing percentage changes in county and State populations for the same time periods (Table J-2).

J.1.2 Local Tax Revenues

The tax revenue impacts on the local communities of plant closure vary widely from zero impact (tax-exempt plants) to a loss of 90 percent of the community tax base. The magnitude of tax-related impacts varies primarily by the size of the taxing jurisdiction and the taxing structure of the State in which the plant is sited, as well as certain plant characteristics. All else being equal, the smaller the taxing community (less economically diverse), the greater the tax-revenue impact when the nuclear facility closes down.

In communities where the revenues from the facility made up over 50 percent of the tax revenue base (with the remaining tax revenues made up primarily of private residential real estate), there were significant increases in the tax rates on the remaining real estate as well as cut-backs in services supported by property-tax revenues. The manner in which a State calculates the value of the plant also affects (a) both the amount and timing of tax losses when a nuclear power facility closes and (b) how much such a closure disrupts the tax revenue stream in a given community:

- At one plant, the assessed value of the plant was calculated as a proportional share of the value of the parent corporation, where the percentage is based on the book value of assets in the State (or sub-State taxing jurisdiction) compared with the book value of the assets of the entire corporation. This approach kept the plant at full assessed value for 7 years after its permanent closure until it was dropped from the books of the parent corporation as an asset.

- Tax rules may or may not permit gradual phase-out. In some cases, the taxable asset value of the plants was allowed to phase out over a period of time (3 to 5 years). In other cases, the plants were simply taken off the tax roles in 1 year.

Table J-1. Impact of Plant Closure on Workforce at Nuclear Power Plants Currently Being Decommissioned

Nuclear Plant	Thermal Power	Decommissioning Option[a]	Shutdown Date[b]	Maximum Workforce	Post-termination Workforce	Maximum Workforce Change	County Population
Big Rock Point	240 MW	DECON	08/30/97	--	232	--	24,496 (1997)
Dresden, Unit 1	700 MW	SAFSTOR	10/31/78	--	--	--	--
Fermi, Unit 1	200 MW	SAFSTOR[c]	09/22/72	--	--	--	--
Fort St. Vrain	842 MW	DECON[d]	08/18/89	--	--	--	--
GE-VBWR	50 MW	SAFSTOR	12/09/63	--	--	--	--
Haddam Neck	1825MW	DECON	07/22/96	--	--	--	--
Humboldt Bay, Unit 3	200 MW	SAFSTOR[c]	07/02/76	150	60	90	99,692 (1975)
Indian Point, Unit 1	615 MW	SAFSTOR	10/31/74	--	--	--	--
La Crosse	165 MW	SAFSTOR	04/30/87	82	23	59	25,965 (1987)
Maine Yankee	2700 MW	DECON	12/06/96	481	360	121	31,760 (1997)
Millstone, Unit 1	2011 MW	SAFSTOR	11/04/95	--	--	--	--
Pathfinder	190 MW	SAFSTOR[d]	09/16/67	--	--	--	--
Peach Bottom, Unit 1	115 MW	SAFSTOR	10/31/74	--	--	--	--
Rancho Seco	2772 MW	SAFSTOR[c]	06/07/89	--	200-250	--	--
San Onofre, Unit 1	1347 MW	SAFSTOR[c]	11/30/92	424	295	129	2,723,782 (1997)
Saxton	23 MW	SAFSTOR[c]	05/01/72	--	--	--	—
Shoreham	2436 MW	DECON[d]	06/28/89	—	—	—	1,303,501 (1989)
Three Mile Island, Unit 2	2772 MW	Accident cleanup, followed by storage	03/28/79	1150	125	1125	222,100 (1979)
Trojan	3411 MW	DECON	11/09/92	1319	177-432	887-1142	44,513 (1997)
Yankee Rowe	600 MW	DECON	10/01/91	--	--	--	--
Zion, Unit 1	3250 MW	SAFSTOR	02/21/97	--	--	--	--
Zion, Unit 2	3250 MW	SAFSTOR	09/19/96	--	--	--	—

(a) The option shown in the table for each plant is the option that has been officially provided to NRC. Plants in DECON may have had a short (1 to 4 yr) SAFSTOR period. Likewise, plants in SAFSTOR may have performed some DECON activities or may have transitioned from the storage phase into the decontamination and dismantlement phase of SAFSTOR.
(b) The shutdown date corresponds to the date of the last criticality.
(c) Plant has recently performed or is currently performing the decontamination and dismantlement phase of SAFSTOR.
(d) Plants has completed decommissioning

Table J-2. County and State Population Changes During Plant Closure and Decommissioning

Nuclear Plant	Reactor Type	Thermal Power	Decommissioning Option	Location	County	County Population	County Population Change, %	State Pop. Change, %
Big Rock Point	BWR	240 MW	DECON	Charlevoix, MI	Charlevoix	24,496 (1997)	6.5	1.7
Dresden, Unit 1	BWR	700 MW	SAFSTOR	Morris, IL	Grundy	28,400 (1975)	14.9	2.8
Fermi, Unit 1	FBR	200 MW	SAFSTOR	Monroe Co., MI	Monroe	126,300 (1975)	12.7	4.1
Fort St. Vrain	HTGR	842 MW	DECON	Platteville, CO	Weld	130,764 (1979)	18	18
GE-VBWR	BWR	50 MW	SAFSTOR	Alameda Co., CA	Alameda	1,071,446 (1975)	2.6	16.4
Haddam Neck	PWR	1825 MW	DECON	Haddam, CT	Middlesex	149,010 (1997)	4.1	4.2
Humboldt Bay, Unit 3	BWR	200 MW	SAFSTOR	Eureka, CA	Humboldt	99,692 (1975)	9.8	25.8
Indian Point, Unit 1	PWR	615 MW	SAFSTOR	Buchanan, NY	Westchester	874,300 (1975)	-2.7	-3.3
La Crosse	BWR	165 MW	SAFSTOR	Genoa, WI	Vernon	25,965 (1987)	6.1	5.7
Maine Yankee	PWR	2700 MW	DECON	Wiscasset, ME	Lincoln	31,760 (1997)	5.8	2.6
Millstone, Unit 1	BWR	2011 MW	SAFSTOR	Waterford, CT	New London	246,959 (1997)	-0.8	-0.5
Pathfinder	BWR	190 MW	SAFSTOR	Sioux Falls, SD	Minnehaha	95,209 (1975)	12.2	3.4
Peach Bottom, Unit 1	HTGR	115 MW	SAFSTOR	Delta, PA	York	272,603 (1975)	13.8	1
Rancho Seco	PWR	2772 MW	SAFSTOR	Sacramento, CA	Sacramento	869,581 (1989)	8.1	8.3
San Onofre, Unit 1	PWR	1347 MW	SAFSTOR	San Clemente, CA	San Diego	2,723,782 (1997)	9	8.3
Saxton	PWR	23 MW	SAFSTOR	Saxton, PA	Bedford	42,353 (1975)	10.7	1
Shoreham	BWR	2436 MW	DECON	Suffolk County, NY	Suffolk	1,303,501 (1989)	3.1	0.5
Three Mile Island, Unit 2	PWR	2772 MW	Accident cleanup, followed by storage	Middletown, PA	Dauphin	232,317 (1979)	2.4	0.2
Trojan	PWR	3411 MW	DECON	Rainier, OR	Columbia	44,513 (1997)	16.5	14.1
Yankee Rowe	PWR	600 MW	DECON	Rowe, MA	Franklin	70,626 (1997)	1.8	1.7
Zion, Unit 1	PWR	3250 MW	SAFSTOR	Zion, IL	Lake	594,799 (1997)	8.3	4.4
Zion, Unit 2	PWR	3250 MW	SAFSTOR	Zion, IL	Lake	594,799 (1997)	8.3	4.4

- The State may or may not share the burden with local government. In one State, school districts' lost property-tax collections were offset by equalization methods at the State level, which reduced the impact due to plant closures. In another State, the small neighboring township was the sole recipient of all property-tax revenues generated by the plant. Thus, the community's tax revenues were significantly reduced when the revenue source shut down.

- In addition, ratepayers in some jurisdictions are entitled to share in funds recovered from the sale of plant components and commodities and unspent decommissioning funds. These are not taxes but are available to general fund revenues.

In addition to characteristics specific to the taxing jurisdiction, the size, age, and ownership of the facilities play a role in how much the facilities affect tax revenues. Generally, the larger the facility (in the MWt), the larger the tax revenue impact. In addition, aging of the facilities depreciates its book value and assessed value over time. Usually, the falling assessed value of an aging facility will have reduced the tax revenue of the facility before closure, thus lessening the change in tax revenues generated by the facility after closure. A facility that closes suddenly, well before the end of its license expiration, will have a greater impact on the community tax base. Finally, if a facility is owned by a public entity, there is no effect on the tax base from closure because the facility was never taxable.

Changes in tax revenues of less than 10 percent are considered not detectable, i.e., they resulted in little or no change in local property tax rates and the provision of public services. Losses between 10 percent and 20 percent result in detectable impacts, with increased property tax levies (where State statutes permit) and decreased services by local municipalities. Changes over 20 percent have destabilizing impacts on the governments involved. Tax levies must usually be increased substantially or services cut substantially, and the payment of debt for any substantial infrastructure improvements made in the past becomes extremely problematic. Borrowing costs for local jurisdictions may also increase because bond rate agencies downgrade their credit rating. However, it is important to remember that these rules of thumb are based on uncompensated changes. For example, if a local taxing jurisdiction lost a nuclear facility that amounted to 35 percent of its tax base, but 30 percentage points of this loss were made up by the opening of a new manufacturing facility, the net impact would be 5 percent or not detectable. Small, rural areas are more likely to be affected than more urban areas having a wider variety of economic opportunities and more sources of tax revenue. Impacts depend on the type of plant, size of plant, and whether or not there are multiple units at a site, all of which help determine the net loss in employment at plant closure as well as the loss of tax base.

Table J-3 shows the impact of closure on local tax revenues for selected plants currently in decommissioning (or that have completed decommissioning), for which data are available. The primary taxing authorities for most of the closed plants are the county and city in which the plant is sited. Tax information is typically provided by local taxing authorities (an assessor's office) or from town planners familiar with the tax revenues generated by the plants. Only in the case of Humboldt Bay was tax-impact information available on a smaller, older plant (-$377,000 in 1983-84). The plants where information is not available are very small plants that most likely had very little impact on the tax base of the community. Many of these plants were shut down in the 1960s and 1970s.

Table J-3. Impact of Plant Closure on Local Tax Revenues

Nuclear Plant	Location	Shutdown Date	Thermal Power	Decom-missioning Option	Tax Revenues Change, millions (M)	Tax Change, %	Notes
Big Rock Point	Charlevoix, MI	08/30/97	240 MW	DECON	--	--	--
Haddam Neck	Middlesex, CT	07/22/96	1825 MW	DECON	yr 1 -$0 7M yr 2 -$0.7M yr 3 -$1.3M yr 4 -$1.2M yr 5 -$0 5M	-30% (phased out over 5 yr)	
Maine Yankee	Wiscassset, ME	12/06/96	2700 MW	DECON	yr 1 -$6 3M yr 2 -$2 5M yr 3 -$1.1M yr 4 -$0 6M	-70% (phased out in 4 yr)	Taxes paid to town. Plant made up about 90% of tax revenue. They have phased out tax expenditure payments over 6-yr period
Millstone, Unit 1	Waterford, CT	11/04/95	2011 MW	SAFSTOR	-$0 8M	-2% due to plant closure	Impacts to tax revenues in this area during this time include 1) the natural depreciation rate of Unit 1. Assessment had become less than 5% of market value of plant by time of closure (2) Deregulation environment brings assessed value of plants down 50%
Rancho Seco	Sacramento, CA	6/7/89	2772 MW	SAFSTOR	no change	0	Rancho Seco was tax-exempt because it is considered to be owned by the government. Besides sales tax, etc., no impact.
San Onofre, Unit 1	San Clemente, CA	11/30/92	1347 MW	SAFSTOR	yr 1 -$1 2M yr 2 -$1.1M yr 3 -$1.2M		
Shoreham	Suffolk Co , NY	06/28/89	2436 MW	DECON	-$10M/yr up to -$115M total change after phase-out	10% decrease in yr 1, to 60% decrease by 2003	This county was hit hard by the abrupt manner in which this plant ceased operation and the lawsuits over tax assessment that proceeded (in which a judge determines assessed value close to 0 based on projected income stream from plant).
Three Mile Island, Unit 2	Middletown, PA	03/28/79	2772 MW	Accident cleanup followed by storage	no change	0	Utilities were tax exempt in 1979.
Trojan	Rainier, OR	11/09/92	3411 MW	DECON	yr 1-7 no change yr 8 -$2 3M	7.3% reduction for the county as a whole Loss of 52 6% for one rural fire protection district.	Oregon taxes on the basis of the percentage of capital value of the parent company (ENRON) in county, based on 87% of book value of the parent in state. The Trojan "asset" stayed on ENRON's books until the year 2000.
Yankee Rowe	Rowe, MA	10/01/91	600 MW	DECON	-$0 4M	12% reduction	Rowe has a hydro-electric plant that generates most of the tax revenue (over 75%) This alleviated some of the tax impacts
Zion, Units 1 and 2	Zion, IL	02/21/97 and 09/19/96	3250 MW (each)	SAFSTOR	yr 1 -$0 4M yr 2 -$3M yr 3 -$7M	12% in yr 1, rising to 50% by yr 5 (2002)	This is an assessment of both units together. There is a phase- out approach, where assessed value is reduced from $210 M to $10 M over 8 yr

J.1.3 Housing Availability

The prevailing belief of realtors and planners in communities surrounding the case study facilities is that closing the facilities has had a range of effects on the marketability or value of homes in the vicinity. Housing choices of local residents are rarely affected by the presence of the facility, but people may move into the area in response to (temporarily) softer housing prices and commute to a nearby urban area.

J.1.4 Public Services

The impacts of closure on public services are closely related to the tax-related impacts on the community and are affected by the same characteristics of the plant: its size and age, its tax treatment, and the dependence of the local community on plant-related revenues, but not on the choice of decommissioning option or the amount of time between shutdown and active decommissioning. The impacts to the following public services may occur as a result of plant closure: education, transportation, public safety, social services, public utilities, and tourism and recreation.

Inquiries were made to local governments in the vicinity of closed plants about public service impacts during and after shutdown and decommissioning (Table J-4). Analysis was also conducted in the course of preparing NUREG-1437 (NRC 1996). Based on that experience, the following generalizations can be made.

In general, detectable impacts arise when the demand for service or use of the infrastructure is sizeable and would noticeably decrease the level of service or require additional resources to maintain the level of service. Destabilizing impacts would result when new programs, upgraded or new facilities, or substantial additional resources and staff are required because of facility-related demand.

In general, the communities that suffered the most from the tax-related impacts of plant closure also experienced the greatest impacts on public services. To some extent, the communities themselves control the amount of impact by how they allocate property taxes to local budgets before shutdown and how they prioritize these services post-shutdown. For example, one community channeled a great deal of the surplus revenues into building extensive social services for the elderly and for local youth in its community. After the plant ceased operations, the tax revenues decreased, all of the social services were downsized, and many will be eliminated because these are not considered to be priority programs (relative to public safety and education). In a second case, the county provided relatively few social services. Thus, the impact on social services after the shutdown was minor, although several other categories of

Table J-4. Impact of Plant Closure on Local Public Services

Nuclear Plant	Housing	Education	Transportation	Public Safety	Social Services	Public Utilities	Tourism and Recreation
Big Rock Point	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL
Dresden, Unit 1	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL
Fermi, Unit 1	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL
Fort St. Vrain	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL
GE-VBWR	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL
Haddam Neck	SMALL to MODERATE	MODERATE	SMALL to MODERATE	MODERATE	SMALL to MODERATE	SMALL	SMALL
Humboldt Bay, Unit 3	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL
Indian Point, Unit 1	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL
La Crosse	SMALL	SMALL to MODERATE	SMALL	SMALL to MODERATE	SMALL	SMALL	SMALL
Maine Yankee	MODERATE	MODERATE	SMALL	MODERATE	SMALL	SMALL	SMALL
Millstone, Unit 1	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL
Pathfinder	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL
Peach Bottom, Unit 1	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL
Rancho Seco	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL
San Onofre, Unit 1	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL
Saxton	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL
Shoreham	MODERATE	MODERATE to LARGE	MODERATE	MODERATE	SMALL to MODERATE	MODERATE	SMALL
Three Mile Island, Unit 2	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL
Trojan	SMALL to MODERATE	MODERATE	SMALL	SMALL to MODERATE	SMALL	SMALL	SMALL
Yankee Rowe	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL
Zion, Unit 1	SMALL	MODERATE	MODERATE	MODERATE	MODERATE to LARGE	SMALL	SMALL
Zion, Unit 2	SMALL	MODERATE	MODERATE	MODERATE	MODERATE to LARGE	SMALL	SMALL

public service experienced larger impacts. For example, education was largely funded by plant tax revenues and the responsible school district has recently indicated that it may have to file for bankruptcy, so the impact there was substantial.[a]

(a) The size of impact can be significantly influenced by the mechanism that the State uses for funding, e.g., if the State makes up the difference between what the local school districts can fund from the local property tax and what the State has decided is the appropriate level of per-student expenditures.

In general, impacts are nondetectable and nondestabilizing if the existing infrastructure (facilities, programs, and staff) could accommodate any plant-related demand without a noticeable effect on the level of service. Detectable and nondestabilizing impacts arise when the demand for service or use of the infrastructure is sizeable and would noticeably decrease the level of service or require additional resources to maintain the level of service. Detectable and destabilizing impacts would result when new programs, upgraded or new facilities, or substantial additional staff are required because of plant-related demand. The impacts of plant closure were determined for education, transportation, public safety, social services, public utilities, and tourism and recreation.

Education: The NRC considered changes in enrollment in another licensing framework (see *The Generic Environmental Impact Statement for License Renewal of Nuclear Plants*, NUREG-1437 [NRC 1996]) that is useful in the context of plant closure. In general, nondetectable and nondestabilizing impacts are associated with project-related enrollment increases of 3 percent or less. Impacts are considered nondetectable and nondestabilizing if there is no change in the school systems' abilities to provide educational services and if no changes in the number of teaching staff or classroom space are needed. Detectable but destabilizing impacts generally are associated with 4 to 8 percent decreases in enrollment. Impacts are considered moderate if a school system must decrease its teaching staff or classroom space even slightly to preserve its pre-project level of service. Any decrease in teaching staff, however small (e.g., 0.5 full-time equivalent), that occurs from retiring or laying off personnel or changing the duties of existing personnel (e.g., a guidance counselor assuming classroom duties) may result in moderate impacts, particularly in small school systems. Detectable and destabilizing impacts are associated with project-related enrollment decreases of more than 8 percent. Some of the case-study communities had challenges adjusting to the loss of children of the plant staff from the local school systems. For example, some of the local schools had to go on a 4-day week in the Rainier, Oregon, area because loss of enrollment made the schools much more expensive to run per student served.

Transportation: The U.S. Nuclear Regulatory Commission (NRC) considered transportation issues in another licensing framework (see NUREG-1437 [NRC 1996]) that is useful in the context of plant closure. That framework considered impacts on the Transportation Research Board's level of service (LOS) definitions (Transportation Research Board 1985). LOS is a qualitative measure describing operational conditions within a traffic stream and their perception by motorists.

LOS A and B are associated with nondetectable and nondestabilizing impacts because the operation of individual users is not substantially affected by the presence of other users. At this level, no delays occur and no improvements are needed. LOS C and D are associated with detectable and nondestabilizing impacts because the operation of individual users begins to be severely restricted by other users, and at level D small increases in traffic cause operational problems. Consequently, upgrading of roads or additional control systems may be required. LOS E and F are associated with detectable and destabilizing impacts because the use of the roadway is at or above capacity level, causing breakdowns in flow that result in long traffic delays and a potential increase in accident rates. Major renovations of existing roads or additional roads may be needed to accommodate the traffic flow.

Impacts to transportation during the license renewal term would be similar to or less than those experienced during current operations, driven mainly by the workers involved in plant closure, who are generally fewer in number than the operating staff. Consequently, LOS conditions are likely to move in the direction of A and B at all plants. Based on past and projected impacts at the case study sites, transportation impacts would continue to be nondetectable and nondestabilizing at all sites.

Public safety: Impacts on public safety are considered nondetectable and nondestabilizing if there is little or no need for additional police or fire personnel. No disruptions of police and fire-protection services occurred at the case-study sites after plant closure. Existing services were adequate to handle the influx of decommissioning staff, who are less numerous than the operations staff.

Social services: The impacts on social services are considered nondetectable and nondestabilizing if no change in the current level of service occurs, detectable and nondestabilizing if service declines noticeably, and detectable and destabilizing if services are seriously disrupted. Impacts on social services following closure largely depend on the ability of the community to replace the jobs lost at the end of operations or to successfully assist the laid-off workers and other affected workers in the community to transition out of the community. Most of the case-study sites have been able to do this, so closure impacts have been nondetectable and nondestabilizing to detectable but nondestablizing.

Public utilities: The NRC considered public utility issues in another licensing framework (see NUREG-1437 [NRC 1996]) that is useful in the context of plant closure. As in that framework, impacts on public-utility services are considered nondetectable and nondestabilizing if little or no change occurs in the ability to respond to the level of demand, and, thus, there is no need to add to capital facilities. Impacts are considered detectable and nondestabilizing if overtaxing of facilities during peak demand periods occurs. Impacts are considered detectable and destabilizing if existing service levels (such as the quality of water and sewage treatment) are substantially degraded and additional capacity is needed to meet ongoing demands for services. Overall, there have been nondetectable and nondestabilizing impacts on public utilities as a result of plant closure. The existing capacity of public utilities was sufficient to accommodate the small influx of decommissioning staff, and some locales experienced a noticeable decrease in the level of demand for services with the completion of plant operations.

Tourism and recreation: Few adverse effects have occurred during current operations at the case-study sites, and some positive effects have resulted because taxes paid by the plants and tours of the plants have also increased local tourism. Based on the case-study analysis, it is projected that because decommissioning essentially turns the operating facility back into a construction site while removing tax payments, the impacts of plant closure should be temporary, nondetectable and nondestabilizing at all plants. Some positive impact to tourism and recreation also may continue if the plant site is then converted for tourism activities, as planned for Trojan.

J.2 Environmental Justice

An evaluation of environmental justice is performed to determine if minority and low-income groups bear a disproportionate share of negative environmental consequences. Selected socioeconomic indicators are found in Table J-5 for closed nuclear power plants for which data were available. These include the median county family income as a percentage of State median family income in the year 1989, and the percentage of minority (non-white plus white Hispanic) persons in the county in the year 2000.

J.3 Reference

U. S. Nuclear Regulatory Commission (NRC). 1996. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants.* NUREG-1437, NRC, Washington, D.C.

Table J-5. Socioeconomic Indicators Relevant to Environmental Justice at Closed Nuclear Power Plants

Nuclear Plant	Reactor Type	Decommissioning Option	Public Services Impacts	County Median Family Income (MFI), as % of State MFI[a]	Minority (Non-White and White Hispanic) in County, %[b]
Big Rock Point	BWR	DECON	SMALL	79.5	< 5
Dresden, Unit 1	BWR	SAFSTOR	SMALL	107.4	< 6
Fermi, Unit 1	FBR	SAFSTOR	SMALL	110.4	< 6
Fort St. Vrain	HTGR	DECON	SMALL	85 8	30
GE-VBWR	BWR	SAFSTOR	SMALL	110 9	59
Haddam Neck	PWR	DECON	SMALL to MODERATE	103.4	10
Humboldt Bay, Unit 3	BWR	SAFSTOR	SMALL	74 8	18
Indian Point, Unit 1	PWR	SAFSTOR	SMALL	148.3	35
La Crosse	BWR	SAFSTOR	SMALL	75.4	< 2
Maine Yankee	PWR	DECON	SMALL to MODERATE	103.1	< 2
Millstone, Unit 1	BWR	SAFSTOR	SMALL	87.9	15
Pathfinder	BWR	SAFSTOR	SMALL	124.2	< 8
Peach Bottom, Unit 1	HTGR	SAFSTOR	SMALL	107.7	< 9
Rancho Seco	PWR	SAFSTOR	SMALL	93.2	42
San Onofre, Unit 1	PWR	SAFSTOR	SMALL	128.3	45
Saxton	PWR	SAFTSOR	SMALL	72.7	< 2
Shoreham	BWR	DECON	SMALL to MODERATE	134 0	21
Three Mile Island, Unit 2	PWR	Accident cleanup, followed by storage	SMALL	106.9	24
Trojan	PWR	DECON	SMALL to MODERATE	106 5	< 7
Yankee Rowe	PWR	DECON	SMALL	82 4	< 6
Zion, Unit 1	PWR	SAFSTOR	MODERATE	135.2	26
Zion, Unit 2	PWR	SAFSTOR	MODERATE	135 2	26

(a) Source: 1990 Census of Population. *American Factfinder* Table 1990 QT. http://factfinder.census.gov
(b) Source: 2000 Census of Population. *American Factfinder* Table QT. http //factfinder census.gov

Appendix K

Transportation Impacts

Appendix K

Transportation Impacts

A generic analysis was conducted to estimate human health impacts associated with transporting decontamination and dismantlement wastes from reactor sites to low-level waste (LLW) burial grounds using the RADTRAN 4 computer code (Neuhauser and Kanipe 1992). RADTRAN was originally developed by Sandia National Laboratory to support the NUREG-0170 (NRC 1977) environment impact analysis and is commonly used for transportation impact calculations in support of environmental documentation. The more recent code, RADTRAN 5 (Neuhauser and Kanipe 1996), which uses the RADTRAN 4 models in stochastic framework, was not used because the goal of the analysis was to estimate bounds of impacts rather than a probabilistic distribution of impacts. The results of the RADTRAN 4 analysis are found in Section 4.3.17. The following is a discussion of the model input parameters.

- Waste volumes: The total volume of LLW generated during reactor decontamination and dismantlement is a function of the alternative being implemented. Waste volume estimates for decommissioning facilities were obtained for eight facilities from Post Shutdown Decommissioning Activity Reports (PSDARs), Environmental Reports (ERs), or data provided by licensees with the assistance of the Nuclear Energy Institute (NEI). Because of the small number of facilities from which estimates were obtained, the data tends to be skewed by the unique attributes of the decommissioning process for a given plant. For example, the only pressurized water reactor (PWR) facility with data for the SAFSTOR option is San Onofre, a plant that is removing all structures. The information received on LLW is summarized in Table K-1. The actual number of shipments of waste from a site during decommissioning may be inflated by State and local government regulations that require removal of all structures and concrete from the site, whether contaminated or not. For a number of sites listed in Table K-1, all waste was considered LLW, which inflated the values in the table.

  The Trojan Nuclear Plant Radiological Site Characterization Report (Trojan 1995) and the Maine Yankee License termination plan (Maine Yankee 2001) clearly show that all low-level waste is not the same. There is a relatively small volume of waste that includes the reactor vessel and internal components that has most of the residual radioactivity following cessation of operations (about 2.5-million curies). There is a slightly smaller volume of waste, such as concrete containing activation products, that contains most of the remaining residual activity (several hundred curies), and a much larger volume of waste that contains

Table K-1. Low-Level Waste Shipment Data for Decommissioning Nuclear Power Facilities

Nuclear Plant	Reactor Type	Decommissioning Option	LLW Volume, cubic meters	LLW Shipments	Distance, km (mi)
Maine Yankee	PWR	DECON	31,924 plus 853[b]	364 (truck), 181 (rail), 2 (barge)[b]	1900-4600 (1200-2860)
Haddam Neck	PWR	DECON	8017	496-582	1500-4000 (1400-2500)
Trojan	PWR	DECON	9765	470	482 (300)
San Onofre, Unit 1	PWR	SAFSTOR	--	91 (truck) 869 (rail)	--
Saxton	PWR	SAFSTOR	580	100	1000 (620)
Rancho Seco	PWR	SAFSTOR		1250 (truck) <25 (rail)	1000-4300 (620-2700)
Big Rock Point	BWR	DECON	2042	--	--
Millstone, Unit 1	BWR	SAFSTOR	18,014	--	--
Yankee Rowe[a]	PWR	DECON	4136	--	--

(a) From NUREG-1307, Rev. 9, p. A.3.
(b) Reactor pressure vessel and steam generators.

small amounts of activity (a few curies). The breakdown of LLW assumed for the evaluation of impacts of LLW transportation is shown in Table K-2.

- Number of shipments: The number of shipments was also determined from PSDARs, ERs, and data provided by NEI. These numbers represent the total number of shipments over the entire decommissioning period, which mostly occurs during decontamination and dismantlement and takes place in a period of 2-6 years. Shipment estimates were obtained for six facilities. The estimates vary significantly based on mode of transportation available at the site (truck, rail or barge), the decommissioning option chosen, the decommissioning methods being employed, the extent of facility dismantlement, and state and local requirements.

  Table K-2 includes the number of shipments estimated for each type of LLW in this analysis. The estimates were derived from the volume estimates by assuming that, on the average, each shipment of high-activity waste moved 5.3 m^3 (6.9 cubic yards) of material (capacity of a CNS 14-190 shipping cask), and each shipment of low-activity and very low-activity waste .

Table K-2. Volume and Activity Assumed for Evaluation of Radiological Impacts of Transportation of Low-Level Waste

	Total Volume, m^3 (ft^3)	Total Activity, Bq (Ci)	Activity Density, Bq/m^3 (Ci/m^3)	Shipments
High-activity waste (reactor vessel and internal components)	1200 (42,400)	9.81×10^{16} (2,650,000)	8.14×10^{13} (2200)	227
Low-activity waste (activated concrete)	750 (26,500)	1.5×10^{13} (400)	1.97×10^{10} (0.533)	84
Very low-activity waste (debris, soil)	5400 (191,00)	3.7×10^{11} (10)	6.85×10^{7} (0.0019)	360

moved 9 m^3 (12 cubic yards) of material (equivalent to 48 55-gal. drums). The reduced volume of material per shipment of the high activity waste reflects the shielding required to keep dose rates and truck weight within legal limits.

- Shipping distance: Transportation impacts and costs are a function of the distance traveled. Distances for decommissioning facilities range from 8 km (5 mi) to 4540 km (2840 mi). A bounding shipping distance of 4800 km (3000 mi) one-way was assumed for evaluation of radiological impacts of transportation; a round trip distance of 9600 km (6000 mi) was assumed for nonradiological impacts.

- Land class information: RADTRAN permits division of the transportation route into urban, suburban, and rural segments. Input to the code includes the fraction of the route that falls into each of these land-use classes, the population density in each segment, and the transport speed in each segment. Table K-3 gives the values for RADTRAN parameters used in the evaluation of LLW transport that are functions of land-use class. The percentage of the route and population density for each land-use class was estimated from routes for transport from the northeast and southeast United States to Nevada (Ramsdell et al. 2001), and the transport speeds were taken from NUREG/CR-6672 (Sprung et al. 2000). Accident rates given by Saricks and Tompkins (1999) were used in the calculations. They give the national average fatality rate for trucks as 5.5×10^{-9} fatalities per kilometer (8.8×10^{-9} fatalities per mile).

- Radiation dose rate: In calculating the doses to the public (onlookers and along the route), the radiation dose rate emitted from the shipping container was assumed to be at

Table K-3. RADTRAN Land-Use Class Dependent Parameter Values Assumed for Evaluation of Impacts of Transportation of LLW

Land-Use	Percent of Route	Population Density, people/km^2 (people/mi^2)	Transport Speed, km/h (mi/h)	Accidents per km (mi)
Urban	3	7.7 (20)	88 (55)	3.15×10^{-7} (5.07×10^{-7})
Suburban	18	390 (1000)	88 (55)	3.66×10^{-7} (5.89×10^{-7})
Rural	79	2300 (6000)	88 (55)	6.54×10^{-7} (1.05×10^{-7})

the regulatory maximum limit for transportation of high-activity waste and one-tenth of the regulatory limit for transportation of low-activity waste. The activity estimates for very low-activity waste are sufficiently small that the activity may be neglected in the evaluation of the radiological impacts of transportation of LLW. Dose rates for workers were calculated assuming 2.0×10^{-5} Sv/h (2 mrem/h).

- Radioactive material inventory: The inventory of radioactive material in a given shipment is variable. For the high-activity waste, which includes reactor vessel and internal components, the dominant radionuclides are activation products of the constituents of steel. Similarly, the dominant radionuclides in the low-activity waste are activation products of the constituents of concrete, with lesser contributions from surface contamination. Radionuclide distributions reported for residual radiation at Trojan (Trojan 1995) and Maine Yankee (Maine Yankee 2001) form the basis for the activity assumed in evaluation of the radiological impacts of LLW transport, which is shown in Table K-4. The specific isotopes for each type of LLW were selected by considering the fraction of the total activity represented by each isotope combined with the radiological consequences of exposure to the isotope. The total activity and radionuclide distributions given in these reports are generally consistent with activity and distribution estimates given in early estimates for reference reactors (Smith et al. 1978; Oak et al. 1980). RADTRAN 4 does not include nickel-63 in its library, so it was not included in the dose calculations for accidents. However, the dose is dominated by the contribution of cobalt-60 such that the dose from nickel-63 would have been negligible had it been included.

The transportation of the very low-activity waste is considered in evaluation of the nonradiological impacts of LLW transportation. In fact, most of the nonradiological impacts of transporting LLW are the result of transporting the very low-level activity because these impacts are directly associated with the number of miles driven but not with the amount of activity moved.

- Material Characterization: RADTRAN offers several default options for characterization of the dispersability of material for purposes of evaluation of the radiological consequences of transportation accidents. For this analysis, the high-activity waste was characterized as immobile because the material being transported is primarily composed of metal and the activity is primarily activation products in the metal. In an accident, 0.0001 percent of the immobile material is assumed to become airborne, and 5 percent of the airborne material is assumed to be respirable. Similarly, the low-activity waste was characterized as "loose chunks" because it tends to be concrete pieces with activation products dominating the activity. In an accident, 1 percent of the material in loose chunks is assumed to become airborne, and 5 percent of the airborne material is assumed to be respirable. These fractions, which are the RADTRAN default values, are adapted from NUREG-0170 (NRC 1977).

Table K-4. Low-Level Waste Activity Distributions Assumed for Evaluation of Radiological Impacts of LLW

	Activity Fraction		Activity per Truckload, Bq (Ci)	
	High-Activity Waste	**Low-Activity Waste**	**High-Activity Waste**	**Low-Activity Waste**
Mn-54	0.001	--	5.2×10^{11} (14)	--
Fe-55	0.348	--	1.5×10^{14} (4070)	--
Co-60	0.573	0.269	2.5×10^{14} (6680)	8.0×10^{10} (1.29)
Ni-63	0.078	--	3.4×10^{13} (920)	--
Cs-134	--	0.020	--	3.7×10^{9} (0.10)
Cs-137	--	0.010	--	1.9×10^{9} (0.05)
Eu-152	--	0.652	--	1.1×10^{11} (3.08)
Eu-154	--	0.059	--	1.0×10^{10} (0.28)

K.1 References

Maine Yankee, License No. DPR-36. January 13, 2000. Letter from George A. Zinke to U.S. Nuclear Regulatory Commission. "Maine Yankee's License Termination Plan."

Neuhauser, K. S., and F. L. Kanipe. 1992. *RADTRAN 4 – Volume 3:User's Guide.* SAND89-2370, Sandia National Laboratories, Albuquerque, New Mexico.

Neuhauser, K. S., and F. L. Kanipe. 1996. *RADTRAN 5–A Computer Code for Transportation*

Risk Analysis. SAND91-2600C, Sandia National Laboratories, Albuquerque, New Mexico.

Oak, H. D., G. M. Holter, W. E. Kennedy, Jr., and G. J. Konzek. 1980. *Technology, Safety and Costs of Decommissioning a Reference Boiling Water Reactor Power Station.* NUREG/CR-0672, Vol. 2, NRC, Washington, D.C.

Ramsdell, J. V., Jr., C. E. Beyer, D. D. Lanning, U. P. Jenquin, R. A. Schwarz, D. L. Strenge, P. M. Daling, and R. T. Dahowski. 2001. *Environmental Effects of Extending Fuel Burnup Above 60 GWd/MTU.* NUREG/CR-6703 (PNNL-13257), NRC, Washington, D.C.

Saricks, C.L., and M.M. Tompkins. 1999. *State-Level Accident Rates of Surface Freight Transportation: A Reexamination.* ANL/ESD/TM-150, Argonne National Laboratory, Argonne, Illinois.

Smith, R. I., G. J. Konzek, and W. E. Kennedy, Jr. 1978. *Technology, Safety and Costs of Decommissioning a Reference Pressurized Water Reactor Power Station.* NUREG/CR-0130, Vol. 2, NRC, Washington, D.C.

Sprung, J. L., D. J. Ammerman, N. L. Breivik, R. J. Dukhart, F. L. Kanipe, J. A. Koski, G. S. Mills, K. S. Neuhauser, H. D. Radloff, R. F. Weiner, and H. R. Yoshimura. 2000. *Reexamination of Spent Fuel Shipment Risk Estimates.* NUREG/CR-6672 (SAND2000-0234), NRC, Washington, D.C.

Trojan Nuclear Plant. 1995. *Trojan Nuclear Plant Radiological Site Characterization Report.* Revision 0.1, Portland General Electric Company, Portland, Oregon.

U.S. Nuclear Regulatory Commission (NRC). 1977. *Final Environmental Statement on the Transportation of Radioactive Material by Air and Other.* NUREG-0170, Vol. 1, NRC, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 1999. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Main Report, Section 6.3–Transportation, Table 9.1, "Summary of findings on NEPA issues for license renewal of nuclear power plants."* NUREG-1437, Vol. 1, Addendum 1, NRC, Washington, D.C.

K.2 Related Documents

Connecticut Yankee Atomic Power Company, Letter CY-00-129. August 1, 2000. Letter from Noah W. Fetherston to U.S. Nuclear Regulatory Commission. "Submittal of Decommissioning Environmental Review."

Connecticut Yankee Atomic Power Company, Letter CY-97-075. August 22, 1997. Letter from T.C. Feigenbaum to U.S. Nuclear Regulatory Commission. "Haddam Neck Plant-Post Shutdown Decommissioning Activities Report."

Consumers Energy Company, License DPR-6. September 19, 1997. Letter from Kenneth P. Powers to U.S. Nuclear Regulatory Commission. "Big Rock Point Plant-Post Shutdown Decommissioning Activities Report; Revision 2."

Maine Yankee, MN-01-009, RA-01-033. March 21, 2001. Letter from Thomas L. Williamson to U.S. Nuclear Regulatory Commission. "Request for Information to Support GEIS Supplement."

Maine Yankee Letter, License No. DPR-36. September 19, 1997. Letter from Michael J. Meisner to U.S. Nuclear Regulatory Commission. "Maine Yankee Plant-Post Shutdown Decommissioning Activities Report."

Northeast Nuclear Energy Company. June 14, 1999. Letter from R. P. Necci to U.S. Nuclear Regulatory Commission. "Millstone Nuclear Power Station Unit No. 1-Post Shutdown Decommissioning Activities Report."

Portland General Electric, SMQ-008-2001. January 31, 2001. Letter from Stephen M. Quennoz to U.S. Nuclear Regulatory Commission. "Request for Information to Support GEIS Supplement."

Sacramento Municipal Utility District. January 31, 2001. Letter from Sacramento Municipal Utility District to U.S. Nuclear Regulatory Commission. "Request for Information to Support GEIS Supplement."

Saxton Nuclear Experimental Corporation Facility. February 2000. "Decommissioning Environmental Report, Revision 1."

Southern California Edison. February 5, 2001. Letter from A. Edward Scherer to U.S. Nuclear Regulatory Commission. "Request for Information to Support GEIS Supplement."

U.S. Nuclear Regulatory Commission (NRC). 1977. *Final Environmental Impact Statement on the Transportation of Radioactive Materials by Air and Other Modes.* Vols. 1 and 2, NUREG-0170, NRC, Washington, D.C.

Appendix L

Relevant Regulations and Federal Permits

Appendix L

Relevant Regulations and Federal Permits

This appendix highlights the U. S. Nuclear Regulatory Commission's (NRC's) regulations and Federal statutes and regulations enacted by other Federal agencies as well as Executive Orders that are applicable to decommissioning nuclear power plants.

L.1 Applicable NRC Regulations

A brief summary of the applicable regulations of Title 10 CFR related to decommissioning are provided in this subsection. Although not a comprehensive list, this appendix briefly discusses those regulations that are most pertinent to decommissioning and were considered to be potentially of greatest interest to the reader. Licensees of facilities being decommissioned are required to continue following the regulations applicable to an operating plant unless directed otherwise by the regulations.

L.1.1 10 CFR Part 20, Standards for Protection Against Radiation

Sections of 10 CFR Part 20 establish the NRC regulations pertaining to radiological protection.

Subpart B - Radiation Protection Programs

Subpart B of 10 CFR Part 20 provides the framework for the radiation protection programs required at licensed facilities. It requires that each licensee develop and implement a radiation protection program, that the concept of keeping doses as low as reasonably achievable (ALARA) be an integral part of the program, and that the licensee annually review the program to ensure compliance with all regulations. The need for an adequate radiation protection program is essential for decommissioning plants to ensure the health and welfare of the licensee's personnel and the public.

Subpart C - Occupational Dose Limits

Subpart C of 10 CFR Part 20 provides the radiological occupational dose limits for licensee personnel and the public and the method used to demonstrate compliance with these limits.

Subpart D - Radiation Dose Limits for Individual Members of the Public

Subpart D of 10 CFR Part 20 contains the regulations that define the maximum dose limits that an individual member of the public may receive and acceptable compliance methods. These regulations are applicable for operating and decommissioning plants until license termination. Appendix B provides reference material used for determining annual limits on intake and derived air concentrations of radionuclides for occupational exposure and effluent and sewage release concentrations.

Subpart E - Radiological Criteria for License Termination

Subpart E of 10 CFR Part 20 contains the radiological criteria for license termination that apply to unrestricted and restricted use. Important aspects of the criteria include the opportunity for public participation and the assurance of adequate decommissioning funds to ensure sufficient oversight to protect public health.

Subpart F - Surveys and Monitoring

Subpart F of 10 CFR Part 20 requires surveys and monitoring commensurate with the conditions at a licensed facility. Until the license is terminated at a facility, there is a potential for radiological exposure, which would necessitate continued radiological monitoring and surveys.

Subpart G - Control of Exposure from External Sources in Restricted Areas

Subpart G of 10 CFR Part 20 requires the licensee to control access to high and very high radiation areas. These regulations are applicable to a decommissioning plant, especially in the early years of decommissioning.

Subpart H - Respiratory Protection and Controls to Restrict Internal Exposure in Restricted Areas

Subpart H of 10 CFR Part 20 requires measures to control airborne radioactive materials and the use of protective equipment to limit personnel intake.

Subpart I - Storage and Control of Licensed Material

Subpart I of 10 CFR Part 20 addresses the security and control issues related to licensed material (source material or by-product material that includes highly irradiated materials).

Subpart J - Precautionary Procedures

Subpart J of 10 CFR Part 20 defines radiological posting requirements to indicate where radiation areas are located and to label containers of licensed materials. The minimum quantities that require labeling are provided in Appendix C of 10 CFR Part 20.

Subpart K - Waste Disposal

Subpart K of 10 CFR Part 20 provides the requirements for the disposal of licensed material, including low-level waste. It provides the regulations related to manifests and manifest tracking.

Subpart L - Records

Subpart L of 10 CFR Part 20 provides requirements for recordkeeping of radiological control records. This includes individual exposure records, historical recordkeeping, and any release of radioactive effluents to the environment. Audit rectors and other reviews of the radiological control program content and implementation are required to be maintained for a period of 3 yrs, which could conceivably extend beyond the decommissioning process.

Subpart M - Reports

Subpart M of 10 CFR Part 20 provides the regulations pertaining to reporting requirements at licensed facilities. The reporting requirements contained in this subpart pertain to theft or loss of licensed materials, incident notification, radiological exposures that exceed limits, special exposures, individual overexposure, and individual monitoring. Annual personnel monitoring reports on personnel exposure are also required to be submitted.

L.1.2 10 CFR Part 50, Domestic Licensing of Production and Utilization Facilities

10 CFR 50.82, Termination of License

The current rule for decommissioning was published in August 1996 providing major changes from the previous rule. The current rule redefines the decommissioning process and requires licensees to provide the NRC with early notification of planned decommissioning activities. The rule describes the following:

- information on certifications of permanent cessation of operation and permanent removal of fuel from the plant [10 CFR 50.82(a)(1)(i), and (ii)]

- the submittal of the post-shutdown decommissioning activities report (PSDAR) (10 CFR 50.82(a)(4)(i)), which discusses the decommissioning activities and schedule for the activities, an estimate of expected costs, and the reasons for concluding that the environmental impacts associated with the site-specific decommissioning activities will be bounded by previously described environmental impacts [10 CFR 50.82(a)(4)(i)]

- the restrictions of activities of licensees performing decommissioning activities that may (a) foreclose release of the site for possible unrestricted use, (b) result in significant environmental impacts not previously reviewed, or (c) result in there no longer being reasonable assurance that adequate funds will be available for decommissioning [10 CFR 50.82(a)(6)]

- the requirement for the licensee to notify the NRC before performing any decommissioning activity inconsistent with, or making any significant schedule change from, those activities and schedules described in the PSDAR [10 CFR 50.82(a)(7)]

- how the decommissioning trust funds can be used - Withdrawals from the decommissioning trust fund can only be used [10 CFR 50.82(a)(8)(i)]

  -- if they are used for legitimate decommissioning activities that are consistent with the definition of decommissioning in 10 CFR 50.2

  -- if they do not reduce the value of the decommissioning trust below an amount necessary to place and maintain the reactor in a safe storage condition if unforeseen expenses or conditions arise

  -- if they do not inhibit the ability of the licensee to complete funding of any shortfalls in the decommissioning trust needed to ensure the availability of funds to ultimately release the site and terminate the license.

- the amount of funds available to the licensee, which varies depending on the stage of decommissioning [10 CFR 50.82(a)(8)(ii)(iii)]

  -- initially, 3 percent of the generic amount specified in 10 CFR 50.75 may be used for decommissioning planning

  -- an additional 20 percent may be used 90 days after the NRC has received the PSDAR

- -- remaining funds can be used following submittal of the site-specific decommissioning cost estimate, which is required within 2 yrs following permanent cessation of operation

- submittal of the license termination plan [10 CFR 50.82(a)(9)] and the termination of the license [10 CFR 50.82(a)(11)].

10 CFR 50.36, Technical Specifications

10 CFR 50.36(c)(6) describes requirements for technical specifications specific to decommissioning. However, the requirements of 10 CFR 50.36(a), (b) and (c) still remain applicable, as modified by paragraph (c)(6). For example, a decommissioning licensee should still evaluate paragraphs (c)(1) thru (5) regarding safety limits, limiting safety-system settings, limiting control settings, limiting conditions for operation, surveillance requirements, design features, and administrative controls; (c)(7) regarding initial notification reports; and (c)(8) regarding written reports. This is reflected by the requirement of 10 CFR 50.36(e), which states that the "provisions of this section apply to each nuclear reactor licensee whose authority to operate the reactor has been removed by license amendment, order, or regulations."

10 CFR 50.48, Fire Protection

10 CFR 50.48(f) requires that licensees of permanently shutdown nuclear power plants maintain a fire-protection program to address the potential for fires that could result in the release or spread of radioactive materials.

10 CFR 50.59, Changes, Tests, and Experiments

This section allows licensees to make changes to facilities undergoing decommissioning using these requirements.

10 CFR 50.65, Requirements for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants

The maintenance rule (10 CFR 50.65) requires monitoring the performance or condition of structures, systems, or components (SSCs). For licensees that have permanently ceased operation, this section applies only to the extent that the licensee shall monitor the performance or condition of SSCs associated with the storage, control, and maintenance of spent fuel. The number of SSCs within the maintenance rule program at a decommissioning facility will be significantly less than that at an operating facility.

10 CFR 50.68, Criticality Accident Requirements

This section describes the requirements that are used in lieu of maintaining a monitoring system capable of detecting a criticality in the spent fuel pool, as described in 10 CFR 70.24.

10 CFR 50.71, Inspection

This section describes the maintenance of records and making of reports. Although all paragraphs of this section are applicable, one difference between an operating facility and one being decommissioned is the requirement to update the final safety analysis report, or equivalent. As described in 10 CFR 50.71(e)(4), the decommissioning requirement is for revisions to be filed every 24 months.

10 CFR 50.73, Licensee Event Reporting System

Licensees are still required to submit a licensee event report for specific events described in the regulations within 60 days after discovery of the event. This includes airborne or liquid-effluent releases at specific levels above the concentrations in Appendix B to 10 CFR Part 20.

10 CFR 50.75, Reporting and Recordkeeping for Decommissioning Planning

Reporting and recordkeeping require that subsequent revisions updating the licensing basis must be filed with the NRC at least every 24 months by nuclear power facilities that have certified permanent cessation of operation and permanent removal of fuel for decommissioning planning. This regulation, in part, discusses how the licensee will provide reasonable assurance that funds will be available for decommissioning of the nuclear reactor.

L.1.3 10 CFR Part 71, Packaging and Transportation of Radioactive Material

Requirements for packaging, preparation for shipment, and transportation of licensed (radioactive) material are provided in these regulations. In addition, these regulations refer to the regulations of the Department of Transportation given in Title 49 of the Code of Federal Regulations.

L.1.4 10 CFR Part 72, Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater Than Class C Waste

The regulations in 10 CFR Part 72 contain requirements, procedures, and criteria for the issuance of licenses to receive, transfer, and possess power-reactor spent fuel, power-reactor-related Greater-than-Class-C (GTCC) Waste, and other radioactive materials associated with spent fuel storage in an independent spent fuel storage installation and the terms and conditions under which the Commission will issue these licenses. The regulations also establish requirements, procedures, and criteria for the issuance of licenses to the U.S. Department of Energy (DOE) to receive, transfer, package, and possess power-reactor spent fuel, high-level radioactive waste, power-reactor-related GTCC waste, and other radioactive materials associated with the storage of these materials in a monitored retrievable storage installation. Finally, these regulations also establish requirements, procedures, and criteria for the issuance of Certificates of Compliance approving spent fuel storage cask designs.

L.2 Federal Statutes

Following are examples of major laws, regulations, and other requirements that may be applicable to decommissioning and environmental evaluations that occur during the decommissioning process.

American Indian Religious Freedom Act of 1978 (42 USC 1996): This act reaffirms Native American religious freedom under the First Amendment and sets United States policy to protect and preserve the inherent and constitutional right of American Indians to believe, express, and exercise their traditional religions. The act requires that Federal actions avoid interfering with access to sacred locations and traditional resources that are integral to the practice of religions.

Archaeological Resource Protection Act, as amended (16 USC 470aa et seq.): This Act requires a permit for any excavation or removal of archaeological resources from public or Indian lands. Excavations must be undertaken for the purpose of furthering archaeological knowledge in the public interest, and resources removed are to remain the property of the United States. Consent must be obtained from the Indian tribe owning lands on which a resource is located before issuance of a permit, and the permit must contain terms or conditions requested by the tribe.

Atomic Energy Act of 1954, as amended (42 USC 2011 et seq.): The Atomic Energy Act of 1954 authorizes NRC to regulate the Nation's civilian use of by-product, source, and special nuclear materials to ensure adequate protection of the public health and safety and the

DOE to establish standards to protect health or minimize dangers to life or property with respect to activities under its jurisdiction. The Atomic Energy Act and the Reorganization Plan No. 3 of 1970 [5 USC (app. at 1343)] and other related statutes gave the U.S. Environmental Protection Agency (EPA) responsibility and authority for developing generally applicable environmental standards for protection of the general environment from radioactive material. The EPA has promulgated several regulations under this authority.

Bald and Golden Eagle Protection Act, as amended (16 USC 668-668d): The Bald and Golden Eagle Protection Act makes it unlawful to take, pursue, molest, or disturb bald (American) and golden eagles, their nests, or their eggs anywhere in the United States (Section 668, 668c). A permit must be obtained from the U.S. Department of the Interior to relocate a nest that interferes with resource development or recovery operations.

Clean Air Act, as amended (42 USC 7401 et seq.): The Clean Air Act, as amended, is intended to "protect and enhance the quality of the Nation's air resources so as to promote the public health and welfare and the productive capacity of its population." Section 118 of the Clean Air Act, as amended, requires that each Federal agency, such as DOE, with jurisdiction over any property or facility that might result in the discharge of air pollutants, comply with "all Federal, state, interstate, and local requirements" with regard to the control and abatement of air pollution. The Act requires the EPA to establish National Ambient Air Quality Standards as necessary to protect public health, with an adequate margin of safety, from any known or anticipated adverse effects of a regulated pollutant (42 USC 7409). The Act also requires establishing national standards of performance for new or modified stationary sources of atmospheric pollutants (42 USC 7411) and requires specific emission increases to be evaluated so as to prevent a significant deterioration in air quality (42 USC 7470). Hazardous air pollutants, including radionuclides, are regulated separately (42 USC 7412). Air emissions are regulated by the EPA in 40 CFR Parts 50 through 99. In particular, radionuclide emissions and hazardous air pollutants are regulated under the National Emission Standard for Hazardous Air Pollutants Program (see 40 CFR Parts 61 and 63).

Clean Water Act, as amended (33 USC 1251 et seq.): The Clean Water Act, which amended the Federal Water Pollution Control Act, was enacted to "restore and maintain the chemical, physical and biological integrity of the Nation's water." The Clean Water Act prohibits the "discharge of toxic pollutants in toxic amounts" to navigable waters of the United States. Section 313 of the Clean Water Act, as amended, requires all branches of the Federal government engaged in any activity that might result in a discharge or runoff of pollutants to surface waters to comply with Federal, State, interstate, and local requirements. In addition to setting water quality standards for the nation's waterways, the Clean Water Act supplies guidelines and limitations for effluent discharges from point-source discharges and provides authority for the EPA to implement the National Pollutant Discharge Elimination System (NPDES) permitting program. The NPDES program is administered by the Water Management Division of the EPA pursuant to regulations in 40 CFR Part 122 et seq.

Sections 401 and 405 of the Water Quality Act of 1987 added Section 402(p) to the Clean Water Act Section 402(p) requires that the Environmental Protection Act establish regulations for issuing permits for stormwater discharges associated with industrial activity. Stormwater discharges associated with industrial activity are permitted through the NPDES. General Permit requirements are published in 40 CFR Part 122.

Emergency Planning and Community Right-to-Know Act of 1986 (42 USC 11001 et seq.) (also known as SARA Title III): Under Subtitle A of this Act, Federal facilities provide various information (such as inventories of specific chemicals used or stored and releases that occur from these sites) to the State Emergency Response Commission and to the Local Emergency Planning Committee to ensure that emergency plans are sufficient to respond to unplanned releases of hazardous substances. Implementation of the provisions of this Act began voluntarily in 1987, and inventory and annual emissions reporting began in 1988, based on 1987 activities and information. The requirements for this Act were promulgated by the EPA in 40 CFR Parts 350 through 372.

Endangered Species Act, as amended (16 USC 1531 et seq.): The Endangered Species Act, as amended, is intended to prevent the further decline of endangered and threatened species and to restore these species and their habitats. The Act is jointly administered by the U.S. Departments of Commerce and the Interior. Section 7 of the Act requires consultation with the U.S. Fish and Wildlife Service to determine whether endangered and threatened species or their critical habitats are known to be in the vicinity of the proposed action.

Migratory Bird Treaty Act, as amended (10 USC 703 at seq.): The Migratory Bird Treaty Act, as amended, is intended to protect birds that have common migration patterns between the United States and Canada, Mexico, Japan, and Russia. It regulates the harvest of migratory birds by specifying the mode of harvest, hunting seasons, and bag limits. The Act stipulates that it is unlawful at any time, by any means, or in any manner to "kill ... any migratory bird." Although no permit is required under the Act, Federal agencies are required to consult with the U.S. Fish and Wildlife Service regarding impacts to migratory birds and to evaluate ways to avoid these effects in accordance with the U.S. Fish and Wildlife Service Mitigation Policy.

Native American Grave Protection and Repatriation Act of 1990 (25 USC 3001): This law directs the Secretary of Interior to guide responsibilities in repatriation of Federal archaeological collections and collections held by museums receiving Federal funding that are culturally affiliated to Native American tribes. Major actions to be taken under this law include (a) establishing a review committee with monitoring and policy-making responsibilities, (b) developing regulations for repatriation, including procedures for identifying lineal descent or cultural affiliation needed for claims, (c) overseeing of museum programs designed to meet the inventory requirements and deadlines of this law, and (d) developing procedures to handle unexpected discoveries of graves or grave goods during activities on Federal or tribal land.

National Environmental Policy Act of 1969 as amended (42 USC 4321 et seq.): The National Environmental Policy Act (NEPA) establishes a national policy promoting awareness of the environmental consequences of the activity of humans on the environment and promoting consideration of the environmental impacts during the planning and decisionmaking stages of a project. NEPA requires all agencies of the Federal government to prepare a detailed statement on the environmental effects of proposed major Federal actions that may significantly affect the quality of the human environment. The environmental document should discuss reasonable alternatives to the proposed action and their potential environmental consequences in accordance with the Council on Environmental Quality regulations for implementing the procedural provisions of the NEPA Implementing Procedures (40 CFR Parts 1501 through 1508) and NRC implementing regulations (10 CFR Part 51).

National Historic Preservation Act, as amended (16 USC 470 et seq.): The National Historic Preservation Act, as amended, provides that sites with significant national historic value be placed on the *National Register of Historic Places.* There are no permits or certifications required under the Act. However, if a particular Federal activity may impact a historic property resource, consultation with the Advisory Council on Historic Preservation will generally generate a Memorandum of Agreement, including stipulations that must be followed to minimize adverse impacts. Coördinations with the State Historic Preservation officer are also undertaken to ensure that potentially significant sites are properly identified and appropriate mitigative actions are implemented. These regulations are included in 36 CFR Part 800. 10 CFR Part 63 contains guidance by which historic properties are evaluated and determined eligible for listing on the National Register.

Noise Control Act of 1972, as amended (42 USC 4901 et seq.): Section 4 of the Noise Control Act of 1972, as amended, directs all Federal agencies to carry out "to the fullest extent within their authority" programs within their jurisdictions in a manner that furthers a national policy of promoting an environment free from noise that jeopardizes health and welfare.

Nuclear Waste Policy Act of 1982, as amended (42 USC 10101): The Act authorizes the Federal agencies to develop a geologic repository for the permanent disposal of spent nuclear fuel and high-level radioactive waste. The Act specifies the process for selecting a repository site and constructing, operating, closing, and decommissioning the repository. The Act also establishes programmatic guidance for these activities, including guidance to the NRC regarding the adoption of DOE's EIS for the proposed repository.

Occupational Safety and Health Act of 1970, as amended (29 USC 651 et seq.): The Occupational Safety and Health Act establishes standards to enhance safe and healthful working conditions in places of employment throughout the United States. The Act is administered and enforced by the Occupational Safety and Health Administration, a U.S. Department of Labor agency. While the Occupational Safety and Health Administration and the EPA both have a mandate to reduce exposures to toxic substances, the Occupational Safety and Health Administration's jurisdiction is limited to safety and health conditions that exist in the workplace environment. In general, under the Act, it is the duty of each employer to furnish all employees a place of employment free of recognized hazards likely to cause death or serious physical harm. Employees have a duty to comply with the occupational safety and health standards and all rules, regulations, and orders issued under the Act. Occupational Safety and Health Administration regulations (published in Title 29 of the Code of Federal Regulations) establish specific standards telling employers what must be done to achieve a safe and healthful working environment.

Pollution Prevention Act of 1990 (42 USC 13101 et seq.): The Pollution Prevention Act of 1990 establishes a national policy for waste management and pollution control that focuses first on source reduction, followed sequentially by environmentally safe recycling, treatment, and disposal. Disposal or releases to the environment should only occur as a last resort.

Resource Conservation and Recovery Act, as amended (42 USC 6901 et seq.): The treatment, storage, or disposal of hazardous and nonhazardous waste is regulated under the Solid Waste Disposal Act, as amended by the Resource Conservation and Recovery Act and the Hazardous and Solid Waste Amendments of 1984. Pursuant to Section 3006 of the Act, any State that seeks to administer and enforce a hazardous waste program pursuant to the Resource Conservation and Recovery Act may apply for EPA authorization of its program. The EPA regulations implementing the Resource Conservation and Recovery Act are found in 40 CFR Parts 260 through 280. These regulations define hazardous wastes and specify hazardous waste transportation, handling, treatment, storage, and disposal requirements.

The regulations imposed on a generator or a treatment, storage, and/or disposal facility vary according to the type and quantity of material or waste generated, treated, stored, and/or disposed of. The method of treatment, storage, and/or disposal also impacts the extent and complexity of the requirements.

Safe Drinking Water Act, as amended (42 USC 300 [F] et seq.): The primary objective of the Safe Drinking Water Act, as amended, is to protect the quality of the public water supplies and all sources of drinking water. The implementing regulations, administered by the EPA unless delegated to the states, establish standards applicable to public water systems. They promulgate maximum contaminant levels, including those for radioactivity, in public water systems, which are defined as public water systems that serve at least 15 service connections used by year-round residents or regularly serve at least 25 yr-round residents. Safe Drinking Water Act requirements have been promulgated by the EPA in 40 CFR Parts 100 through 149. For radionuclides, the regulations in effect now specify that the average annual concentration of beta particle and photon radioactivity from manmade radionuclides in drinking water shall not produce an annual dose equivalent to the total body or any internal organ greater than 0.004 rem (4 millirem) per year. The maximum contaminant level for gross alpha particle activity is 15 picocuries per liter. The EPA proposed revisions to limits on regulating radionuclides on July 18, 1991. The proposed rule has not been finalized, and the more conservative standards were used for purposes of analysis. Other programs established by the Safe Drinking Water Act include the Sole Source Aquifer Program, the Wellhead Protection Program, and the Underground Injection Control Program.

Toxic Substances Control Act (15 USC 2601 et seq.): The Toxic Substances Control Act provides the EPA with the authority to require testing of chemical substances, both new and old, entering the environment and regulates them where necessary. The law complements and expands existing toxic substance laws such as §112 of the Clean Air Act and §307 of the Clean Water Act. The Toxic Substances Control Act came about because there were no general Federal regulations for the potential environmental or health effects of the thousands of new chemicals developed each year before they were introduced into the public or commerce. The Toxic Substances Control Act also regulates the treatment, storage, and disposal of toxic substances, specifically polychlorinated biphenyls, chlorofluorocarbons, asbestos, dioxins, certain metal-working fluids, and hexavalent chromium. The asbestos regulations under the Toxic Substances Control Act were ultimately overturned. However, regulations pertaining to asbestos removal, storage, and disposal are promulgated through the National Emission Standard for Hazardous Air Pollutants Program (40 CFR Part 61, Subpart M). For chlorofluorocarbons, Title VI of the Clean Air Act Amendments of 1990 requires a reduction of chlorofluorocarbons beginning in 1991 and prohibits production beginning in 2000.

L.3 Executive Orders

During the history of NEPA implementation, a number of Executive Orders have been issued that may be applicable to environmental evaluation during the decommissioning process. The following provides a short summary of some of these Orders.

Executive Order 11988 (Floodplain Management): Directs Federal agencies to establish procedures to ensure that the potential effects of flood hazards and floodplain management are considered for any action undertaken in a floodplain and that floodplain impacts be avoided to the extent practicable.

Executive Order 11990 (Protection of Wetlands): Directs government agencies to avoid, to the extent practicable, any short- and long-term adverse impacts on wetlands wherever there is a practicable alternative.

Executive Order 12898 (Environmental Justice): Directs Federal agencies to achieve environmental justice by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations in the United States and its territories and possessions. The Order creates an Interagency Working Group on Environmental Justice and directs each Federal agency to develop strategies within prescribed time limits to identify and address environmental justice concerns. The Order further directs each Federal agency to collect, maintain, and analyze information on the race, national origin, income level, and other readily accessible and appropriate information for areas surrounding facilities or sites expected to have a substantial environmental, human health, or economic effect on the surrounding populations, when such facilities or sites become the subject of a substantial Federal environmental administrative or judicial action and to make such information publicly available.

Executive Order 13007 (Indian Sacred Sites): Directs Federal agencies to accommodate, to the extent practicable, access to and ceremonial use of Indian sacred sites by Indian religious practitioners, and avoid adversely affecting the physical integrity of these sites.

Appendix M

Glossary

Appendix M

Glossary

Absorbed dose — The amount of radiation energy absorbed, especially by human tissue; measured in rads.

Absorption — The process of taking in, as when a sponge takes up water. Chemicals can be absorbed through the skin into the bloodstream and then transported to other organs. Chemicals can also be absorbed into the bloodstream after breathing or swallowing.

Acute — Occurring over a short time, usually a few minutes or hours. An acute effect happens within a short time after exposure. An acute exposure can result in short-term or long-term health effects. See Chronic.

ALARA — Acronym for "as low as reasonably achievable," i.e., making every reasonable effort to maintain exposures to ionizing radiation as far below the dose limits as practical, consistent with the purpose for which the licensed activity is undertaken and taking into account the state of technology, the economics of technological improvements and of the benefits to public health and safety, and other societal and socioeconomic considerations, and in relation to utilization of nuclear energy and licensed materials in the public interest. See 10 CFR 20.1003.

Alpha particle — A positively charged particle ejected spontaneously from the nuclei of some radioactive elements. It is identical to a helium nucleus that has a mass number of 4 and an electrostatic charge of +2. It has low penetrating power and a short range (a few centimeters in air). The most energetic alpha particle will generally fail to penetrate the dead layers of cells covering the skin and can be easily stopped by a sheet of paper. Alpha particles are hazardous when an alpha-emitting isotope is inside the body.

Ambient Surrounding. Ambient air is usually outdoor air (as opposed to indoor air).

Aquifer An underground source of water geologically contained in a layer of rock, sand, or gravel.

Background level A typical or average level of a chemical or element in the environment. Background often refers to naturally occurring or uncontaminating levels.

Background radiation Radiation from cosmic sources; naturally occurring radioactive materials, including radon (except as a decay product of source or special nuclear material) and global fallout as it exists in the environment from the testing of nuclear explosive devices. It does not include radiation from source, by-product, or special nuclear materials regulated by the Nuclear Regulatory Commission (NRC). The typically quoted U.S. average individual exposure from background radiation is 360 mrem per yr.

Becquerel (Bq) The unit of radioactive decay equal to 1 disintegration per second. 37 billion (3.7×10^{10}) Bq = 1 curie (Ci).

Beta particle A charged particle emitted from a nucleus during radioactive decay, with a mass equal to 1/1837 that of a proton. A negatively charged beta particle is identical to an electron. A positively charged beta particle is called a positron. Large amounts of beta radiation may cause skin burns. Beta-emitters are harmful if they enter the body. Beta particles may be stopped by thin sheets of metal or plastic.

Boiling water reactor (BWR) A reactor in which water, used as both coolant and moderator, is allowed to boil in the core. The resulting steam can be used directly to drive a turbine and electrical generator, thereby producing electricity.

By-product material Any radioactive material, tailings or wastes (except special nuclear material) that is 1) yielded in, or made radioactive by, exposure to the radiation incident to the process of producing or using special nuclear material (as in a reactor) and 2) produced by the extraction or concentration of uranium or thorium from ore. See 10 CFR 20.1003.

Calibration The adjustment, as necessary, of a measuring device such that it responds within the required range and accuracy to known values of input.

Certified fuel-handler A nonlicensed operator who is qualified in accordance with a fuel-handler training program approved by the NRC.

Chronic Occurring over an extended period of time, e.g., several weeks, months, or years. See Acute.

Committed dose equivalent (CDE) This is the dose to some specific organ or tissue that is received from an intake of radioactive material by an individual during the 50-yr period following the intake. See 10 CFR 20.1003.

Committed effective dose equivalent (CEDE) The sum of the committed dose equivalents for a given organ or tissue multiplied by a weighting factor (W_t) expressed in units of sieverts (Sv) or rems. See 10 CFR 20.1003.

Compact A group of two or more States formed to dispose of low-level radioactive waste on a regional basis. Forty-two States have formed nine compacts.

Contamination Undesired radioactive material or residual radioactivity that is deposited on the surface of or inside structures, areas, objects or people in excess of acceptable levels (e.g., for a release of a site or facility for unrestricted use).

Curie (Ci) The basic unit used to describe the intensity of radioactivity in a sample of material. The curie is equal to 37-billion (3.7×10^{10}) disintegrations per second, which is approximately the activity of 1 gram of radium. A curie is also a quantity of any radionuclide that decays at a rate of

37-billion disintegrations per second. It is named for Marie Curie, who discovered radium in 1898.

Decommission (decommissioning)
The process of safely removing a facility from service followed by reducing residual radioactivity to a level that permits termination of the NRC license. See 10 CFR 20.1003.

DECON
An option for decommissioning in which the equipment, structures, and portions of a facility and site containing radioactive contaminants are removed or decontaminated to a level that permits termination of the license shortly after cessation of operations.

Decontamination
The reduction or removal of contaminated radioactive material from a structure, area, object, or person. See 10 CFR 20.1003 and 20.1402.

Dermal
Referring to the skin. For example, dermal absorption means absorption through the skin.

Disproportionately high and adverse environmental effects
When determining whether environmental effects are disproportionately high and adverse, agencies are to consider the following three factors to the extent practicable: (a) whether there is or will be an impact on the natural or physical environment that significantly (as used by NEPA) and adversely affects a minority population, low-income population, or Indian tribe - Such effects may include ecological, cultural, human health, economic, or social impacts on minority communities, low-income communities, or Indian tribes when those impacts are interrelated to impacts on the natural or physical environment, (b) whether environmental effects are significant (as employed by NEPA) and are or may be having an adverse impact on minority populations, low-income populations, or Indian tribes that appreciably exceeds or is likely to appreciably exceed those on the general population or other appropriate comparison group, and (c) whether the environmental effects occur or would occur in a minority population, low-income population, or Indian tribe affected by cumulative or multiple adverse exposures from environ-

mental hazards.

Disproportionately high and adverse human health effects

When determining whether human health effects are disproportionately high and adverse, agencies are to consider the following three factors to the extent practicable: (a) whether the health effects, which may be measured in risks and rates, are significant (as used by NEPA), or above generally accepted norms (adverse health effects may include bodily impairment, infirmity, illness, or death), (b) whether the risk or rate of hazard exposure by a minority population, low-income population, or Indian tribe to an environmental hazard is significant (as employed by NEPA) and appreciably exceeds or is likely to appreciably exceed the risk or rate to the general population or other appropriate comparison group, and (c) whether health effects occur in a minority population, low-income population, or Indian tribe affected by cumulative or multiple adverse exposures from environmental hazards.

Dose equivalent (dose)

The product of absorbed dose in tissue multiplied by a quality factor, and then sometimes multiplied by other necessary modifying factors at the location of interest. It is expressed numerically in rems or sieverts. See 10 CFR 20.1003.

Dosimeter

A portable instrument (e.g., a film badge, thermoluminescent, or pocket dosimeter) worn by plant personnel for measuring and recording the total accumulated dose of ionizing radiation.

Dosimetry

The theory and application of the principles and techniques involved in the measurement and recording of ionizing radiation doses.

Effective half-life

The time required for a radionuclide contained in a biological system, such as a human or an animal, to reduce its activity by one-half as a combined result of radioactive decay and biological elimination.

ENTOMB
A method of decommissioning in which radioactive structures, systems, and components are encased in a structurally long-lived material, such as concrete. The entombed structure is appropriately maintained, and continued surveillance is carried out until the radioactivity decays to a level that permits termination of the license.

Exposure
Contact with a chemical or element by swallowing, breathing, or direct contact (such as through the skin or eyes). Exposure may be either short-term (acute) or long- term (chronic).

External radiation
Exposure to ionizing radiation when the radiation source is located outside the body.

Fissile material
Any material fissionable by thermal (slow) neutrons. The three primary fissile materials are uranium-233, uranium-235, and plutonium-239. Although sometimes used as a synonym for fissionable material, this term has acquired a more restricted meaning.

Fission (fissioning)
The splitting of a nucleus into at least two other nuclei and the release of a relatively large amount of energy. Two or three neutrons are usually released during this type of transformation.

Fission gases
Those fission products that exist in the gaseous state. In nuclear power reactors, this includes primarily the noble gases, such as krypton and xenon.

Fission products
The nuclei (fission fragments) formed by the fission of heavy elements, plus the nuclide formed by the fission fragments' radioactive decay.

Fissionable material
Commonly used as a synonym for fissile material, the meaning of this term has been extended to include material that can be fissioned by fast neutrons, such as uranium-238.

Fuel assembly A cluster of fuel rods (or plates). Also called a fuel element. A reactor core is made up of many fuel assemblies.

Fuel cycle The series of steps involved in supplying fuel for nuclear power reactors. It can include mining, milling, isotopic enrichment, fabrication of fuel elements, use in a reactor, chemical reprocessing to recover the fissionable material remaining in the spent fuel, re-enrichment of the fuel material, refabrication into new fuel elements, and waste disposal.

Fuel rod A long, slender tube that holds fissionable material (fuel) for nuclear reactor use. Fuel rods are assembled into bundles called fuel elements or fuel assemblies, which are loaded individually into the reactor core.

Fusion reaction A reaction in which at least one heavier, more stable nucleus is produced from two lighter, less stable nuclei. Reactions of this type are responsible for enormous releases of energy, e.g., in the energy of stars.

Gamma radiation High-energy, short wave-length, electromagnetic radiation emitted from the nucleus. Gamma radiation frequently accompanies alpha and beta emissions and always accompanies fission. Gamma rays are very penetrating and are best stopped or shielded by dense materials, such as lead or depleted uranium. Gamma rays are similar to x-rays.

Graphite A form of carbon, similar to the lead used in pencils, used as a moderator in some nuclear reactors.

Greenfield One possible end state of decommissioning in which above-ground structures have been removed and efforts made to revegetate the site. Buildings may have been removed to below-grade and then covered with soil. NRC decommissioning regulations do not require a greenfield end state.

Groundwater

The supply of fresh water found beneath the earth's surface (usually in aquifers) that is often used for supplying wells and springs.

Hazardous waste

By-products of society that can pose a substantial or potential hazard to human health or the environment when improperly managed. Possesses at least one of four characteristics (ignitability, corrosivity, reactivity, or toxicity), or appears on special EPA lists.

High decommissioning activity (HDA)

The licensee is actively dismantling, decontaminating, or performing activities that contribute to site release or license termination. Includes, but is not limited to, (1) major decommissioning activities or (2) periods of decommissioning in which the aggregate of licensee activities represents a significant change in facility configuration, increase in occupational dose, curies relocated, or decommissioning cost expenditure.

Highly enriched uranium

Uranium enriched to 20 percent or greater in the isotope Uranium-235.

High-level waste (HLW)

Consists of (1) irradiated (spent) reactor fuel, (2) liquid waste resulting from the operation of the first cycle solvent extraction system, and the concentrated wastes from subsequent extraction cycles, in a facility for reprocessing irradiated reactor fuel, or (3) solids into which such liquid wastes have been converted. Primarily in the form of spent fuel discharged from commercial nuclear power reactors, HLW also includes some reprocessed HLW from defense activities, and a small quantity of reprocessed commercial HLW. See Low-level waste and Radioactive waste.

High radiation area

Any area with dose rates greater than 1 mSv (100 mrems) in 1 hour, 30 centimeters from the source or from any surface through which the ionizing radiation penetrates. Areas at licensee facilities must be posted as "high radiation areas" and access into these areas is maintained under strict control.

Hot spot — The region in a radiation/contamination area in which the level of radiation/contamination is significantly greater than in neighboring regions in the area.

Ingestion — Swallowing (such as eating or drinking). Ingestion of radioactive material or other contaminants can occur via contact with contaminated food, drink, utensils, cigarettes, hands, or other surfaces. After ingestion, chemicals can be absorbed into the blood and distributed throughout the body.

Inhalation — Breathing. Exposure may occur from inhaling contaminants because they can be deposited in the lungs, taken into the blood, or both.

Ion — (1) An atom that has too many or too few electrons, causing it to have an electrical charge, and, therefore, be chemically active (2) An electron that is not associated (in orbit) with a nucleus.

Ionizing radiation — Any radiation capable of displacing electrons from atoms or molecules, thereby producing ions. Some examples are alpha, beta, gamma, x-rays, neutrons, and ultraviolet light. High doses of ionizing radiation may produce severe skin or tissue damage.

Independent spent fuel storage installation (ISFSI) — A complex designed and constructed for the interim storage of spent nuclear fuel and other radioactive materials associated with spent fuel storage. The most common design for an ISFSI at this time is a concrete pad with dry casks containing spent fuel bundles.

Industrial use area — An area that has been designated appropriate for industrial activities.

Irradiation — Exposure to radiation.

Isotope — One of two or more atoms with the same number of protons, but different numbers of neutrons in their nuclei. Thus, carbon-12, carbon-13, and carbon-14 are isotopes of the element carbon, the numbers denoting the approximate atomic weights. Isotopes have very nearly the same chemical properties, but often different physical properties (for example, carbon-12 and carbon-13 are stable, whereas carbon-14 is radioactive).

Leaching

Residual contamination transported into the subsurface as water trickles through soils or materials that contain the contamination. The water can carry the contamination through the soil and pollute nearby groundwater or surface water.

License termination plan

The license termination plan is a document that is required by 10 CFR 50.82(a)(9). The license termination plan, submitted by the licensee at least 2 yrs before termination of the license, addresses the following items: site characterization, identification of remaining site dismantlement activities, plans for site remediation, detailed plans for final radiation surveys for release of the site, method for demonstrating compliance with the radiological criteria for license termination, updated site-specific estimate of remaining decommissioning costs, and supplement to the environmental report pursuant to 10 CFR 51.53(d). The license termination plan approval process is by license amendment.

Licensing basis

The set of NRC requirements applicable to a specific plant and a licensee's written commitments for ensuring compliance with and operation within applicable NRC requirements and the plant-specific design basis (including all modifications and additions to such commitments over the life of the license) that are docketed and in effect. The licensing basis includes the NRC regulations and appendixes, orders, license conditions, exemptions, and technical specifications. It also includes the plant-specific design-basis information defined in 10 CFR 50.2, as documented in the most recent final safety analysis report (as required by 10 CFR 50.71) and the licensee's commitments remaining in effect that were made in docketed licensing correspondence, such as licensee responses to NRC bulletins, generic letters, and enforcement actions, required certifications and submittals, NRC safety evaluations, and licensee event reports.

Light water reactor (LWR)

A term used to describe reactors using ordinary water as coolant, including boiling water reactors (BWRs) and pressurized water reactors (PWRs), the most common types used in the United States.

Low decommissioning activity (LDA)

Periods of decommissioning when a licensee either (1) maintains their facility in a true SAFSTOR configuration or (2) incrementally dismantles, decontaminates, or decommissions structures, systems, or components at such a low rate or small volume that there are only trivial changes to facility configuration, occupational dose, curie relocation, or decommissioning cost expenditure.

Low-income population

Low-income populations in an affected area should be identified with the annual statistical poverty thresholds from the Bureau of the Census' Current Population Reports, Series P-60 on Income and Poverty. In identifying low-income populations, agencies may consider as a community either a group of individuals living in geographic proximity to one another or a set of individuals (e.g., migrant workers or Native Americans), where either type of group experiences common conditions of environmental exposure or effect.

Low-level waste (LLW)

A general term for a wide range of wastes. Industries, hospitals, research institutions, private or government laboratories, and nuclear fuel-cycle facilities (e.g., nuclear power reactors and fuel fabrication plants) using radioactive materials generate LLW as part of their normal operations. These wastes are generated in many physical and chemical forms and levels of contamination. LLW usually comprises the following material contaminated with radionuclides: rags, papers, filters, solidified liquids, ion-exchange resins, tools, equipment, discarded protective clothing, dirt, construction rubble, concrete, or piping. See High-level waste and Radioactive waste.

Major decommissioning activity For a nuclear power facility, any activity that results in permanent removal of major radioactive components, permanently modifies the structure of the containment (for PWRs, the primary containment; for BWRs, the primary and secondary containments), or results in the dismantling of components or systems for shipment containing "greater than Class C" waste (10 CFR 61.55). The licensee is precluded by regulation from conducting major decommissioning activities until 90 days after the NRC has received the Post-Shutdown Decommissioning Activities Report and the 10 CFR 50.82(a)(1) certifications have been submitted.

Major radioactive component For a nuclear power plant, this includes the reactor vessel and internals, steam generators, pressurizer, large-bore reactor coolant system piping, and other large components that are radioactive to a comparable degree.

MARSSIM The Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM), which provides detailed guidance for planning, implementing, and evaluating environmental and facility radiological surveys conducted to demonstrate compliance with dose- or risk-based regulation. The MARSSIM guidance focuses on the demonstration of compliance during the final status survey following scoping, characterization, and any necessary remedial actions.

Media Soil, water, air, plants, animals, or any other parts of the environment that can contain contaminants. Body tissues or fluids such as blood, bone or urine may also be media. The singular of "media" is "medium."

Minority Individuals who are members of the following population groups: American Indian or Alaskan Native; Asian or Pacific Islander; Black, not of Hispanic origin; or Hispanic.

Minority population According to the CEQ, minority populations should be identified where either (a) the minority population of the affected area exceeds 50 percent or (b) the minority population percentage of the affected area is meaningfully greater than the minority population percentage in the general population or other appropriate unit of geographic analysis. In identifying minority communities, agencies may consider as a community either a group of individuals living in geographic proximity to one another or a geographically dispersed/transient set of individuals (e.g., migrant workers or Native American), where either type of group experiences common conditions of environmental exposure or effect. The selection of the appropriate unit of geographic analysis may be a governing body's jurisdiction, a neighborhood, census tract, or other similar unit that is to be chosen so as not to artificially dilute or inflate the affected minority population. A minority population also exists if there is more than one minority group present and the minority percentage, as calculated by aggregating all minority persons, meets one of the above-stated thresholds. NRR adopted a standard of 20 percentage points as "meaningfully greater."

Mixed waste Mixed radioactive and hazardous waste (mixed waste). (EPA 1997)

Nuclear energy The energy liberated by a nuclear reaction (fission or fusion) or by radioactive decay.

Nuclear island The nuclear island concept is used during decommissioning as a model for reducing the focus of the safeguards and security systems to the location where the fuel is being stored. For example, if the fuel is being stored in the spent fuel pool, the focus of the safeguards are on protection of only the spent fuel pool building and not the balance of the plant.

Nuclear waste See High-level waste and Low-level waste.

Operational Area The portion of the plant site where most or all of the site activities occur, such as reactor operations, materials and equipment storage, parking, substation operation, facility service and maintenance, etc. This includes all areas within the protected area fence, the intake and discharge structures, the cooling system, and other site structures, as well as associated paved, graveled, and maintained landscaped areas.

Partial site release

The release of a portion of an operating or decommissioning nuclear power reactor facility site for unrestricted use. The licensee maintains a license for the remainder of the site. At this time there is a proposed rulemaking to change the regulations to specifically address the criteria for a partial site release. The rulemaking ensures that any remaining residual radioactivity from licensed activities in parts of a site released fro unrestricted use will meet the radiological criteria for license termination. For more detail, see the text in Chapter 3.

Permanent cessation of power operations

The permanent cessation of power operations is a licensee determination certified to the NRC in writing in accordance with 10 CFR 50.82(a)(1)(i). Following this certification, the licensee would possess the power reactor structures, systems, and components, site, and related radioactive material, but be prohibited by regulation from operating the reactor.

Personnel monitoring

The use of portable survey meters to determine the amount of contamination on an individual, or the use of dosimetry to determine an individual's occupational radiation dose.

Possession-only license (POL)

A name for the license retained by a 10 CFR Part 50 licensee that was amended to reflect the permanent shutdown condition of the facility and the licensee's continued possession of nuclear fuel.

Post-operational phase

The interval between the final reactor shutdown and the licensee's certification that all fuel has been permanently removed from the reactor vessel. See 10 CFR 50.82(a)(1)(ii). During this phase, the licensee would establish safe shutdown conditions and could conduct activities to dismantle and decontaminate structures, systems, and components or place them in a storage configuration.

Post-shutdown decommissioning activities report (PSDAR)
The PSDAR is required by 10 CFR 50.82(a)(4). The licensee is required to submit a PSDAR to the NRC within two yrs after permanent cessation of operations. Includes a description of the planned decommissioning activities, a schedule for the completion of these activities, an estimate of expected costs, and a discussion that provides the reasons for concluding that the environmental impacts associated with the site-specific decommissioning activities will be bounded by appropriate environmental impact statements previously issued.

Pressurized water reactor (PWR)
A power reactor in which heat is transferred from the core to an exchanger by high-temperature water kept under high pressure in the primary system. Steam is generated in a secondary circuit. Many reactors producing electric power are PWRs.

Previously disturbed area
An area that has been physically moved, uncovered, destabilized, or otherwise modified from its undisturbed natural condition. This definition excludes areas restored to a natural state, such that vegetative ground cover and soil characteristics that are similar to adjacent or nearby natural conditions.

Quality assurance and quality control (QA/QC)
A system of procedures, checks, and audits to judge the quality of measurements and reduce the uncertainty of environmental data.

Rad
The special unit for radiation absorbed dose, which is the amount of energy from any type of ionizing radiation (e.g., alpha, beta, gamma, neutrons, etc.) deposited in any medium (e.g., water, tissue, air). A dose of 1 rad means the absorption of 100 ergs (a small but measurable amount of energy) per gram of absorbing tissue. 100 rad = 1 gray.

Radiation
Particles (alpha, beta, neutrons) or photons (gamma) emitted from the nucleus of unstable radioactive atoms as a result of radioactive decay.

Radiation standards — Exposure standards, permissible concentrations, rules for safe handling, regulations for transportation, regulations for industrial control of radiation, and control of radioactive material by legislative means.

Radioactive contamination — Deposition of radioactive material in any place where it may harm persons or equipment.

Radioactive waste — Solid, liquid, and gaseous materials from nuclear operations that are radioactive or become radioactive and for which there is no further use. Wastes are generally classified as high-level (having radioactivity concentrations of hundreds of thousands of curies per gallon or foot), low-level (in the range of 1 microcurie per gallon or foot), or intermediate level (between these extremes). See 10 CFR Parts 60 and 61.

Radioactivity — The spontaneous emission of radiation, generally alpha or beta particles, often accompanied by gamma rays, from the nucleus of an unstable isotope. Also, the rate at which radioactive material emits radiation. Measured in units of becquerels or disintegrations per second.

Radioisotope — An unstable isotope of an element that decays or disintegrates spontaneously, emitting radiation. Approximately 5000 natural and artificial radioisotopes have been identified.

Radiologically non-impacted — Areas that have no reasonable potential for radioactive residual contamination are classified as non-impacted by MARSSIM (NRC 1997).

Radiological waste — See "radioactive waste."

Radionuclide — A radioisotope.

Reactor — A device in which nuclear fission may be sustained and controlled in a self-supporting nuclear reaction. The varieties are many, but all incorporate features, such as fissionable material or fuel, a moderating material (unless the reactor is operated on fast neutrons), a reflector to conserve escaping neutrons, provisions for removal of heat, measuring and controlling instruments, and protective devices. The reactor is the heart of a nuclear power plant.

Real property

Includes land, improvements on the land, or both, including interests therein. All equipment or fixtures (e.g., plumbing, electrical, heating, built-in cabinets, and elevators) that are installed in a building in more or less permanent manner or that are essential to its primary purpose.

Reference man

A hypothetical person with the anatomical and physiological characteristics of an average individual, used in calculations assessing internal dose (also may be called "standard man").

rem

A conventional standard unit that measures the effects of ionizing radiation on humans. The international system (SI) equivalent unit is the sievert.

Restricted use

A category of use of the facility after license termination. In restricted use, a licensee has demonstrated that further reductions in residual radioactivity would result in net public or environmental harm or that residual levels are as low as reasonably achievable, and that the licensee has made provisions for legally enforceable institutional controls (e.g., restrictions placed in the deed for the property describing what the land can and cannot be used for) that provide reasonable assurance that the radiological criteria set by the NRC will not be exceeded. In addition, the licensee must have provided sufficient financial assurance to an amenable independent third party to assume and carry out responsibilities for any necessary control and maintenance of the site. There are also regulations relating to the documentation of how the advice of individuals and institutions in the community who may be affected by the decommissioning has been sought and incorporated in the license termination plan related to decommissioning by unrestricted use.

Risk
The probability of harm. For example, for a person who has measles, the risk of death is one in one million.

Roentgen (R)
A unit of exposure to ionizing radiation. It is the amount of gamma or x-rays required to produce ions resulting in a charge of 0.000258 coulombs/kilogram of air under standard conditions. Named after Wilhelm Roentgen, the German scientist who discovered x-rays in 1895.

Rubblization
The demolition of onsite concrete structures. Rubblizing these structures could result in material ranging from gravels to large concrete blocks, or a mixture of both.

Safety limit
A limit placed upon important process variables that are found to be necessary to reasonably protect the integrity of the physical barriers guarding against the uncontrolled release.

Safety-related structures, systems, and components
Nuclear plant structures, systems, and components that are relied upon to remain functional during and following design-basis events to ensure:

- the integrity of the reactor coolant pressure boundary
- the capability to shut down the reactor and maintain it in a safe shutdown condition, or
- the capability to prevent or mitigate the consequences of accidents that could result in potential offsite exposures comparable to the applicable guideline exposures set forth in 10 CFR 50.34(a)(1) or 10 CFR 100.11.

SAFSTOR
A method of decommissioning in which the nuclear facility is placed and maintained in a safe stable condition for a number of years until it is subsequently decontaminated and dismantled to levels that permit license termination. During SAFSTOR, a facility is left intact, but the fuel has been removed from the reactor vessel and radioactive liquids have been drained from systems and components

and then processed. Radioactive decay occurs during the SAFSTOR period, thus reducing the quantity of contaminated and radioactive material that must be disposed of during decontamination and dismantlement.

Sewage The waste and wastewater produced by residential and commercial sources and discharged into sewers.

Sewage waste By-products of society from sewer sources.

Sewer sludge Sludge produces at a Publicly Owned Treatment Works, the disposal of which is regulated under the Clean Water Act.

Sievert An international system (SI) unit that measures the effects of ionizing radiation on humans. The conventional equivalent unit is the rem.

Site characterization One of the final steps before the termination of the license. The site characterization contains a description of (1) the radiological contamination on the site before any cleanup activities associated with decommissioning took place, (2) a historical description of site operations, spills, and accidents, and (3) a map of remaining contamination levels and contamination locations. The purpose of the site characterization is to assist in planning for remediation, selection of remediation techniques, and assessment of radiological impacts and cost estimates.

Sludge A semi-solid residue from any of a number of air or water treatment processes; can be a hazardous waste.

Spent nuclear fuel Depleted fuel that has been removed from a nuclear reactor because it can no longer sustain power production (cannot effectively sustain a chain reaction) for economic or other reasons.

Target organ An organ (such as the liver or kidney) that is specifically affected by a toxic chemical.

Technical specifications (TS)	An appendix to the facility license that contains safety requirements, bases, safety limits, limiting conditions for operation, and administrative requirements to provide assurance that decommissioning can be conducted safely and in accordance with regulatory requirements. Terminology such as "defueled TSs" or "decommissioning TSs" has been used to describe technical specifications that have been amended to reflect the permanent shutdown condition of reactor.
Transfer	Includes all real estate transfers (e.g., donation, exchange, disposal, easement, lease, permit, license).
Transuranic element	An artificially made, radioactive element that has an atomic number higher than uranium in the periodic table of elements, e.g., neptunium, plutonium, americium, and others.
Transuranic waste	Material contaminated with transuranic elements that is produced primarily from reprocessing spent fuel and from use of plutonium in fabrication of nuclear weapons.
Unrestricted area	The area outside the owner-controlled portion of a nuclear facility (usually the site boundary). An area in which a person could not be exposed to radiation levels in excess of 2 mrem in any 1 hour from external sources. See 10 CFR 20.1003.
Unrestricted use	A category of facility use after license termination. Unrestricted use means that there are no restrictions on how the site may be used. The licensee is free to continue to dismantle any remaining buildings or structures, and to use the land or sell the land for any type of application.
Vapor	The gaseous form of substances that are normally in liquid or solid form.
Volatile organic compound (VOC)	An organic chemical that evaporates easily. Petroleum products such as kerosene, gasoline, and mineral spirits contain VOCs.
Weighting factor (W_t)	Multipliers of the equivalent dose to an organ or tissue used for radiation protection purposes to account for differ-

ent sensitivities of different organs and tissues to the induction of stochastic effects of radiation. See 10 CFR 20.1003.

Whole-body counter

A device used to identify and measure the radioactive material in the bodies of human beings and animals. It uses heavy shielding to keep out naturally existing background radiation and measures radiation levels with ultra sensitive radiation detectors and electronic counting equipment.

Whole-body exposure

An exposure of the body to radiation, in which the entire body, rather than an isolated part, is irradiated. Where a radioisotope is uniformly distributed throughout the body tissues, rather than being concentrated in certain parts, the irradiation can be considered as whole-body exposure.

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11. ABSTRACT *(200 words or less)*

This document is a final supplement to the NRC Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities (GEIS), issued in 1988 as NUREG-0586. This supplement was prepared because of the technological advances in decommissioning operations, experience gained by licensees, and changes made to NRC regulations since the 1988 GEIS. It is intended to be used to evaluate environmental impacts during the decommissioning of nuclear power reactors as residual radioactivity at the site is reduced to levels that allow for termination of the NRC license. This supplement addresses only the decommissioning of nuclear power reactors licensed by the NRC. It updates the sections of the 1988 GEIS relating to pressurized water reactors, boiling water reactors, and multiple reactor stations. It goes beyond the 1988 GEIS to consider high-temperature gas-cooled reactors and the fast breeder reactors. This document can be considered a stand-alone document and the environmental impacts described herein supercede those described in the 1988 GEIS.

The scope of this supplement is based on the decommissioning activities performed to remove radioactive materials from structures, systems, and components from the time that the licensee certifies that they have permanently ceased power operations until the license is terminated. An evaluation process was developed to determine environmental impacts from the specific activities that occur during reactor decommissioning, based on data from site visits and from licensees at reactor facilities being decommissioned. The data obtained from the sites were analyzed and then evaluated against a list of variables that defined the parameters for facilities that are currently operating but which one day will be decommissioned. This evaluation resulted in a range of impacts for each environmental issue that may be used for comparison by licensees that are or will be decommissioning their facilities. The staff has considered public comments received during scoping and on the draft in preparation of this final supplement.

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