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DECOMMISSIONING COST ANALYSIS

for the

WATERFORD STEAM ELECTRIC STATION, UNIT 3

prepared for

Entergy Louisiana, LLC

prepared by

TLG Services, Inc.
Bridgewater, Connecticut

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APPROVALS

Project Manager	William A. Cloutier, Jr.	23 May 2019 Date
Project Engineer	Timothy A. Arnold	5/23/2019 Date
Technical Manager	Francis W. Seymore	5/23/19 Date

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EXECUTIVE SUMMARY

This report presents estimates of the cost to decommission the Waterford Steam Electric Station, Unit 3 (Waterford 3) for the selected decommissioning alternatives following the scheduled and permanent cessation of plant operations. The estimates are designed to provide the owner, Entergy Louisiana, LLC (Entergy Louisiana) with the information to assess its current decommissioning liability, as it relates to Waterford 3.

The analysis relies upon site-specific, technical information from an evaluation prepared in 2015,[1] updated to reflect current plant inventory, current assumptions pertaining to the operating life of the reactor, disposition of the nuclear plant and relevant industry experience in undertaking such projects. The costs are based on several key assumptions in areas of regulation, component characterization, high-level radioactive waste management, low-level radioactive waste disposal, performance uncertainties (contingency) and site restoration requirements.

The analysis is not a detailed engineering evaluation, but estimates prepared in advance of the detailed engineering required to carry out the decommissioning of the nuclear unit. It may also not reflect the actual plan to decommission Waterford 3; the plan may differ from the assumptions made in this analysis based on facts that exist at the time of decommissioning.

The plant inventory, the basis for the decontamination and dismantling requirements and cost, and the decommissioning waste streams, was reviewed for this analysis. There were no substantive changes made to the plant inventory (that would impact decommissioning).

The costs to decommission Waterford 3 for the alternatives evaluated are tabulated at the end of this section. Costs are reported in 2019 dollars and include monies anticipated to be spent for radiological remediation and operating license termination, spent fuel management, and site restoration activities.

A complete discussion of the assumptions relied upon in this analysis is provided in Section 3, along with schedules of annual expenditures for each scenario. A sequence of significant project activities is provided in Section 4 with a timeline for each scenario. Detailed cost reports used to generate the summary tables contained within this document are provided in Appendices C and D.

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1 "Decommissioning Cost Analysis for the Waterford Steam Electric Station, Unit 3," Document E11-1712-001, Rev. 0, TLG Services, Inc., January 2016

Consistent with the 2015 analysis, the current cost estimates assume that the shutdown of the nuclear unit is a scheduled and pre-planned event (e.g., there is no delay in transitioning the plant and workforce from operations or in obtaining regulatory relief from operating requirements). The estimates include the continued operation of the fuel handling building as an interim wet fuel storage facility for approximately five and one-half years after operations cease. During this time period, it is assumed that the spent fuel residing in the pool that cannot be transferred to the Department of Energy (DOE) will be transferred to an independent spent fuel storage installation (ISFSI) located on the site.

The ISFSI will remain operational until the DOE is able to complete the transfer of the fuel to a federal facility (e.g., a monitored retrievable storage facility).[2] DOE has breached its obligations to remove fuel from reactor sites, and has also failed to provide the plant owner with information about how it will ultimately perform. DOE officials have stated that DOE does not have an obligation to accept already-canistered fuel without an amendment to DOE's contracts with plant licensees to remove the fuel (the "Standard Contract"), but DOE has not explained what any such amendment would involve. Consequently, the plant owner has no information or expectations on how DOE will remove fuel from the site in the future. In the absence of information about how DOE will perform, and for purposes of this analysis only, it is assumed that DOE will accept already-canistered fuel. (It is recognized that the canisters may not be licensed or licensable for transportation when DOE performs.) If this assumption is incorrect, it is assumed that DOE will have liability for costs incurred to transfer the fuel to DOE-supplied containers.

Alternatives and Regulations

The Nuclear Regulatory Commission (NRC) provided general decommissioning requirements in a rule adopted on June 27, 1988.[3] In this rule, the NRC set forth technical and financial criteria for decommissioning licensed nuclear facilities. The regulations addressed planning needs, timing, funding methods, and environmental review requirements for decommissioning. The rule also defined three decommissioning alternatives as being acceptable to the NRC: DECON, SAFSTOR, and ENTOMB.

> DECON is defined as "the alternative in which the equipment, structures, and portions of a facility and site containing radioactive

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2 Projected expenditures for spent fuel management identified in the cost analyses do not consider the outcome of the litigation with the DOE with regard to the delays incurred by Entergy in the timely removal of spent fuel from the site.

3 U.S. Code of Federal Regulations, Title 10, Parts 30, 40, 50, 51, 70 and 72 "General Requirements for Decommissioning Nuclear Facilities," Nuclear Regulatory Commission, Federal Register Volume 53, Number 123 (p 24018 et seq.), June 27, 1988

contaminants are removed or decontaminated to a level that permits the property to be released for unrestricted use shortly after cessation of operations."[4]

SAFSTOR is defined as "the alternative in which the nuclear facility is placed and maintained in a condition that allows the nuclear facility to be safely stored and subsequently decontaminated (deferred decontamination) to levels that permit release for unrestricted use."[5] Decommissioning is required to be completed within 60 years, although longer time periods will be considered when necessary to protect public health and safety.

ENTOMB is defined as "the alternative in which radioactive contaminants are encased in a structurally long-lived material, such as concrete; the entombed structure is appropriately maintained and continued surveillance is carried out until the radioactive material decays to a level permitting unrestricted release of the property."[6] As with the SAFSTOR alternative, decommissioning is currently required to be completed within 60 years, although longer time periods will also be considered when necessary to protect public health and safety.

The 60-year restriction has limited the practicality for the ENTOMB alternative at commercial reactors that generate significant amounts of long-lived radioactive material. In 2017, the NRC's staff issued the regulatory basis for proposed new regulations on the decommissioning of commercial nuclear power reactors. In the regulatory basis, the NRC staff proposed removing any discussion of the ENTOMB option from existing guidance documents "since the method is not deemed practically feasible for current U.S. power reactors, and the timeframe for decommissioning completion using the ENTOMB method is generally inconsistent with current regulations."[7]

In 1996, the NRC published revisions to its general requirements for decommissioning nuclear power plants to clarify ambiguities and codify procedures and terminology as a means of enhancing efficiency and uniformity in the decommissioning process.[8] The

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4 Ibid. Page FR24022, Column 3

5 Ibid.

6 Ibid. Page FR24023, Column 2

7 "Regulatory Improvement for Power Reactors Transitioning to Decommissioning," NRC Regulatory Basis Document, Docket ID NRC-2015-0070, RIN Number 3150-AJ59, November 20, 2017

8 U.S. Code of Federal Regulations, Title 10, Parts 2, 50, and 51, "Decommissioning of Nuclear Power

amendments allow for greater public participation and better define the transition process from operations to decommissioning. Regulatory Guide 1.184, issued in July 2000, (as revised in October 2013), further described the methods and procedures that are acceptable to the NRC staff for implementing the requirements of the 1996 revised rule that relate to the initial activities and the major phases of the decommissioning process. The costs and schedules presented in this analysis follow the general guidance and sequence in the amended regulations. The format and content of the estimates is also consistent with the recommendations of Regulatory Guide 1.202, issued in February 2005.[9]

In 2011, the NRC issued regulations to improve decommissioning planning and thereby reduce the likelihood that any current operating facility will become a legacy site.[10] The regulations require licensees to report additional details in their decommissioning cost estimate, including a decommissioning estimate for the ISFSI. This estimate is provided in Appendix E.

Decommissioning Scenarios

Two decommissioning scenarios were evaluated for the Waterford 3 nuclear unit. The scenarios selected are representative of alternatives currently available to the owner and are defined as follows:

1. The first scenario assumes that the unit would be promptly decommissioned (DECON alternative) upon the expiration of the current operating license, i.e., 2044.

2. In the second scenario, the nuclear unit is placed into safe-storage (SAFSTOR alternative) at the end of its current operating license. Decommissioning is deferred to the maximum extent such that the license is terminated within the required 60-year period.

Methodology

The methodology used to develop the estimates follows the basic approach originally presented in the cost estimating guidelines[11] developed by the Atomic Industrial

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Reactors," NRC, Federal Register Volume 61, (p 39278 et seq.), July 29, 1996

9 "Standard Format and Content of Decommissioning Cost Estimates for Nuclear Power Reactors," Regulatory Guide 1.202, Nuclear Regulatory Commission, February 2005

10 U.S. Code of Federal Regulations, Title 10, Parts 20, 30, 40, 50, 70, and 72, "Decommissioning Planning," Nuclear Regulatory Commission, Federal Register Volume 76, (p 35512 et seq.), June 17, 2011

11 T.S. LaGuardia et al., "Guidelines for Producing Commercial Nuclear Power Plant Decommissioning

Forum (now Nuclear Energy Institute). This reference describes a unit cost factor method for estimating decommissioning activity costs. The unit cost factors used in this analysis incorporate site-specific costs and the latest available information about worker productivity in decommissioning.

An activity duration critical path is used to determine the total decommissioning program schedule. This is required for calculating the carrying costs, which include program management, administration, field engineering, equipment rental, quality assurance, and security. This systematic approach for assembling decommissioning estimates ensures a high degree of confidence in the reliability of the resulting costs.

The estimates also reflect lessons learned from TLG's involvement in the Shippingport Station Decommissioning Project, completed in 1989, as well as the decommissioning of the Cintichem reactor, hot cells and associated facilities, completed in 1997. In addition, the planning and engineering for the Rancho Seco, Trojan, Yankee Rowe, Big Rock Point, Maine Yankee, Humboldt Bay-3, Oyster Creek, Connecticut Yankee, Crystal River, Vermont Yankee, Fort Calhoun and Pilgrim nuclear units have provided additional insight into the process, the regulatory aspects, and the technical challenges of decommissioning commercial nuclear units.

Contingency

Consistent with cost estimating practice, contingencies are applied to the decontamination and dismantling costs developed as "specific provision for unforeseeable elements of cost within the defined project scope, particularly important where previous experience relating estimates and actual costs has shown that unforeseeable events which will increase costs are likely to occur."[12] The cost elements in the estimates are based on ideal conditions; therefore, the types of unforeseeable events that are almost certain to occur in decommissioning, based on industry experience, are addressed through a percentage contingency applied on a line-item basis. This contingency factor is a nearly universal element in all large-scale construction and demolition projects. It should be noted that contingency, as used in this analysis, does not account for price escalation and inflation in the cost of decommissioning over the remaining operating life of the station.

Contingency funds are expected to be fully expended throughout the program. As such, inclusion of contingency is necessary to provide assurance that sufficient funding will be available to accomplish the intended tasks.

Cost Estimates," AIF/NESP-036, May 1986

12 Project and Cost Engineers' Handbook, Second Edition, American Association of Cost Engineers, Marcel Dekker, Inc., New York, New York, p. 239

Low-Level Radioactive Waste Management

The contaminated and activated material generated in the decontamination and dismantling of a commercial nuclear reactor is generally classified as low-level radioactive waste, although not all of the material is suitable for shallow-land disposal. With the passage of the "Low-Level Radioactive Waste Disposal Act" in 1980 and its Amendments of 1985,[13] the states became ultimately responsible for the disposition of low-level radioactive waste generated within their own borders.

With the exception of Texas, no new compact facilities have been successfully sited, licensed, and constructed. The Texas Compact disposal facility is now operational and waste is being accepted from generators within the Compact by the operator, Waste Control Specialists (WCS). The facility is also able to accept limited volumes of non-Compact waste.

Disposition of the various waste streams produced by the decommissioning process considered all options and services currently available to Entergy Operations (Entergy). The majority of the low-level radioactive waste designated for direct disposal (Class A[14]) can be sent to Energy*Solutions'* facility in Clive, Utah. Therefore, disposal costs for Class A waste were based upon Entergy's *Life of Plant Agreement* and other service agreements with Energy*Solutions*. This facility is not licensed to receive the higher activity portion (Classes B and C) of the decommissioning waste stream.

The WCS facility is able to receive the Class B and C waste. As such, for this analysis, Class B and C waste was assumed to be shipped to the WCS facility and disposal costs for the waste were based upon Entergy's current agreement with WCS.

The dismantling of the components residing closest to the reactor core generates radioactive waste that may be considered unsuitable for shallow-land disposal (i.e., low-level radioactive waste with concentrations of radionuclides that exceed the limits established by the NRC for Class C radioactive waste (GTCC)). The Low-Level Radioactive Waste Policy Amendments Act of 1985 assigned the federal government the responsibility for the disposal of this material. The Act also stated that the beneficiaries of the activities resulting in the generation of such radioactive waste bear all reasonable costs of disposing of such waste. However, to date, the federal government has not identified a cost, if any, for GTCC disposal or a schedule for acceptance.

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13 "Low-Level Radioactive Waste Policy Amendments Act of 1985," Public Law 99-240, January 15, 1986

14 Waste is classified in accordance with U.S. Code of Federal Regulations, Title 10, Part 61.55

For purposes of this analysis only, the GTCC radioactive waste is assumed to be packaged and disposed of in a manner similar to high-level waste and at a cost equivalent to that envisioned for the spent fuel. The GTCC is packaged in the same canisters used for spent fuel and either stored on site or shipped directly to a federal facility as it is generated (depending upon the timing of the decommissioning and whether the spent fuel has already been removed from the site prior to the start of decommissioning).

A significant portion of the waste material generated during decommissioning may only be potentially contaminated by radioactive materials. This waste can be analyzed on site or shipped off site to licensed facilities for further analysis, for processing and/or for conditioning/recovery. Reduction in the volume of low-level radioactive waste requiring disposal in a licensed low-level radioactive waste disposal facility can be accomplished through a variety of methods, including analyses and surveys or decontamination to eliminate the portion of waste that does not require disposal as radioactive waste, compaction, incineration or metal melt. The estimates reflect the savings from waste recovery/volume reduction.

<u>High-Level Radioactive Waste Management</u>

Congress passed the "Nuclear Waste Policy Act" (NWPA) in 1982, assigning the federal government's long-standing responsibility for disposal of the spent nuclear fuel created by the commercial nuclear generating plants to the DOE. The DOE was to begin accepting spent fuel by January 31, 1998; however, to date no progress in the removal of spent fuel from commercial generating sites has been made.

Completion of the decommissioning process is dependent upon the DOE's ability to remove spent fuel from the site in a timely manner. DOE's repository program assumes that spent fuel allocations will be accepted for disposal from the nation's commercial nuclear plants, with limited exceptions, in the order (the "queue") in which it was discharged from the reactor.[15] Entergy's current spent fuel

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15 In 2008, the DOE issued a report to Congress in which it concluded that it did not have authority, under present law, to accept spent nuclear fuel for interim storage from decommissioned commercial nuclear power reactor sites. However, the Blue Ribbon Commission, in its final report, noted that: "[A]ccepting spent fuel according to the OFF [Oldest Fuel First] priority ranking instead of giving priority to shutdown reactor sites could greatly reduce the cost savings that could be achieved through consolidated storage if priority could be given to accepting spent fuel from shutdown reactor sites before accepting fuel from still-operating plants. …. The magnitude of the cost savings that could be achieved by giving priority to shutdown sites appears to be large enough (i.e., in the billions of dollars) to warrant DOE exercising its right under the Standard Contract to move this fuel first." For planning purposes only, this estimate does not assume that Waterford 3, as a permanently shutdown unit, will receive priority; the fuel removal schedule assumed in this estimate is based upon DOE acceptance of fuel according to the "Oldest Fuel First" priority ranking. The plant owner will seek the most expeditious means of removing

management plan for the Waterford 3 spent fuel is based in general upon: 1) a 2030 start date for DOE initiating transfer of commercial spent fuel from the industry to a federal facility (not necessarily a final repository), and 2) an assumed schedule for spent fuel receipt by the DOE for the Waterford fuel. The DOE's generator allocation/receipt schedules are based upon the oldest fuel receiving the highest priority. Assuming a maximum rate of transfer of 3,000 metric tons of uranium (MTU)/year, [16] the removal of spent fuel from the site could be completed in 2080 for a 2044 shutdown. Different DOE acceptance schedules may result in different completion dates.

Today, the country is at an impasse on high-level waste disposal, despite DOE's submittal of its License Application for a geologic repository to the NRC in 2008. The Obama administration eliminated the budget for the repository program while promising to "conduct a comprehensive review of policies for managing the back end of the nuclear fuel cycle … and make recommendations for a new plan."[17] Towards this goal, the Obama administration appointed a Blue Ribbon Commission on America's Nuclear Future (Blue Ribbon Commission) to make recommendations for a new plan for nuclear waste disposal. The Blue Ribbon Commission's charter included a requirement that it consider "[o]ptions for safe storage of used nuclear fuel while final disposition pathways are selected and deployed."[18]

On January 26, 2012, the Blue Ribbon Commission issued its "Report to the Secretary of Energy" containing a number of recommendations on nuclear waste disposal. Two of the recommendations that may impact decommissioning planning are:

- "[T]he United States [should] establish a program that leads to the timely development of one or more consolidated storage facilities"[19]
- "[T]he United States should undertake an integrated nuclear waste management program that leads to the timely development of one or more permanent deep geological facilities for the safe disposal of spent fuel and high-level nuclear waste."[20]

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fuel from the site when DOE commences performance.

16 "Acceptance Priority Ranking & Annual Capacity Report," DOE/RW-0567, July 2004

17 "Advisory Committee Charter, Blue Ribbon Commission on America's Nuclear Future," Appendix A, January 2012

18 Ibid.

19 "Blue Ribbon Commission on America's Nuclear Future, Report to the Secretary of Energy," p.32, January 2012

20 Ibid., p.27

In January 2013, the DOE issued the "Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste," in response to the recommendations made by the Blue Ribbon Commission and as "a framework for moving toward a sustainable program to deploy an integrated system capable of transporting, storing, and disposing of used nuclear fuel..."[21]

"With the appropriate authorizations from Congress, the Administration currently plans to implement a program over the next 10 years that:

- Sites, designs and licenses, constructs and begins operations of a pilot interim storage facility by 2021 with an initial focus on accepting used nuclear fuel from shut-down reactor sites;
- Advances toward the siting and licensing of a larger interim storage facility to be available by 2025 that will have sufficient capacity to provide flexibility in the waste management system and allows for acceptance of enough used nuclear fuel to reduce expected government liabilities; and
- Makes demonstrable progress on the siting and characterization of repository sites to facilitate the availability of a geologic repository by 2048."[22]

The NRC's review of DOE's license application to construct a geologic repository at Yucca Mountain was suspended in 2011 when the Obama administration significantly reduced the budget for completing that work. However, the US Court of Appeals for the District of Columbia Circuit issued a writ of mandamus (in August 2013)[23] ordering NRC to comply with federal law and resume its review of DOE's Yucca Mountain repository license application to the extent allowed by previously appropriated funding for the review. That review is now complete with the publication of the five-volume safety evaluation report. A supplement to DOE's environmental impact statement and adjudicatory hearing on the contentions filed by interested parties must be completed before a licensing decision can be made. Although the DOE proposed it would start fuel acceptance in 2025, no progress has been made in the repository program since DOE's 2013 strategy was issued except for the completion of the Yucca Mountain safety evaluation report. Because of this continued delay, this estimate revises the assumed start date for DOE fuel acceptance from 2025 used in the 2015 evaluation to 2030.

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[21] "Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste," U.S. DOE, January 11, 2013

[22] Ibid., p.2

[23] U.S. Court of Appeals for the District Of Columbia Circuit, In Re: Aiken County, et al, Aug. 2013

The NRC requires that licensees establish a program to manage and provide funding for the caretaking of all irradiated fuel at the reactor site until title of the fuel is transferred to the DOE.[24] Interim storage of the fuel, until the DOE has completed the transfer, will be in the fuel handling building's spent fuel storage pool, as well as at an on-site ISFSI.

An ISFSI, operated under a Part 50 General License (in accordance with 10 CFR 72, Subpart K[25]), has been constructed to support continued plant operations. The facility is assumed to be available to support future decommissioning operations. As such, the fuel that cannot be transferred directly to the DOE from the wet pool is packaged for interim storage at the ISFSI. Once the spent fuel storage pool is emptied, the fuel handling building can be either decontaminated and dismantled or prepared for long term storage.

Entergy's position is that the DOE has a contractual obligation to accept the spent fuel earlier than the projections set out above consistent with its contract commitments. No assumption made in this study should be interpreted to be inconsistent with this claim. However, at this time, including the cost of storing spent fuel in this study is the most reasonable approach because it insures the availability of sufficient decommissioning funds at the end of the station's life if, contrary to its contractual obligation, the DOE has not performed earlier.

<u>Site Restoration</u>

The efficient removal of the contaminated materials at the site may result in damage to many of the site structures. Blasting, coring, drilling, and the other decontamination activities can substantially damage power block structures, potentially weakening the footings and structural supports. It is unreasonable to anticipate that these structures would be repaired and preserved after the radiological contamination is removed. The cost to dismantle site structures with a work force already mobilized is more efficient and less costly than if the process is deferred.

Consequently, this study assumes that non-essential site structures addressed by this analysis are removed, once remediation is complete, to a nominal depth of three feet below the local grade level wherever possible. The site is then graded and stabilized.

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24 U.S. Code of Federal Regulations, Title 10, Part 50, – "Domestic Licensing of Production and Utilization Facilities," - Subpart 54 (bb), "Conditions of Licenses"

25 U.S. Code of Federal Regulations, Title 10, Part 72, Subpart K, "General License for Storage of Spent Fuel at Power Reactor Sites"

Summary

The estimates to decommission Waterford 3 assume the removal of all contaminated and activated plant components and structural materials such that the owner may then have unrestricted use of the site with no further requirements for an operating license. Low-level radioactive waste, other than GTCC waste, is sent to a commercial processor for treatment/conditioning or to a controlled disposal facility.

Decommissioning is accomplished within the 60-year period required by current NRC regulations. In the interim, the spent fuel remains in storage at the site until such time that the transfer to a DOE facility is complete.

The alternatives evaluated in this analysis are described in Section 2. The assumptions are presented in Section 3, along with schedules of annual expenditures. The major cost contributors are identified in Section 6, with detailed activity costs, waste volumes, and associated manpower requirements delineated in Appendices C and D. The major cost components are also identified in the cost summary provided at the end of this section.

The cost elements in the estimates for the DECON and SAFSTOR alternatives are assigned to one of three subcategories: NRC License Termination (radiological remediation), Spent Fuel Management, and Site Restoration. The subcategory "NRC License Termination" is used to accumulate costs that are consistent with "decommissioning" as defined by the NRC in its financial assurance regulations (i.e., 10 CFR §50.75). The cost reported for this subcategory is generally sufficient to terminate the unit's operating license, recognizing that there may be some additional cost impact from spent fuel management. The License Termination cost subcategory also includes costs to decommission the ISFSI (as required by 10 CFR §72.30). Section 3.4.1 provides the basis for the ISFSI decommissioning cost delineated in Appendix E.

The "Spent Fuel Management" subcategory contains costs associated with the containerization and transfer of spent fuel from the wet storage pool to the DOE or to the ISFSI for interim storage, as well as the transfer of the spent fuel in storage at the ISFSI to the DOE. Costs are included for the operation of the storage pool and the management of the ISFSI until such time that the transfer is complete. It does not include any spent fuel management expenses incurred prior to the cessation of plant operations, nor does it include any costs related to the final disposal of the spent fuel.

"Site Restoration" is used to capture costs associated with the dismantling and demolition of buildings and facilities demonstrated to be free from contamination. This includes structures never exposed to radioactive materials, as well as those facilities that have been decontaminated to appropriate levels. Structures are removed to a depth of three feet and backfilled to conform to local grade.

It should be noted that the costs assigned to these subcategories are allocations. Delegation of cost elements is for the purposes of comparison (e.g., with NRC financial guidelines) or to permit specific financial treatment (e.g., Asset Retirement Obligation determinations). In reality, there can be considerable interaction between the activities in the three subcategories. For example, an owner may decide to remove non-contaminated structures early in the project to improve access to highly contaminated facilities or plant components. In these instances, the non-contaminated removal costs could be reassigned from Site Restoration to an NRC License Termination support activity. However, in general, the allocations represent a reasonable accounting of those costs that can be expected to be incurred for the specific subcomponents of the total estimated program cost, if executed as described.

As noted within this document, the estimates were developed and costs are presented in 2019 dollars. As such, the estimates do not reflect the escalation of costs (due to inflationary and market forces) over the remaining operating life of the plant or during the decommissioning period.

DECON COST SUMMARY
DECOMMISSIONING COST ELEMENTS
(thousands of 2019 dollars)

Cost Element	Cost
Decontamination	15,975
Removal	135,534
Packaging	31,584
Transportation	19,476
Waste Disposal	75,739
Off-site Waste Processing	47,260
Program Management [1]	414,653
Site Security	192,678
Spent Fuel Pool Isolation	14,174
Dry Fuel Storage (Capital and Transfer) [2]	160,484
Insurance and Regulatory Fees	45,936
Energy	10,111
Characterization and Licensing Surveys	28,244
Property Taxes	4,277
Site O&M (Non-Labor Overhead)	19,357
Corporate A&G	44,771
Miscellaneous Equipment / Site Services	11,234
Severance	6,000
Total [3]	1,277,489

Cost Category	Cost
License Termination	856,219
Spent Fuel Management	351,173
Site Restoration	70,097
Total [3]	1,277,489

[1] Includes engineering costs
[2] Includes costs for operating the spent fuel pools and ISFSI, emergency planning and the cost to transfer the fuel to the DOE and/or ISFSI
[3] Columns may not add due to rounding

SAFSTOR COST SUMMARY
DECOMMISSIONING COST ELEMENTS
(thousands of 2019 dollars)

Cost Element	Cost
Decontamination	18,427
Removal	135,109
Packaging	20,223
Transportation	16,980
Waste Disposal	60,196
Off-site Waste Processing	49,912
Program Management [1]	497,187
Site Security	264,412
Spent Fuel Pool Isolation	14,174
Dry Fuel Storage (Capital and Transfer) [2]	151,728
Insurance and Regulatory Fees	74,487
Energy	20,070
Characterization and Licensing Surveys	27,016
Property Taxes	7,268
Site O&M (Non-Labor Overhead)	25,246
Corporate A&G	64,535
Miscellaneous Equipment / Site Services	33,468
Severance	6,000
Total [3]	1,486,438

Cost Category	Cost
License Termination	1,095,521
Spent Fuel Management	321,603
Site Restoration	69,314
Total [3]	1,486,438

[1] Includes engineering costs
[2] Includes costs for operating the spent fuel pools and ISFSI, emergency planning and the cost to transfer the fuel to the DOE and/or ISFSI
[3] Columns may not add due to rounding

1. INTRODUCTION

This report presents estimates of the cost to decommission the Waterford Steam Electric Station, Unit 3 (Waterford 3) for the selected decommissioning alternatives following the scheduled and permanent cessation of plant operations. The estimates are designed to provide the owner, Entergy Louisiana, LLC, with the information to assess its current decommissioning liability, as it relates to Waterford 3.

The analysis relies upon site-specific, technical information from an earlier evaluation prepared in 2015,[1]* updated to reflect current plant inventory, current assumptions pertaining to the disposition of the nuclear plant and relevant industry experience in undertaking such projects. The costs are based on several key assumptions in areas of regulation, component characterization, high-level radioactive waste management, low-level radioactive waste disposal, performance uncertainties (contingency) and site restoration requirements.

The analysis is not a detailed engineering evaluation, but rather estimates prepared in advance of the detailed engineering required to carry out the decommissioning of the nuclear unit. It may also not reflect the actual plan to decommission Waterford 3; the plan may differ from the assumptions made in this analysis based on facts that exist at the time of decommissioning.

The 2015 plant inventory, the basis for the decontamination and dismantling requirements and cost, and the decommissioning waste streams, was reviewed for this analysis. There were no substantive changes made to the plant (that would impact decommissioning).

1.1 OBJECTIVES OF STUDY

The objectives of this study are to prepare comprehensive estimates of the costs to decommission Waterford 3, to provide a sequence or schedule for the associated activities, and to develop waste stream projections from the decontamination and dismantling activities.

The original operating license for Waterford 3 was issued in December 1984, and under the terms of its license could operate through December 18, 2024. In March 2016, Entergy Operations, Inc. (Entergy) and Entergy Louisiana submitted an application for license renewal. In December 2018, the NRC approved the application, extending the license through December 18, 2044.

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* References provided in Section 7 of the document

1.2 SITE DESCRIPTION

Waterford 3 is located on the west (right descending) bank of the Mississippi River in St. Charles Parish, near the town of Taft, Louisiana. The nuclear unit is operated by Entergy Operations, a nuclear management company, subject to the owner oversight of Entergy Louisiana, LLC ("ELL"). Entergy Operations and ELL are wholly-owned subsidiaries of Entergy Corporation.

Combustion Engineering provided the Nuclear Steam Supply System (NSSS). The NSSS is arranged as two closed loops connected in parallel to the reactor vessel, each containing two reactor coolant pumps and a steam generator. The two steam generators are vertical shell and U-tube units. Four electric-motor-driven, single-suction centrifugal pumps circulate the reactor coolant. With the extended power uprate in 2005, the maximum steady-state reactor core power level increased to 3,716 megawatts-thermal, with a corresponding nominal generator output of 1,231 megawatts-electric.

A containment vessel houses the reactor pressure vessel, the reactor coolant piping, the pressurizer, the quench tank, the reactor coolant pumps, the steam generators, and the safety injection tanks. The containment vessel is an independent, free-standing structure. It is completely enclosed by a reinforced concrete shield building. The shield building and the containment vessel are supported on a common foundation mat.

The steam and power conversion system removes heat energy from the reactor coolant in two U-tube steam generators, and converts the steam into electrical energy by means of a turbine-generator. The circulating water system transfers the unusable heat in the steam cycle to the main condenser for rejection. The resulting condensate is then deaerated, heated through feedwater heaters, and returned to the steam generators as feedwater.

The main turbine is a Westinghouse Electric Corporation 1800 rpm, tandem compound, six flow exhaust unit with one double axial flow high pressure section and three double axial flow low pressure sections. Moisture separators and reheaters dry and superheat the steam between the high and low-pressure elements of the turbine.

The main condenser is a single-pass, three shell, single pressure type with divided water boxes. The tubes in each shell are oriented transverse to the turbine shaft. The circulating water system provides a heat sink with sufficient capacity to remove the heat rejected in the main condenser. River water is pumped from the intake structure to the tube side of the main condensers and turbine building closed cooling water heat exchangers by the circulating water pumps. Water from the condensers and the heat exchangers is discharged to a discharge structure, which discharges into the river downstream of the intake structure.

1.3 REGULATORY GUIDANCE

The Nuclear Regulatory Commission (NRC or Commission) provided initial decommissioning requirements in its rule "General Requirements for Decommissioning Nuclear Facilities," issued in June 1988.[2] This rule set forth financial criteria for decommissioning licensed nuclear power facilities. The regulation addressed decommissioning planning needs, timing, funding methods, and environmental review requirements. The intent of the rule was to ensure that decommissioning would be accomplished in a safe and timely manner and that adequate funds would be available for this purpose. Subsequent to the rule, the NRC issued Regulatory Guide 1.159, “Assuring the Availability of Funds for Decommissioning Nuclear Reactors,”[3] which provided additional guidance to the licensees of nuclear facilities on the financial methods acceptable to the NRC staff for complying with the requirements of the rule. The regulatory guide addressed the funding requirements and provided guidance on the content and form of the financial assurance mechanisms indicated in the rule.

The rule defined three decommissioning alternatives as being acceptable to the NRC: DECON, SAFSTOR, and ENTOMB. The DECON alternative assumes that any contaminated or activated portion of the plant’s systems, structures and facilities are removed or decontaminated to levels that permit the site to be released for unrestricted use shortly after the cessation of plant operations, while the SAFSTOR and ENTOMB alternatives defer the process.

The rule also placed limits on the time allowed to complete the decommissioning process. For all alternatives, the process is restricted in overall duration to 60 years, unless it can be shown that a longer duration is necessary to protect public health and safety. At the conclusion of a 60-year dormancy period (or longer if the NRC approves such a case), the site would still require significant remediation to meet the unrestricted release limits for license termination.

The 60-year restriction has limited the practicality for the ENTOMB alternative at commercial reactors that generate significant amounts of long-lived radioactive material. In 2017, the NRC’s staff issued the regulatory basis for proposed new regulations on the decommissioning of commercial nuclear power reactors. In the regulatory basis, the NRC staff proposed removing any discussion of the ENTOMB option from existing guidance documents “since the method is not deemed practically feasible for current U.S. power reactors, and the timeframe for decommissioning completion using the ENTOMB method is generally inconsistent with current regulations."[4]

In 1996, the NRC published revisions to the general requirements for decommissioning nuclear power plants.[5] When the decommissioning regulations were adopted in 1988, it was assumed that the majority of licensees would decommission at the end of the facility's operating licensed life. Since that time, several licensees permanently and prematurely ceased operations. Exemptions from certain operating requirements were required once the reactor was defueled to facilitate the decommissioning. Each case was handled individually, without clearly defined generic requirements. The NRC amended the decommissioning regulations in 1996 to clarify ambiguities and codify procedures and terminology as a means of enhancing efficiency and uniformity in the decommissioning process. The amendments allow for greater public participation and better define the transition process from operations to decommissioning.

Under the revised regulations, licensees will submit written certification to the NRC within 30 days after the decision to cease operations. Certification will also be required once the fuel is permanently removed from the reactor vessel. Submittal of these notices, along with related changes to Technical Specifications, entitle the licensee to a fee reduction and eliminate the obligation to follow certain requirements needed only during operation of the reactor. Within two years of submitting notice of permanent cessation of operations, the licensee is required to submit a Post-Shutdown Decommissioning Activities Report (PSDAR) to the NRC. The PSDAR describes the planned decommissioning activities, the associated sequence and schedule, and an estimate of expected costs. Prior to completing decommissioning, the licensee is required to submit an application to the NRC to terminate the license, which includes a license termination plan (LTP).

In 2011, the NRC issued regulations to improve decommissioning planning and thereby reduce the likelihood that any current operating facility will become a legacy site.[6] The regulations require licensees to report additional details in their decommissioning cost estimate including a decommissioning estimate for the ISFSI. This estimate is provided in Appendix E.

1.3.1 High-Level Radioactive Waste Management

Congress passed the "Nuclear Waste Policy Act"[7] (NWPA) in 1982, assigning the federal government's long-standing responsibility for disposal of the spent nuclear fuel created by the commercial nuclear generating plants to the DOE. It was to begin accepting spent fuel by January 31, 1998; however, to date no progress in the removal of spent fuel from commercial generating sites has been made.

Completion of the decommissioning process is dependent upon the DOE's ability to remove spent fuel from the site in a timely manner. DOE's repository program assumes that spent fuel allocations will be accepted for disposal from the nation's commercial nuclear plants, with limited exceptions, in the order (the "queue") in which it was discharged from the reactor. Entergy's current spent fuel management plan for the Waterford 3 spent fuel is based in general upon: 1) a 2030 start date for DOE initiating transfer of commercial spent fuel from the industry to a federal facility (not necessarily a final repository), and 2) an assumed schedule for spent fuel receipt by the DOE for the Waterford fuel. The DOE's generator allocation/receipt schedules are based upon the oldest fuel receiving the highest priority. Assuming a maximum rate of transfer of 3,000 metric tons of uranium (MTU)/year, as reflected in DOE's latest Acceptance Priority Ranking and Annual Capacity Report dated June 2004 (DOE/RW-0567),[8] the removal of spent fuel from the site is completed in 2080 for a 2044 shutdown. Different DOE acceptance schedules may result in different completion dates.

Today, the country is at an impasse on high-level waste disposal, even with the License Application for a geologic repository submitted by the DOE to the NRC in 2008. The Obama administration cut the budget for the repository program while promising to "conduct a comprehensive review of policies for managing the back end of the nuclear fuel cycle … and make recommendations for a new plan." Towards this goal, the Obama administration appointed a Blue Ribbon Commission on America's Nuclear Future (Blue Ribbon Commission) to make recommendations for a new plan for nuclear waste disposal. The Blue Ribbon Commission's charter includes a requirement that it consider "[o]ptions for safe storage of used nuclear fuel while final disposition pathways are selected and deployed."[9]

On January 26, 2012, the Blue Ribbon Commission issued its "Report to the Secretary of Energy" containing a number of recommendations on nuclear waste disposal. Two of the recommendations that may impact decommissioning planning are:

- "[T]he United States [should] establish a program that leads to the timely development of one or more consolidated storage facilities"

- "[T]he United States should undertake an integrated nuclear waste management program that leads to the timely development of one or more permanent deep geological facilities for the safe disposal of spent fuel and high-level nuclear waste."[10]

In January 2013, the DOE issued the "Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste," in response to the recommendations made by the Blue Ribbon Commission and as "a framework for moving toward a sustainable program to deploy an integrated system capable of transporting, storing, and disposing of used nuclear fuel..."[11]

"With the appropriate authorizations from Congress, the Administration currently plans to implement a program over the next 10 years that:

- Sites, designs and licenses, constructs and begins operations of a pilot interim storage facility by 2021 with an initial focus on accepting used nuclear fuel from shut-down reactor sites;
- Advances toward the siting and licensing of a larger interim storage facility to be available by 2025 that will have sufficient capacity to provide flexibility in the waste management system and allows for acceptance of enough used nuclear fuel to reduce expected government liabilities; and
- Makes demonstrable progress on the siting and characterization of repository sites to facilitate the availability of a geologic repository by 2048."

The NRC's review of DOE's license application to construct a geologic repository at Yucca Mountain was suspended in 2011 when the Obama administration significantly reduced the budget for completing that work. However, the US Court of Appeals for the District of Columbia Circuit issued a writ of mandamus (in August 2013)[12] ordering NRC to comply with federal law and resume its review of DOE's Yucca Mountain repository license application to the extent allowed by previously appropriated funding for the review. That review is now complete with the publication of the five-volume safety evaluation report. A supplement to DOE's environmental impact statement and adjudicatory hearing on the contentions filed by interested parties must be completed before a licensing decision can be made. Although the DOE proposed it would start fuel acceptance in 2025, no progress has been made in the repository program since DOE's 2013 strategy was issued except for the completion of the Yucca Mountain safety evaluation report. Because of this continued delay, this estimate revises the assumed start date for DOE fuel acceptance from 2025, as used in the 2015 evaluation, to 2030.

The NRC requires that licensees establish a program to manage and provide funding for the caretaking of all irradiated fuel at the reactor site until title of the fuel is transferred to the DOE.[13] Interim storage of the fuel, until the DOE has completed the transfer, will be in the fuel handling building's spent fuel storage pool, as well as at an on-site ISFSI. DOE has breached its obligations to remove fuel from reactor sites, and has also failed to provide the plant owner with information about how it will ultimately perform. DOE officials have stated that DOE does not have an obligation to accept already-canistered fuel without an amendment to DOE's contracts with plant licensees to remove the fuel (the "Standard Contract"), but DOE has not explained what any such amendment would involve. Consequently, the plant owner has no information or expectations on how DOE will remove fuel from the site in the future. In the absence of information about how DOE will perform, and for purposes of this analysis only, it is assumed that DOE will accept already-canistered fuel. (It is recognized that the canisters may not be licensed or licensable for transportation when DOE performs.) If this assumption is incorrect, it is assumed that DOE will have liability for costs incurred to transfer the fuel to DOE-supplied containers.

An ISFSI, operated under a Part 50 General License (in accordance with 10 CFR 72, Subpart K[14]), has been constructed to support continued plant operations. The facility is assumed to be available to support future decommissioning operations. As such, the fuel that cannot be transferred directly to the DOE from the wet pool is packaged for interim storage at the ISFSI. Once the fuel handling building's spent fuel storage pool is emptied, the building can be either decontaminated and dismantled or prepared for long-term storage.

Entergy's position is that the DOE has a contractual obligation to accept Waterford 3's fuel earlier than the projections set out above consistent with its contract commitments. No assumption made in this study should be interpreted to be inconsistent with this claim. However, at this time, including the cost of storing spent fuel in this study is the most reasonable approach because it insures the availability of sufficient decommissioning funds at the end of the station's life if, contrary to its contractual obligation, the DOE has not performed earlier.

1.3.2 Low-Level Radioactive Waste Management

The contaminated and activated material generated in the decontamination and dismantling of a commercial nuclear reactor is classified as low-level (radioactive) waste, although not all of the material is suitable for “shallow-land” disposal. With the passage of the “Low-Level Radioactive Waste Policy Act” in 1980,[15] and its Amendments of 1985,[16] the states became ultimately responsible for the disposition of low-level radioactive waste generated within their own borders.

With the exception of Texas, no new compact facilities have been successfully sited, licensed, and constructed. The Texas Compact disposal facility is now operational and waste is being accepted from generators within the Compact by the operator, Waste Control Specialists (WCS). The facility is also able to accept limited volumes of non-Compact waste.

Disposition of the various waste streams produced by the decommissioning process considered all options and services currently available to Entergy. The majority of the low-level radioactive waste designated for direct disposal (Class A[17]) can be sent to Energy*Solutions’* facility in Clive, Utah. Therefore, disposal costs for Class A waste were based upon Entergy’s *Life of Plant Agreement* and other service agreements with Energy*Solutions*. This facility is not licensed to receive the higher activity portion (Classes B and C) of the decommissioning waste stream.

The WCS facility is able to receive the Class B and C waste. As such, for this analysis, Class B and C waste was assumed to be shipped to the WCS facility and disposal costs for the waste were based upon Entergy’s current agreement with WCS.

The dismantling of the components residing closest to the reactor core generates radioactive waste that may be considered unsuitable for shallow-land disposal (i.e., low-level radioactive waste with concentrations of radionuclides that exceed the limits established by the NRC for Class C radioactive waste (GTCC)). The Low-Level Radioactive Waste Policy Amendments Act of 1985 assigned the federal government the responsibility for the disposal of this material. The Act also stated that the beneficiaries of the activities resulting in the generation of such radioactive waste bear all reasonable costs of disposing of such waste. However, to date, the federal government has not identified a cost, if any, for GTCC disposal or a schedule for acceptance.

For purposes of this analysis only, the GTCC radioactive waste is assumed to be packaged and disposed of in a manner similar to high-level waste and at a cost equivalent to that envisioned for the spent fuel. The GTCC is packaged in the same canisters used for spent fuel and either stored on site or shipped directly to a federal facility as it is generated (depending upon the timing of the decommissioning and whether the spent fuel has already been removed from the site prior to the start of decommissioning).

A significant portion of the waste material generated during decommissioning may only be potentially contaminated by radioactive materials. This waste can be analyzed on site or shipped off site to licensed facilities for further analysis, for processing and/or for conditioning/recovery. Reduction in the volume of low-level radioactive waste requiring disposal in a licensed low-level radioactive waste disposal facility can be accomplished through a variety of methods, including analyses and surveys or decontamination to eliminate the portion of waste that does not require disposal as radioactive waste, compaction, incineration or metal melt. The estimates reflect the savings from waste recovery/volume reduction.

1.3.3 Radiological Criteria for License Termination

In 1997, the NRC published Subpart E, "Radiological Criteria for License Termination,"[18] amending 10 CFR Part 20. This subpart provides radiological criteria for releasing a facility for unrestricted use. The regulation states that the site can be released for unrestricted use if radioactivity levels are such that the average member of a critical group would not receive a Total Effective Dose Equivalent (TEDE) in excess of 25 millirem per year, and provided that residual radioactivity has been reduced to levels that are As Low As Reasonably Achievable (ALARA). The decommissioning estimates assume that the Waterford 3 site will be remediated to a residual level consistent with the NRC-prescribed level.

It should be noted that the NRC and the Environmental Protection Agency (EPA) differ on the amount of residual radioactivity considered acceptable in site remediation. The EPA has two limits that apply to radioactive materials. An EPA limit of 15 millirem per year is derived from criteria established by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund).[19] An additional and separate limit of 4 millirem per year, as defined in 40 CFR §141.66, is applied to drinking water.[20]

On October 9, 2002, the NRC signed an agreement with the EPA on the radiological decommissioning and decontamination of NRC-licensed sites. The Memorandum of Understanding (MOU)[21] provides that EPA will defer exercise of authority under CERCLA for the majority of facilities decommissioned under NRC authority. The MOU also includes provisions for NRC and EPA consultation for certain sites when, at the time of license termination, (1) groundwater contamination exceeds EPA-permitted levels; (2) NRC contemplates restricted release of the site; and/or (3) residual radioactive soil concentrations exceed levels defined in the MOU.

The MOU does not impose any new requirements on NRC licensees and should reduce the involvement of the EPA with NRC licensees who are decommissioning. Most sites are expected to meet the NRC criteria for unrestricted use, and the NRC believes that only a few sites will have groundwater or soil contamination in excess of the levels specified in the MOU that trigger consultation with the EPA. However, if there are other hazardous materials on the site, the EPA may be involved in the cleanup. As such, the possibility of dual regulation remains for certain licensees. The present study does not include any costs for this occurrence.

2. DECOMMISSIONING ALTERNATIVES

Detailed cost estimates were developed to decommission Waterford 3 based upon the NRC's approved decommissioning alternatives: DECON and SAFSTOR.

Two decommissioning scenarios were evaluated for the Waterford 3 nuclear unit. The scenarios selected are representative of alternatives available to the owner and are defined as follows:

1. The first scenario assumes that the unit would be promptly decommissioned (DECON alternative) upon the expiration of the current operating license, i.e., 2044.

2. In the second scenario, the nuclear unit is placed into safe-storage (SAFSTOR alternative) at the end of its current operating license. Decommissioning is deferred to the maximum extent such that the license is terminated within the required 60-year period.

The following sections describe the basic activities associated with each alternative. Although detailed procedures for each activity identified are not provided, and the actual sequence of work may vary, the activity descriptions provide a basis not only for estimating but also for the expected scope of work, i.e., engineering and planning at the time of decommissioning.

The conceptual approach that the NRC has described in its regulations divides decommissioning into three phases. The initial phase commences with the effective date of permanent cessation of operations and involves the transition of both plant and licensee from reactor operations (i.e., power production) to facility de-activation and closure. During the first phase, notification is to be provided to the NRC certifying the permanent cessation of operations and the removal of fuel from the reactor vessel. The licensee is then prohibited from reactor operation.

The second phase encompasses activities during the storage period or during major decommissioning activities, or a combination of the two. The third phase pertains to the activities involved in license termination. The decommissioning estimates developed for Waterford 3 are also divided into phases or periods; however, demarcation of the phases is based upon major milestones within the project or significant changes in the projected expenditures.

2.1 DECON

The DECON alternative, as defined by the NRC, is "the alternative in which the equipment, structures, and portions of a facility and site containing radioactive contaminants are removed or decontaminated to a level that permits the property to be released for unrestricted use shortly after cessation of operations." This study does not address the cost to dispose of the spent fuel residing at the site; such costs are funded through a surcharge on electrical generation. However, the study does estimate the costs incurred with the interim on-site storage of the fuel pending shipment by the DOE to an off-site disposal facility.

2.1.1 Period 1 - Preparations

In anticipation of the cessation of plant operations, detailed preparations are undertaken to provide a smooth transition from plant operations to site decommissioning. Through implementation of a staffing transition plan, the organization required to manage the intended decommissioning activities is assembled from available plant staff and outside resources. Preparations include the planning for permanent defueling of the reactor, revision of technical specifications applicable to the operating conditions and requirements, a characterization of the facility and major components, and the development of the PSDAR.

Engineering and Planning

The PSDAR, required prior to or within two years of permanent cessation of operations, provides a description of the licensee's planned decommissioning activities, a timetable, a site-specific decommissioning cost estimate, and the associated financial requirements of the intended decommissioning program. Upon receipt of the PSDAR, the NRC will make the document available to the public for comment in a local hearing to be held in the vicinity of the reactor site. Ninety days following submittal and NRC receipt of the PSDAR, the licensee may begin to perform major decommissioning activities under a modified 10 CFR §50.59 procedure (10 CFR §50.59 establishes the conditions under which licensees may make changes to the facility or procedures and conduct tests or experiments without prior NRC approval). Major activities are defined as any activity that results in permanent removal of major radioactive components, permanently modifies the structure of the containment, or results in dismantling components (for shipment) containing GTCC, as defined by 10 CFR §61.55. Major components are further defined as comprising the reactor vessel and internals, large bore reactor coolant system piping, and other large components that are radioactive. The NRC includes the following additional criteria for use of the §50.59 process in decommissioning. The proposed activity must not:

- foreclose release of the site for possible unrestricted use,
- significantly increase decommissioning costs,
- cause any significant environmental impact, or
- violate the terms of the licensee's existing license

Existing operational technical specifications are reviewed and modified to reflect plant conditions and the safety concerns associated with permanent cessation of operations. The environmental impact associated with the planned decommissioning activities is also considered. Typically, a licensee will not be allowed to proceed if the consequences of a particular decommissioning activity are greater than that bounded by previously evaluated environmental assessments or impact statements. In this instance, the licensee would have to submit a license amendment for the specific activity and update the environmental report.

The decommissioning program outlined in the PSDAR will be designed to accomplish the required tasks within the ALARA guidelines (as defined in 10 CFR Part 20) for protection of personnel from exposure to radiation hazards. It will also address the continued protection of the health and safety of the public and the environment during the dismantling activity. Consequently, with the development of the PSDAR, activity specifications, cost-benefit and safety analyses, work packages, and procedures, would be assembled to support the proposed decontamination and dismantling activities.

<u>Site Preparations</u>

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

- Characterization of the site and surrounding environs. This includes radiation surveys of work areas, major components (including the reactor vessel and its internals), internal piping, and primary shield cores.
- Isolation of the spent fuel storage pool and fuel handling systems, such that decommissioning operations can commence on the balance

of the plant. The pool will remain operational for approximately five and one-half years following the cessation of operations. During this time period, it is assumed that the spent fuel residing in the pool that cannot be directly transferred to the DOE will be moved to an ISFSI for interim storage.

- Specification of transport and disposal requirements for activated materials and/or hazardous materials, including shielding and waste stabilization.
- Development of procedures for occupational exposure control, control and release of liquid and gaseous effluent, processing of radwaste (including dry-active waste, resins, filter media, metallic and non-metallic components generated in decommissioning), site security and emergency programs, and industrial safety.

2.1.2 Period 2 - Decommissioning Operations

This period includes the physical decommissioning activities associated with the removal and disposal of contaminated and activated components and structures, including the successful release of the site from the 10 CFR Part 50 operating license, exclusive of the ISFSI. Significant decommissioning activities in this phase include:

- Construction of temporary facilities and/or modification of existing facilities to support dismantling activities. For example, this will include a centralized processing area to facilitate equipment removal and component preparations for off-site disposal.
- Reconfiguration and modification of site structures and facilities as needed to support decommissioning operations. This will include the upgrading of roads (on- and off-site) as required to facilitate hauling and transport. Modifications will be required to the containment structure to facilitate access of large/heavy equipment. Modifications will also be required to the refueling area of the building to support the segmentation of the reactor vessel internals and component extraction.
- Transfer of the spent fuel from the storage pool to the ISFSI pad.
- Design and fabrication of temporary and permanent shielding to support removal and transportation activities, construction of contamination control envelopes, and the procurement of specialty tooling.

- Procurement (lease or purchase) of shipping canisters, cask liners, and industrial packages.
- Decontamination of components and piping systems as required to control (minimize) worker exposure.
- Removal of piping and components no longer essential to support decommissioning operations.
- Removal of control rod drive housings and the head service structure from reactor vessel head. Segmentation of the vessel closure head.
- Removal and segmentation of the upper internals assemblies. Segmentation will maximize the loading of the shielded transport casks, i.e., by weight and activity. The operations are conducted under water using remotely operated tooling and contamination controls.
- Disassembly and segmentation of the remaining reactor internals, including the core former and lower core support assembly. Some material is expected to exceed Class C disposal requirements. As such, and to the extent required, the segments are packaged in modified fuel storage canisters for geologic disposal.
- Segmentation of the reactor vessel. A shielded platform is installed for segmentation as cutting operations are performed in-air using remotely operated equipment within a contamination control envelope. The water level is maintained just below the cut to minimize the working area dose rates. Segments are transferred in-air to containers that are stored under water, for example, in an isolated area of the refueling canal.
- Removal of the activated portions of the concrete biological shield and accessible contaminated concrete surfaces. If dictated by the steam generator and pressurizer removal scenarios, those portions of the associated cubicles necessary for access and component extraction are removed.
- Removal of the steam generators and pressurizer for material recovery and controlled disposal. The generators will be moved to an on-site processing center, the steam domes removed and the internal components segregated for recycling. The lower shell and tube bundle will be packaged for direct disposal. These components can serve as their own burial containers provided that all penetrations are properly sealed and the internal contaminants are stabilized, e.g., with grout. Steel shielding will be added, as necessary, to those external areas of the package to meet transportation limits and regulations.

At least two years prior to the anticipated date of license termination, an LTP is required. Submitted as a supplement to the Updated Safety Analysis Report (USAR) or its equivalent, the plan must include: a site characterization, description of the remaining dismantling activities, plans for site remediation, procedures for the final radiation survey, designation of the end use of the site, an updated cost estimate to complete the decommissioning, and any associated environmental concerns. The NRC will notice the receipt of the plan, make the plan available for public comment, and schedule a local hearing. LTP approval will be subject to any conditions and limitations as deemed appropriate by the Commission. The licensee may then commence with the final remediation of site facilities and services, including:

- Removal of remaining plant systems and associated components as they become nonessential to the decommissioning program or worker health and safety (e.g., waste collection and treatment systems, electrical power and ventilation systems).
- Removal of the steel liners from refueling canal, disposing of the activated and contaminated sections as radioactive waste. Removal of any activated/ contaminated concrete.
- Surveys of the decontaminated areas of the containment structure.
- Removal of the contaminated equipment and material from the auxiliary and fuel buildings and any other contaminated facility. Use of radiation and contamination control techniques until radiation surveys indicate that the structures can be released for unrestricted access and conventional demolition. This activity may necessitate the dismantling and disposition of most of the systems and components (both clean and contaminated) located within these buildings. This activity will facilitate surface decontamination and subsequent verification surveys required prior to obtaining release for demolition.
- Routing of material removed in the decontamination and dismantling to a central processing area. Material certified to be free of contamination is released for unrestricted disposition, e.g., as scrap, recycle, or general disposal. Contaminated material is characterized and segregated for additional off-site processing (disassembly, chemical cleaning, volume reduction, and waste treatment), and/or packaged for controlled disposal at a low-level radioactive waste disposal facility.

Incorporated into the LTP is the Final Survey Plan. This plan identifies the radiological surveys to be performed once the decontamination activities are completed and is developed using the guidance provided in the "Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)."[22] This document incorporates the statistical approaches to survey design and data interpretation used by the EPA. It also identifies commercially available instrumentation and procedures for conducting radiological surveys. Use of this guidance ensures that the surveys are conducted in a manner that provides a high degree of confidence that applicable NRC criteria are satisfied. Once the survey is complete, the results are provided to the NRC in a format that can be verified. The NRC then reviews and evaluates the information, performs an independent confirmation of radiological site conditions, and makes a determination on the requested change to the operating license (that would release the property, exclusive of the ISFSI, for unrestricted use).

The NRC will amend the operating license if it determines that site remediation has been performed in accordance with the LTP, and that the terminal radiation survey and associated documentation demonstrate that the property (exclusive of the ISFSI) is suitable for release.

2.1.3 Period 3 - Site Restoration

Following completion of decommissioning operations, site restoration activities can begin. Efficient removal of the contaminated materials and verification that residual radionuclide concentrations are below the NRC limits will result in substantial damage to many of the structures. Although performed in a controlled, safe manner, blasting, coring, drilling, scarification (surface removal), and the other decontamination activities will substantially degrade power block structures including the reactor, fuel handling, radioactive waste, solidification facility and condensate polishing buildings. Under certain circumstances, verifying that subsurface radionuclide concentrations meet NRC site release requirements will require removal of grade slabs and lower floors, potentially weakening footings and structural supports. This removal activity will be necessary for those facilities and plant areas where historical records, when available, indicate the potential for radionuclides having been present in the soil, where system failures have been recorded, or where it is required to confirm that subsurface process and drain lines were not breached over the operating life of the station.

It is not currently anticipated that these structures would be repaired and preserved after the radiological contamination is removed. The cost to dismantle site structures, once remediation is complete, with a work force already mobilized on site is more efficient than if the process is deferred.

This cost study presumes that non-essential structures and site facilities, including the GSB, are dismantled as a continuation of the decommissioning activity. Foundations and exterior walls are removed to a nominal depth of three feet below grade. The three-foot depth allows for the placement of gravel for drainage, as well as topsoil, so that vegetation can be established for erosion control. Site areas affected by the dismantling activities are restored and the plant area graded as required to prevent ponding and inhibit the refloating of subsurface materials.

Non-contaminated concrete rubble produced by demolition activities is processed to remove reinforcing steel and miscellaneous embedments. The processed material is then used on site to backfill foundation voids. Excess non-contaminated materials are trucked to an off-site area for disposal as construction debris.

2.1.4 ISFSI Operations and Decommissioning

For purposes only of this estimate, transfer of spent fuel to a DOE repository or interim facility is assumed to be exclusively from the ISFSI once the fuel pool has been emptied and the fuel handling building released for decommissioning. If this assumption is incorrect, it is assumed that DOE will have liability for costs incurred to transfer the fuel to DOE-supplied containers and to dispose of existing containers. The ISFSI will continue to operate under a general license (10 CFR Part 50) following the amendment of the operating license to release the adjacent (power block) property.

Assuming the DOE starts accepting fuel from Waterford 3 in 2037, transfer of spent fuel from the ISFSI is anticipated to continue through the year 2080. This assumption is made for purposes of this estimate, although it is acknowledged that the plant owner will seek the most expeditious means of removing fuel from the site when DOE commences performance.

At the conclusion of the spent fuel transfer process, the ISFSI will be decommissioned. The Commission will terminate the Part 50 license if it determines that the remediation of the ISFSI has been performed in accordance with an ISFSI license termination plan and that the final radiation survey and associated documentation demonstrate that the facility is suitable for release. Once the requirements are satisfied, the NRC can terminate the license for the ISFSI.

The design of the ISFSI is based upon the use of a multi-purpose canister and a vertical concrete module/overpack for pad storage. It is assumed that once the inner canisters containing the spent fuel assemblies have been removed, any required decontamination is performed on the storage modules (some minor neutron activation is assumed), and the license for the facility terminated, the modules can be dismantled using conventional techniques for the demolition of reinforced concrete. The concrete storage pad is then removed and the area regraded to minimize ponding.

2.2 SAFSTOR

The NRC defines SAFSTOR as "the alternative in which the nuclear facility is placed and maintained in a condition that allows the nuclear facility to be safely stored and subsequently decontaminated (deferred decontamination) to levels that permit release for unrestricted use." The facility is left intact (during the dormancy period), with structures maintained in a sound condition. Systems that are not required to support the spent fuel pool or site surveillance and security are drained, de-energized, and secured. Minimal cleaning/removal of loose contamination and/or fixation and sealing of remaining contamination are performed. Access to contaminated areas is secured to provide controlled access for inspection and maintenance.

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

2.2.1 Period 1 - Preparations

Preparations for long-term storage include the planning for permanent defueling of the reactor, revision of technical specifications appropriate to the operating conditions and requirements, a characterization of the facility and major components, and the development of the PSDAR.

The process of placing the plant in safe-storage includes, but is not limited to, the following activities:

- Isolation of the spent fuel storage services and fuel handling systems so that safe-storage operations may commence on the balance of the plant. This activity may be carried out by plant personnel in accordance with existing operating technical specifications. Activities are scheduled around the fuel handling systems to the greatest extent possible.
- Transferring the spent fuel from the storage pool to the DOE or to the ISFSI for interim storage, following the minimum required cooling period in the spent fuel pool.
- Draining and de-energizing of the non-contaminated systems not required to support continued site operations or maintenance.
- Disposing of contaminated filter elements and resin beds not required for processing wastes from layup activities for future operations.
- Draining of the reactor vessel, with the internals left in place and the vessel head secured.
- Draining and de-energizing non-essential, contaminated systems with decontamination as required for future maintenance and inspection.
- Preparing lighting and alarm systems whose continued use is required; de-energizing portions of fire protection, electric power, and HVAC systems whose continued use is not required.
- Cleaning of the loose surface contamination from building access pathways.
- Performing an interim radiation survey of plant, posting warning signs where appropriate.
- Erecting physical barriers and/or securing all access to radioactive or contaminated areas, except as required for inspection and maintenance.
- Installing security and surveillance monitoring equipment and relocating security fence around secured structures, as required.

2.2.2 Period 2 - Dormancy

The second phase identified by the NRC in its rule addresses licensed activities during a storage period and is applicable to the dormancy phases of the deferred decommissioning alternatives. Dormancy activities include a 24-hour security force, preventive and corrective maintenance on security systems, area lighting, general building maintenance, heating and ventilation of buildings, routine radiological inspections of contaminated structures, maintenance of structural integrity, and a site environmental and radiation monitoring program. Resident maintenance personnel perform equipment maintenance, inspection activities, routine services to maintain safe conditions, adequate lighting, heating, and ventilation, and periodic preventive maintenance on essential site services.

An environmental surveillance program is carried out during the dormancy period to ensure that releases of radioactive material to the environment are prevented or detected and controlled. Appropriate emergency procedures are established and initiated for potential releases that exceed prescribed limits. The environmental surveillance program constitutes an abbreviated version of the program in effect during normal plant operations.

Security during the dormancy period is conducted primarily to prevent unauthorized entry and to protect the public from the consequences of its own actions. The security fence, sensors, alarms, and other surveillance equipment are maintained throughout the dormancy period. Fire and radiation alarms are also functional.

Consistent with the DECON scenario, the spent fuel storage pool is emptied within five and one-half years of the cessation of operations. It is assumed that the transfer of the spent fuel from the site to the DOE begins in 2037. The transfer continues throughout the dormancy period until completed in 2080. If the assumption of transfer of fuel from the ISFSI to DOE is incorrect, it is assumed that DOE will have liability for costs incurred to transfer the fuel to DOE-supplied containers. Once emptied, the ISFSI is secured for storage and decommissioned along with the power block structures in Period 4.

After a period of storage (such that license termination is accomplished within 60 years of final shutdown), it is required that the licensee submit an application to terminate the license, along with a LTP (described in Section 2.1.2), thereby initiating the third phase.

2.2.3 Periods 3 and 4 - Delayed Decommissioning

Prior to the commencement of decommissioning operations, preparations are undertaken to reactivate site services and prepare for decommissioning. Preparations include engineering and planning, a detailed site characterization, and the assembly of a decommissioning management organization. Final planning and the assembly of activity specifications and detailed work procedures are also initiated at this time.

Much of the work in developing a termination plan is relevant to the development of the detailed engineering plans and procedures. The activities associated with this phase and the follow-on decontamination and dismantling processes are detailed in Sections 2.1.1 and 2.1.2. The primary difference between the sequences anticipated for the DECON and this deferred scenario is the absence, in the latter, of any constraint on the dismantling process due to the operation of the spent fuel pool in the DECON option.

Variations in the length of the dormancy period are expected to have some effect upon the quantities of radioactive wastes generated from system and structure removal operations. Given the levels of radioactivity and spectrum of radionuclides expected from sixty years of plant operation, no plant process system identified as being contaminated upon final shutdown will become releasable due to the decay period alone. However, due to the lower activity levels, a greater percentage of the waste volume can be designated for off-site processing and recovery.

The delay in decommissioning also yields lower working area radiation levels. As such, the estimate for this delayed scenario incorporates reduced ALARA controls for the SAFSTOR's lower occupational exposure potential.

Although the initial radiation levels due to ^{60}Co will substantially decrease during the dormancy period, the internal components of the reactor vessel will still exhibit sufficiently high radiation dose rates to require remote sectioning under water due to the presence of long-lived radionuclides such as ^{94}Nb, ^{59}Ni, and ^{63}Ni. Therefore, the dismantling procedures described for the DECON alternative would still be employed during this scenario. Portions of the biological shield will still be radioactive due to the presence of activated trace elements with long half-lives (^{152}Eu and ^{154}Eu). Decontamination will require controlled removal and disposal. It is assumed that radioactive corrosion products on inner surfaces of piping and components will not have decayed to levels that will permit unrestricted use or allow conventional removal. These systems and components will be surveyed as they are removed and disposed of in accordance with the existing radioactive release criteria.

2.2.4 Period 5 - Site Restoration

Following completion of decommissioning operations, site-restoration activities begin. Dismantling, as a continuation of the decommissioning process is a cost-effective option, as described in Section 2.1.3. The basis for the dismantling cost is consistent with that described for DECON, presuming the removal of structures and site facilities to a nominal depth of three feet below grade and the limited restoration of the site.

3. COST ESTIMATES

The cost estimates prepared for decommissioning Waterford 3 consider the unique features of the site, including the nuclear steam supply system, electric power generating systems, structures, and supporting facilities. The basis of the estimates, including the sources of information relied upon, the estimating methodology employed, site-specific considerations, and other pertinent assumptions, is described in this section.

3.1 BASIS OF ESTIMATES

The current estimates were developed using the site-specific, technical information relied upon in the decommissioning analysis prepared in 2015. This information was reviewed for the current analysis and updated as deemed appropriate. The site-specific considerations and assumptions used in the previous evaluation were also revisited. Modifications were incorporated where new information was available or experience from ongoing decommissioning programs provided viable alternatives or improved processes.

3.2 METHODOLOGY

The methodology used to develop the estimates follows the basic approach originally presented in the AIF/NESP-036 study report, "Guidelines for Producing Commercial Nuclear Power Plant Decommissioning Cost Estimates,"[23] and the DOE "Decommissioning Handbook."[24] These documents present a unit factor method for estimating decommissioning activity costs, which simplifies the estimating calculations. Unit factors for concrete removal ($/cubic yard), steel removal ($/ton), and cutting costs ($/inch) are developed using local labor rates. The activity-dependent costs are estimated with the item quantities (cubic yards and tons), developed from plant drawings and inventory documents. Removal rates and material costs for the conventional disposition of components and structures rely upon information available in the industry publication, "Building Construction Cost Data," published by RSMeans.[25]

The unit factor method provides a demonstrable basis for establishing reliable cost estimates. The detail provided in the unit factors, including activity duration, labor costs (by craft), and equipment and consumable costs, ensures that essential elements have not been omitted. Appendix A presents the detailed development of a typical unit factor. Appendix B provides the values contained within one set of factors developed for this analysis.

Regulatory Guide 1.184[26] Revision 1, issued in October 2013, describes the methods and procedures that are acceptable to the NRC staff for implementing the requirements that relate to the initial activities and the major phases of the decommissioning process. The costs and schedules presented in this analysis follow the general guidance and sequence in the regulations. The format and content of the estimates is also consistent with the recommendations of Regulatory Guide 1.202,[27] issued February 2005.

This analysis reflects lessons learned from TLG's involvement in the Shippingport Station Decommissioning Project, completed in 1989, as well as the decommissioning of the Cintichem reactor, hot cells, and associated facilities, completed in 1997. In addition, the planning and engineering for the Rancho Seco, Trojan, Yankee Rowe, Big Rock Point, Maine Yankee, Humboldt Bay-3, Oyster Creek, Connecticut Yankee, Crystal River, Vermont Yankee, Fort Calhoun and Pilgrim nuclear units have provided additional insight into the process, the regulatory aspects, and the technical challenges of decommissioning commercial nuclear units.

Work Difficulty Factors

TLG has historically applied work difficulty adjustment factors (WDFs) to account for the inefficiencies in working in a power plant environment. WDFs are assigned to each unique set of unit factors, commensurate with the inefficiencies associated with working in confined, hazardous environments. The ranges used for the WDFs are as follows:

• Access Factor	10% to 20%
• Respiratory Protection Factor	10% to 50%
• Radiation/ALARA Factor	10% to 37%
• Protective Clothing Factor	10% to 30%
• Work Break Factor	8.33%

The factors and their associated range of values were developed in conjunction with the AIF/NESP-036 study. The application of the factors is discussed in more detail in that publication.

Scheduling Program Durations

The unit factors, adjusted by the WDFs as described above, are applied against the inventory of materials to be removed in the radiological controlled areas. The resulting labor-hours, or crew-hours, are used in the development of the decommissioning program schedule, using resource loading and event sequencing considerations. The scheduling of conventional removal and dismantling activities is based upon productivity information available from the "Building Construction Cost Data" publication. In the DECON alternative, dismantling of the fuel handing building systems and decontamination of the spent fuel pool is also dependent upon the timetable for the transfer of the spent fuel assemblies from the pool to the ISFSI.

An activity duration critical path is used to determine the total decommissioning program schedule. The schedule is relied upon in calculating the carrying costs, which include program management, administration, field engineering, equipment rental, and support services such as quality control and security. This systematic approach for assembling decommissioning estimates ensures a high degree of confidence in the reliability of the resulting costs.

3.3 FINANCIAL COMPONENTS OF THE COST MODEL

TLG's proprietary decommissioning cost model, DECCER, produces a number of distinct cost elements. These direct expenditures, however, do not comprise the total cost to accomplish the project goal, i.e., license termination, spent fuel management and site restoration.

3.3.1 Contingency

Inherent in any cost estimate that does not rely on historical data is the inability to specify the precise source of costs imposed by factors such as tool breakage, accidents, illnesses, weather delays, and labor stoppages. In the DECCER cost model, contingency fulfills this role. Contingency is added to each line item to account for costs that are difficult or impossible to develop analytically. Such costs are historically inevitable over the duration of a job of this magnitude; therefore, this cost analysis includes funds to cover these types of expenses.

The activity- and period-dependent costs are combined to develop the total decommissioning cost. A contingency is then applied on a line-item basis, using one or more of the contingency types listed in the AIF/NESP-036 study. "Contingencies" are defined in the American Association of Cost Engineers "Project and Cost Engineers' Handbook"[28] as "specific provision for unforeseeable elements of cost within the defined project scope; particularly important where previous experience relating estimates and actual costs has shown that unforeseeable events which will increase costs are likely to occur." The cost elements in this analysis are based upon ideal conditions and maximum efficiency; therefore, consistent with industry practice, contingency is included. In the AIF/NESP-036 study, the types of unforeseeable events that are likely to occur in decommissioning are discussed and guidelines are provided for a contingency percentage in each category. It should be noted that contingency, as used in this analysis, does not account for price escalation and inflation in the cost of decommissioning over the remaining operating life of the station.

Contingency funds are an integral part of the total cost to complete the decommissioning process. Exclusion of this component puts at risk a successful completion of the intended tasks and, potentially, subsequent related activities. For this study, TLG examined the major activity-related problems (decontamination, segmentation, equipment handling, packaging, transport, and waste disposal) that necessitate a contingency. Individual activity contingencies ranged from 10% to 75%, depending on the degree of difficulty judged to be appropriate from TLG's actual decommissioning experience. The contingency values used in this study are as follows:

- Decontamination 50%
- Contaminated Component Removal 25%
- Contaminated Component Packaging 10%
- Contaminated Component Transport 15%
- Low-Level Radioactive Waste Disposal 25%

- Low-Level Radioactive Waste Processing 15%
- Reactor Segmentation 75%
- NSSS Component Removal 25%
- Reactor Waste Packaging 25%
- Reactor Waste Transport 25%

- Reactor Vessel Component Disposal 50%
- GTCC Disposal 15%
- Non-Radioactive Component Removal 15%
- Heavy Equipment and Tooling 15%
- Supplies 25%

- Engineering 15%
- Energy 15%
- Insurance, Taxes and Fees 10%
- Staffing 15%
- Characterization and Termination Surveys 30%

• Construction	15%
• Spent Fuel Capital Costs (Canisters and Overpacks)	15%
• Spent Fuel Transfer Costs	15%
• Operations and Maintenance Expenses	15%
• ISFSI Decommissioning	25%

The contingency values are applied to the appropriate components of the estimates on a line item basis. A composite value is then reported at the end of each detailed estimate (as provided in Appendix C and D). A contingency of 25% is applied to the subtotal of the ISFSI decommissioning costs.

3.3.2 Financial Risk

In addition to the routine uncertainties addressed by contingency, another cost element that is sometimes necessary to consider when bounding decommissioning costs relates to uncertainty, or risk. Examples can include changes in work scope, pricing, job performance, and other variations that could conceivably, but not necessarily, occur. Consideration is sometimes necessary to generate a level of confidence in the estimate, within a range of probabilities. TLG considers these types of costs under the broad term “financial risk.” Included within the category of financial risk are:

- Transition activities and costs: ancillary expenses associated with reducing the size of the labor force 50% to 80% shortly after the cessation of plant operations, national or company-mandated retraining, and retention incentives for key personnel.
- Delays in approval of the decommissioning plan due to intervention, public participation in local community meetings, legal challenges, and national and local hearings.
- Changes in the project work scope from the baseline estimate, involving the discovery of unexpected levels of contaminants, contamination in places not previously expected, contaminated soil previously undiscovered (either radioactive or hazardous material contamination), variations in plant inventory or configuration not indicated by the as-built drawings.
- Regulatory changes, for example, affecting worker health and safety, site release criteria, waste transportation, and disposal.
- Policy decisions altering national commitments (e.g., in the ability to accommodate certain waste forms for disposition, or in the timetable

for such, or the start and rate of acceptance of spent fuel by the DOE).

- Pricing changes for basic inputs such as labor, energy, materials, and waste disposal.

This cost study does not add any additional costs to the estimate for financial risk, since there is insufficient historical data from which to project future liabilities. Consequently, the areas of uncertainty or risk are revisited periodically and addressed through repeated revisions or updates of the base estimates.

3.4 SITE-SPECIFIC CONSIDERATIONS

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

3.4.1 Spent Fuel Management

The cost to dispose the spent fuel generated from plant operations is not reflected within the estimates to decommission Waterford 3. Ultimate disposition of the spent fuel is within the province of the DOE's Waste Management System, as defined by the Nuclear Waste Policy Act. As such, the disposal cost is financed by a surcharge paid into the DOE's waste fund during operations. On November 19, 2013, the U.S. Court of Appeals for the D.C. Circuit ordered the Secretary of the Department of Energy to suspend collecting annual fees for nuclear waste disposal from nuclear power plant operators until the DOE has conducted a legally adequate fee assessment.

The NRC does, however, requires licensees to establish a program to manage and provide funding for the management of all irradiated fuel at the reactor site until title of the fuel is transferred to the Secretary of Energy. This requirement is prepared for through inclusion of certain high-level waste cost elements within the estimates, as described below.

Completion of the decommissioning process is highly dependent upon the DOE's ability to remove spent fuel from the site. DOE's repository program assumes that spent fuel is accepted for disposal from the nation's commercial nuclear plants in the order (the "queue") in which it was removed from service ("oldest fuel first"). The DOE contracts provide mechanisms for altering the oldest fuel first allocation scheme, including emergency deliveries, exchanges of allocations amongst utilities and the option of providing priority acceptance from permanently shutdown nuclear reactors. Because it is unclear how these mechanisms may operate once DOE begins accepting spent fuel from commercial reactors, this study assumes that DOE will accept spent fuel in an oldest fuel first order. The timing for removal of spent fuel from the site is based upon the DOE's most recently published annual acceptance rates of 400 MTU/year for year 1, 3,800 MTU total for years 2 through 4 and 3,000 MTU/year for year 5 and beyond.[29]

<u>ISFSI</u>

Due to DOE's inability to remove fuel from the site, an ISFSI has been constructed at the site and fuel casks have been emplaced thereon to support continued plant operations.

The ISFSI will be expected to operate throughout decommissioning, and beyond the conclusion of the remediation phase in the DECON decommissioning scenario, until such time that the transfer of spent fuel to the DOE can be completed. Assuming that DOE begins accepting commercial spent fuel from the industry in 2030, Waterford 3 fuel is projected to be removed from the site beginning in 2037. The process is expected to be continue through and beyond the cessation of plant operations. It could be completed by the year 2080, depending upon the shutdown date, although it is acknowledged that the plant owner will seek the most expeditious means of removing fuel from the site when DOE commences performance. The scenario is similar for the SAFSTOR alternative; however, based upon the expected completion date for fuel transfer, the ISFSI will be emptied prior to the commencement of decommissioning operations.

Operation and maintenance costs for the spent fuel pool and the ISFSI are included within the estimates and address the cost for staffing the facility, as well as security, insurance, and licensing fees. The estimates include the costs to purchase, load, and transfer the multi-purpose spent fuel storage canisters (MPCs) from the pool to the DOE and/or ISFSI. Costs are also provided for transfer of the MPCs to the DOE from the ISFSI (although it is acknowledged that this may not occur and that the fuel in the MPCs may have to be repackaged at DOE expense).

Canister Loading and Transfer

The estimates include the cost for the labor and equipment to load and transfer the spent fuel canisters to the DOE and/or the ISFSI from the wet storage pool – based upon HOLTEC's HI-STORM dry storage system (32-assembly capacity MPCs). For estimating purposes, an allowance is used for the cost to transfer the fuel from the ISFSI into the DOE transport cask.

For purposes of this analysis only, it is assumed that DOE will accept already-canistered fuel. (It is recognized that the canisters may not be licensed or licensable for transportation when DOE performs.) If this assumption is incorrect, it is assumed that DOE will have liability for costs incurred to transfer the fuel to DOE-supplied containers.

Operations and Maintenance

The estimates also include the cost of operating and maintaining the spent fuel pool and the ISFSI, respectively. Pool operations are expected to continue approximately five and one half years after the cessation of operations. It is assumed that the five and one-half years provides the necessary cooling period for the final core to meet the dry cask storage vendor's system specifications. ISFSI operating costs are based upon the previously stated assumptions on fuel transfer and DOE performance (in removing the fuel from the site.

ISFSI Decommissioning

In accordance with 10 CFR §72.30, licensees must have a proposed decommissioning plan for the ISFSI site and facilities that includes a cost estimate for the plan. The plan needs to contain sufficient information on the proposed practices and procedures for the decontamination of the ISFSI and for the disposal of residual radioactive materials after all spent fuel, high-level radioactive waste, and reactor-related GTCC waste have been removed.

The dry storage vendor does not expect the concrete casks to have any interior or exterior radioactive surface contamination. Any neutron activation of the steel and concrete is also expected to be extremely small.

However, the decommissioning estimate is based on the premise that some of the concrete casks will contain low levels of neutron-induced residual radioactivity that would necessitate remediation at the time of decommissioning. As an allowance, 7 casks are assumed to be affected, i.e., contain residual radioactivity. The allowance is based upon the number of casks required for the final core off-load (i.e., 217 offloaded assemblies, 32 assemblies per cask) which results in 7 overpacks. It is assumed that these are the final casks offloaded; consequently, they have the least time for radioactive decay of any neutron activation products.

No contamination or activation of the ISFSI pad is assumed. It would be expected that this assumption would be confirmed as a result of good radiological practice of surveying potentially impacted areas after each spent fuel transfer campaign. As such, only verification surveys are included for the pad in the decommissioning estimate. The estimate is limited to costs necessary to terminate the ISFSI's NRC license and meet the §20.1402 criteria for unrestricted use.

In accordance with the specific requirements of 10 CFR §72.30 for the ISFSI work scope, the cost estimate for decommissioning the ISFSI reflects: 1) the cost of an independent contractor performing the decommissioning activities; 2) an adequate contingency factor; and 3) the cost of meeting the criteria for unrestricted use. The cost summary for decommissioning the ISFSI is presented in Appendix E.

<u>GTCC</u>

The dismantling of the reactor internals is expected to generate radioactive waste considered unsuitable for shallow land disposal (i.e., low-level radioactive waste with concentrations of radionuclides that exceed the limits established by the NRC for Class C radioactive waste (GTCC)). The Low-Level Radioactive Waste Policy Amendments Act of 1985 assigned the federal government the responsibility for the disposal of this material. The Act also stated that the beneficiaries of the activities resulting in the generation of such radioactive waste bear all reasonable costs of disposing of such waste. Although the DOE is responsible for disposing of GTCC waste, any costs for that service have not been determined. For purposes of this estimate, the GTCC radioactive waste has been assumed to be packaged in the same canisters used to store spent fuel and disposed of as high-level waste, at a cost equivalent to that envisioned for the spent fuel. The number of canisters required and the packaged volume for GTCC was based upon experience at Maine Yankee (e.g., the constraints on loading as identified in the canister's certificate of compliance).

It is assumed only for purposes of these estimates that the DOE would not accept this waste prior to completing the transfer of spent fuel. Therefore, until such time as the DOE is ready to accept GTCC waste, it is assumed that this material would remain in storage at the Waterford 3 site (for the DECON alternative). In the SAFSTOR scenario, the GTCC material is shipped directly to a DOE facility as it is generated since the fuel has been removed from the site prior to the start of decommissioning. It is acknowledged, however, that the plant owners will seek the most expeditious means of removing GTCC from the site when DOE commences performance.

3.4.2 Reactor Vessel and Internal Components

The reactor pressure vessel and internal components are segmented for disposal in shielded, reusable transportation casks. Segmentation is performed in the refueling canal, where a turntable and remote cutter are installed. The vessel is segmented in place, using a mast-mounted cutter supported off the lower head and directed from a shielded work platform installed overhead in the reactor cavity. Transportation cask specifications and transportation regulations dictate the segmentation and packaging methodology.

Intact disposal of reactor vessel shells has been successfully demonstrated at several of the sites that have been decommissioned. Access to navigable waterways has allowed these large packages to be transported to the Barnwell disposal site with minimal overland travel. Intact disposal of the reactor vessel and internal components can provide savings in cost and worker exposure by eliminating the complex segmentation requirements, isolation of the GTCC material, and transport/storage of the resulting waste packages. Portland General Electric (PGE) was able to dispose of the Trojan reactor as an intact package (including the internals). However, its location on the Columbia River simplified the transportation analysis since:

- the reactor package could be secured to the transport vehicle for the entire journey, i.e., the package was not lifted during transport,
- there were no man-made or natural terrain features between the plant site and the disposal location that could produce a large drop, and
- transport speeds were very low, limited by the overland transport vehicle and the river barge.

As a member of the Northwest Compact, PGE had a site available for disposal of the package - the US Ecology facility in Washington State. The characteristics of this arid site proved favorable in demonstrating compliance with land disposal regulations.

It is not known whether this option will be available when the Waterford 3 plant ceases operation. Future viability of this option will depend upon the ultimate location of the disposal site, as well as the disposal site licensee's ability to accept highly radioactive packages and effectively isolate them from the environment. Consequently, the study assumes that the reactor vessel will require segmentation, as a bounding condition.

3.4.3 Primary System Components

In the DECON scenario, the reactor coolant system components are assumed to be decontaminated using chemical agents prior to the start of dismantling operations. This type of decontamination can be expected to have a significant ALARA impact, since in this scenario the removal work is done within the first few years of shutdown. A decontamination factor (average reduction) of 10 is assumed for the process. Disposal of the decontamination solution effluent is included within the estimate as a "process liquid waste" charge. In the SAFSTOR scenario, radionuclide decay is expected to provide the same benefit and, therefore, a chemical decontamination is not included.

The following discussion deals with the removal and disposition of the steam generators, but the techniques involved are also applicable to other large components, such as heat exchangers, component coolers, and the pressurizer. The steam generators' size and weight, as well as their location within the reactor building, will ultimately determine the removal strategy.

A trolley crane is set up for the removal of the generators. It can also be used to move portions of the steam generator cubicle walls and floor slabs from the reactor building to a location where they can be decontaminated and transported to the material handling area. Interferences within the work area, such as grating, piping, and other components are removed to create sufficient laydown space for processing these large components.

The generators are rigged for removal, disconnected from the surrounding piping and supports, and maneuvered into the open area where they are lowered onto a dolly. Each generator is rotated into the horizontal position for extraction from the containment and placed onto a multi-wheeled vehicle for transport to an on-site processing and storage area.

The generators are disassembled on-site with the outer shell and lightly contaminated subassemblies designated for off-site recycling. The more highly contaminated tube sheet and tube bundle are packaged for direct disposal.

Disposal costs are based upon the displaced volume and weight of the units. Each component is then loaded onto a rail car for transport to the disposal facility.

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

3.4.4 Main Turbine and Condenser

The main turbine is dismantled using conventional maintenance procedures. The turbine rotors and shafts are removed to a laydown area. The lower turbine casings are removed from their anchors by controlled demolition. The main condensers are also disassembled and moved to a laydown area. Material is then prepared for transportation to an off-site recycling facility where it is surveyed and designated for either decontamination or volume reduction, conventional disposal, or controlled disposal. Components are packaged and readied for transport in accordance with the intended disposition.

3.4.5 Retired Components

The estimates include the disposition of two retired steam generators and a reactor vessel closure head.

3.4.6 Transportation Methods

Contaminated piping, components, and structural material other than the highly activated reactor vessel and internal components will qualify as LSA-I, II or III or Surface Contaminated Object, SCO-I or II, as described in Title 49.[30] The contaminated material will be packaged in Industrial Packages (IP-1, IP-2, or IP-3, as defined in subpart 10 CFR §173.411) for transport unless demonstrated to qualify as their own shipping containers. The reactor vessel and internal components are expected to be transported in accordance with 10 CFR Part 71, in Type B containers. It is conceivable that the reactor, due to its limited specific activity, could qualify as LSA II or III. However, the high radiation levels on the outer surface would require that additional shielding be incorporated within the packaging so as to attenuate the dose to levels acceptable for transport.

Any fuel cladding failure that occurred during the lifetime of the plant is assumed to have released fission products at sufficiently low levels that the buildup of quantities of long-lived isotopes (e.g., ^{137}Cs, ^{90}Sr, or transuranics) has been prevented from reaching levels exceeding those that permit the major reactor components to be shipped under current transportation regulations and disposal requirements.

Transport of the highly activated metal, produced in the segmentation of the reactor vessel and internal components, will be by shielded truck cask. Cask shipments may exceed 95,000 pounds, including vessel segment(s), supplementary shielding, cask tie-downs, and tractor-trailer. The maximum level of activity per shipment assumed permissible was based upon the license limits of the available shielded transport casks. The segmentation scheme for the vessel and internal segments is designed to meet these limits.

The transport of large intact components (e.g., large heat exchangers and other oversized components) will be by a combination of truck, rail, and/or multi-wheeled transporter.

Transportation costs for Class A radioactive material requiring controlled disposal are based upon the route and mileage to the Energy*Solutions* facility in Clive, Utah. Transportation costs for the higher activity Class B and C radioactive material are based upon the route and mileage to the WCS facility in Andrews County, Texas. Transportation cost for the GTCC material is assumed to be included within the disposal charge. Transportation costs for off-site waste processing are based upon the route and mileage to Oak Ridge, Tennessee. Truck transport costs were developed from published tariffs from Tri-State Motor Transit.[31]

3.4.7 Low-Level Radioactive Waste Disposal

To the greatest extent practical, metallic material generated in the decontamination and dismantling processes is processed to reduce the total cost of controlled disposal. Material meeting the regulatory and/or site release criterion, is released as scrap, requiring no further cost consideration. Conditioning (preparing the material to meet the waste acceptance criteria of the disposal site) and recovery of the waste stream is performed off site at a licensed processing center. Any material leaving the site is subject to a survey and release charge, at a minimum.

The mass of radioactive waste generated during the various decommissioning activities at the site is shown on a line-item basis in the detailed Appendices C and D, and summarized in Section 5. The quantified waste summaries shown in these tables are consistent with 10 CFR Part 61 classifications. Commercially available steel containers are presumed to be used for the disposal of piping, small components, and concrete. Larger components can serve as their own containers, with proper closure of all openings, access ways, and penetrations. The volumes are calculated based on the exterior package dimensions for containerized material or a specific calculation for components serving as their own waste containers.

The more highly activated reactor components will be shipped in reusable, shielded truck casks with disposable liners. In calculating disposal costs, the burial fees are applied against the liner volume, as well as the special handling requirements of the payload. Packaging efficiencies are lower for the highly activated materials (greater than Class A waste), where high concentrations of gamma-emitting radionuclides limit the capacity of the shipping canisters.

The cost to dispose of the lowest level waste and the majority of the material generated from the decontamination and dismantling activities is based upon the current cost for disposal at Energy*Solutions* facility in Clive, Utah. Disposal costs for the higher activity waste (Class B and C) were based upon Entergy's current agreement with WCS for the Andrews County facility.

3.4.8 Site Conditions Following Decommissioning

The NRC will amend or terminate the site license if it determines that site remediation has been performed in accordance with the license termination plan, and that the terminal radiation survey and associated documentation demonstrate that the facility is suitable for release. The NRC's involvement in the decommissioning process will end at this point. Building codes and environmental regulations will dictate the next step in the decommissioning process, as well as owner's own future plans for the site.

A significant amount of the below grade piping is located around the perimeter of the power block. The estimate includes a cost to excavate this area to an average depth of four feet so as to expose the piping, duct bank, conduit, and any near-surface grounding grid. The overburden is surveyed and stockpiled on site for future use in backfilling the below grade voids.

Only existing site structures are considered in the dismantling cost. The electrical switchyard remains after Waterford 3 is decommissioned in support of the regional transmission and distribution system. Structures, including the GSB, are removed to a nominal depth of three feet below grade. The voids are backfilled with clean debris and capped with soil. The site is then re-graded to conform to the adjacent landscape. Vegetation is established to inhibit erosion. These "non-radiological costs" are included in the total cost of decommissioning.

Concrete rubble generated from demolition activities is processed and made available as clean fill for the power block foundations. Excess construction debris is trucked off site as an alternative to onsite disposal. The excavations will be regraded such that the power block area will have a final contour consistent with adjacent surroundings.

The estimates do not assume the remediation of any significant volume of contaminated soil. Costs are included, however, for the remediation of the firing range, i.e., removal of soil containing lead residue.

3.5 ASSUMPTIONS

The following are the major assumptions made in the development of the estimates for decommissioning the site.

3.5.1 Estimating Basis

Decommissioning costs are reported in the year of projected expenditure; however, the values are provided in 2019 dollars. Costs are not inflated, escalated, or discounted over the periods of performance.

The estimates rely upon the physical plant inventory that was the basis for the 2015 analysis.

The study follows the principles of ALARA through the use of work duration adjustment factors. These factors address the impact of activities such as radiological protection instruction, mock-up training, and the use of respiratory protection and protective clothing. The factors lengthen a task's duration, increasing costs and lengthening the overall schedule. ALARA planning is considered in the costs for engineering and planning, and in the development of activity specifications and detailed procedures. Changes to worker exposure limits may impact the decommissioning cost and project schedule.

3.5.2 Labor Costs

Entergy will engage a Decommissioning Operations Contractor (DOC) to manage the decommissioning. The DOC will provide field level planning and supervision of the work force.

Entergy will provide site security, radiological health and safety, quality assurance and overall site administration during the decommissioning and demolition phases. Contract personnel will provide engineering services, e.g., for preparing the activity specifications, work procedures, activation, and structural analyses, under the direction of Entergy.

Reduction in the operating organization is assumed to be handled through normal company human resource practices (e.g., reassignment and outplacement). An allowance is included for severance, however, the severance is intended for the decommissioning organization only (i.e., not for reduction in the plant operating staff that is not retained for decommissioning. Severance for the non-essential (to decommissioning) operations personnel is typically considered to be an operating expense).

Personnel costs are based upon average salary information provided by Entergy. Overhead costs are included for site and corporate support, reduced commensurate with the staffing of the project.

The craft labor required to decontaminate and dismantle the nuclear plant is acquired through standard site contracting practices. The current cost of labor at the site is used as an estimating basis.

This estimate includes additional plant staffing resources to support the engineering, planning, and licensing efforts for the station, prior to the cessation of operations (a nominal one year in duration). Costs for an external Nuclear Decommissioning Organization (NDO) for project oversight are also included, as well as costs for external support contractors and consultants.

A profile of the staffing levels for decommissioning, including contractors and craft, is provided in Figures 3.1 and 3.2 for the two alternatives. Utility staffing levels will gradually decrease after completing the removal of physical systems. Staffing levels and management support will vary based upon the amount and type of decommissioning work. Craft manpower levels decrease after systems removal and structures decontamination and drop substantially during the license termination survey period. However, craft levels increase again during the site restoration period due to the work associated with structures demolition.

Security, while reduced from operating levels, is maintained throughout the decommissioning for access control, material control, and to safeguard the spent fuel (in accordance with the requirements of 10 CFR Part 37, Part 72, and Part 73). Security costs include provisions for institutional overtime and recurring expenses while the pool is still operational. Once the fuel has been transferred to the DOE in 2080, the security organization will be reduced to Part 37 requirements.

3.5.3 Design Conditions

Any fuel cladding failure that occurred during the lifetime of the plant is assumed to have released fission products at sufficiently low levels that the buildup of quantities of long-lived isotopes (e.g., ^{137}Cs, ^{90}Sr, or transuranics) has been prevented from reaching levels exceeding those that permit the major NSSS components to be shipped under current transportation regulations and disposal requirements.

The curie contents of the vessel and internals at final shutdown are derived from those listed in NUREG/CR-3474.[32] Actual estimates are derived from the curie/gram values contained therein and adjusted for the different mass of the Waterford 3 components, projected operating life, and different periods of decay. Additional short-lived isotopes were derived from NUREG/CR-0130[33] and NUREG/CR-0672,[34] and benchmarked to the long-lived values from NUREG/CR-3474.

It is anticipated that there will be 352 five-fingered control element assemblies (CEAs) in the spent fuel pool at the cessation of operations (including the 87 CEAs from the final core). This analysis assumes that the CEAs can be disposed of along with the spent fuel at no additional cost (in accordance with Appendix E of the Standard Contract).

There are four additional four-fingered CEAs that cannot be reinserted into the fuel assemblies. These units will be included along with the other legacy waste stored in the spent fuel pool and designated for disposal at the WCS site.

Neutron activation of the containment building structure is assumed to be confined to the biological shield.

3.5.4 General

Transition Activities

Existing warehouses are cleared of non-essential material and remain for use by Entergy and its subcontractors. The warehouses are removed once they are no longer needed. The plant's operating staff performs the following activities at no additional cost or credit to the project during the transition period:

- Drain and collect fuel oils, lubricating oils, and transformer oils for recycle and/or sale.
- Drain and collect acids, caustics, and other chemical stores for recycle and/or sale.
- Process operating waste inventories. Disposal of operating wastes (e.g., filtration media, resins) during this initial period is not considered a decommissioning expense; however, the estimates do include the disposition of a small volume of material currently being stored in the spent fuel pool (as described in Section 5).

Scrap and Salvage

The existing plant equipment is considered obsolete and suitable for scrap as deadweight quantities only. Entergy will make economically reasonable efforts to salvage equipment following final plant shutdown. However, dismantling techniques assumed by TLG for equipment in this analysis are not consistent with removal techniques required for salvage (resale) of equipment. Experience has indicated that some buyers wanted equipment stripped down to very specific requirements before they would consider purchase. This required expensive rework after the equipment had been removed from its installed location. Since placing a salvage value on this machinery and equipment would be speculative, and the value would be small in comparison to the overall decommissioning expenses, this analysis does not attempt to quantify the value that an owner may realize based upon those efforts.

It is assumed, for purposes of this analysis, that any value received from the sale of scrap generated in the dismantling process would be more than offset by the on-site processing costs. The dismantling techniques assumed in the decommissioning estimates do not include the additional cost for size reduction and preparation to meet "furnace ready" conditions. For example, the recovery of copper from electrical cabling may require the removal and disposition of any contaminated insulation, an added expense. With a volatile market, the potential profit margin in scrap recovery is highly speculative, regardless of the ability to free release this material. This assumption is an implicit recognition of scrap value in the disposal of clean metallic waste at no additional cost to the project.

Furniture, tools, mobile equipment such as forklifts, trucks, bulldozers, and other property is removed at no cost or credit to the decommissioning project. Disposition may include relocation to other facilities. Spare parts are also made available for alternative use.

Energy

For estimating purposes, the plant is assumed to be de-energized, with the exception of those facilities associated with spent fuel storage. Replacement power costs are used to calculate the cost of energy consumed during decommissioning for tooling, lighting, ventilation, and essential services.

Emergency Planning

FEMA and state fees associated with emergency planning are assumed to continue for approximately 18 months following the cessation of operations. At this time, the fees are discontinued. The timing is based upon the anticipated condition of the spent fuel (i.e., the hottest spent fuel assemblies are assumed to be cool enough that no substantial Zircaloy oxidation and off-site event would occur with the loss of spent fuel pool water). Local fees continue until all fuel has been moved from the pool into dry storage (approximately five and one-half years following the cessation of operations).

Insurance

Costs for continuing coverage (nuclear liability and property insurance) following cessation of plant operations and during decommissioning are included and based upon current operating premiums. Reductions in premiums, throughout the decommissioning process, are based upon the guidance provided in NRC's Regulatory Basis Document, "Regulatory Improvements for Power Reactors Transitioning to Decommissioning."[35] The NRC's financial protection requirements are based on various reactor (and spent fuel) configurations.

Taxes

Property taxes are included within the estimates. However, the tax is based upon the land, without any consideration of any ongoing site operations and property assets.

Site Modifications

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

3.6 COST ESTIMATE SUMMARY

Schedules of expenditures are provided in Tables 3.1 and 3.2. The tables delineate the cost contributors by year of expenditures as well as cost contributor (e.g., labor, materials, and waste disposal).

The tables in Appendices C and D provide additional detail. The cost elements in these tables are assigned to one of three subcategories: "License Termination," "Spent Fuel Management," and "Site Restoration." The subcategory "License Termination" is used to accumulate costs that are consistent with "decommissioning" as defined by the NRC in its financial assurance regulations (i.e., 10 CFR §50.75). The cost reported for this subcategory is generally sufficient to terminate the plant's operating license, recognizing that there may be some additional cost impact from spent fuel management. Costs are included for approximately one year prior to the permanent cessation of operations for pre-planning and decommissioning preparations. The License Termination cost subcategory also includes costs to decommission the ISFSI (as required by 10 CFR §72.30). The basis for the ISFSI decommissioning cost that is included in both Appendices C and D is provided in Appendix E.

The “Spent Fuel Management” subcategory contains costs associated with the containerization and transfer of spent fuel from the wet storage pool to the DOE and/or ISFSI for interim storage, as well as the transfer of the spent fuel in storage at the ISFSI to the DOE. Costs are also included for the operations of the pool and management of the ISFSI until such time that the transfer of all fuel from this facility to an off-site location (e.g., interim storage facility) is complete.

“Site Restoration” is used to capture costs associated with the dismantling and demolition of buildings and facilities demonstrated to be free from contamination. This includes structures never exposed to radioactive materials, as well as those facilities that have been decontaminated to appropriate levels. Structures are removed to a depth of three feet and backfilled.

As discussed in Section 3.4.1, it is assumed that the DOE will not accept the GTCC waste prior to completing the transfer of spent fuel. Therefore, the cost of GTCC disposal is shown in the final year of ISFSI operation (for the DECON alternative). While designated for disposal at a federal facility along with the spent fuel, GTCC waste is still classified as low-level radioactive waste and, as such, included as a “License Termination” expense.

Decommissioning costs are reported in 2019 dollars. Costs are not inflated, escalated, or discounted over the period of expenditure (or projected lifetime of the plant). The schedules are based upon the detailed activity costs reported in Appendices C and D, along with the timelines presented in Section 4.

TABLE 3.1
DECON ALTERNATIVE
TOTAL ANNUAL EXPENDITURES
(thousands, 2019 dollars)

Year	Labor	Equipment & Materials	Energy	Burial	Other	Total
2043	170	0	0	0	495	665
2044	7,592	143	66	1	14,552	22,354
2045	78,715	4,745	1,780	589	31,114	116,943
2046	93,197	41,624	2,467	25,456	37,356	200,100
2047	88,112	51,606	1,629	35,098	23,247	199,692
2048	81,006	32,517	1,373	19,538	20,507	154,942
2049	78,430	26,267	1,286	14,469	19,553	140,005
2050	62,307	17,494	912	10,770	13,412	104,895
2051	35,281	6,682	273	18	4,191	46,445
2052	24,611	11,628	172	0	3,871	40,282
2053	12,341	4,834	64	0	2,691	19,930
2054	4,992	511	0	0	1,997	7,499
2055	4,992	511	0	0	1,997	7,499
2056	5,005	510	0	0	2,002	7,518
2057	4,992	511	0	0	1,997	7,499
2058	4,992	511	0	0	1,997	7,499
2059	4,992	511	0	0	1,997	7,499
2060	5,005	510	0	0	2,002	7,518
2061	4,992	511	0	0	1,997	7,499
2062	4,992	511	0	0	1,997	7,499
2063	4,992	511	0	0	1,997	7,499
2064	5,005	510	0	0	2,002	7,518
2065	4,992	511	0	0	1,997	7,499
2066	4,992	511	0	0	1,997	7,499
2067	4,992	511	0	0	1,997	7,499
2068	5,005	510	0	0	2,002	7,518
2069	4,992	511	0	0	1,997	7,499
2070	4,934	338	0	0	1,997	7,269
2071	4,992	511	0	0	1,997	7,499
2072	5,005	510	0	0	2,002	7,518
2073	4,992	511	0	0	1,997	7,499

TABLE 3.1 (continued)
DECON ALTERNATIVE
TOTAL ANNUAL EXPENDITURES
(thousands, 2019 dollars)

Year	Labor	Equipment & Materials	Energy	Burial	Other	Total
2074	4,992	511	0	0	1,997	7,499
2075	4,934	338	0	0	1,997	7,269
2076	5,005	510	0	0	2,002	7,518
2077	4,992	511	0	0	1,997	7,499
2078	4,992	511	0	0	1,997	7,499
2079	4,992	511	0	0	1,997	7,499
2080	5,005	2,011	0	0	16,117	23,133
2081	3,933	1,432	90	2,929	5,097	13,480
Total	700,448	213,912	10,111	108,868	244,150	1,277,489

TABLE 3.1a
DECON ALTERNATIVE
LICENSE TERMINATION EXPENDITURES
(thousands, 2019 dollars)

Year	Labor	Equipment & Materials	Energy	Burial	Other	Total
2043	170	0	0	0	495	665
2044	7,539	75	66	1	14,457	22,138
2045	77,177	2,623	1,780	589	28,630	110,800
2046	86,464	25,276	2,467	25,456	35,177	174,840
2047	80,496	30,382	1,629	35,098	21,335	168,940
2048	73,676	14,356	1,373	19,538	18,590	127,533
2049	71,219	9,155	1,286	14,469	17,641	113,769
2050	55,641	7,356	912	10,770	12,373	87,053
2051	22,234	1,114	204	18	2,460	26,029
2052	151	0	0	0	0	151
2053	56	0	0	0	0	56
2054-79	0	0	0	0	0	0
2080	185	1,500	0	0	14,178	15,863
2081	744	224	62	2,929	4,424	8,382
Total	475,752	92,062	9,778	108,868	169,758	856,219

TABLE 3.1b
DECON ALTERNATIVE
SPENT FUEL MANAGEMENT EXPENDITURES
(thousands, 2019 dollars)

Year	Labor	Equipment & Materials	Energy	Burial	Other	Total
2043	0	0	0	0	0	0
2044	23	68	0	0	95	186
2045	707	2,121	0	0	2,484	5,313
2046	5,442	16,325	0	0	2,178	23,945
2047	7,060	21,179	0	0	1,912	30,151
2048	6,033	18,098	0	0	1,917	26,048
2049	5,681	17,042	0	0	1,912	24,635
2050	5,957	10,105	0	0	1,039	17,101
2051	5,178	1,076	0	0	838	7,092
2052	5,000	518	0	0	1,662	7,180
2053	5,054	706	0	0	1,870	7,630
2054	4,992	511	0	0	1,997	7,499
2055	4,992	511	0	0	1,997	7,499
2056	5,005	510	0	0	2,002	7,518
2057	4,992	511	0	0	1,997	7,499
2058	4,992	511	0	0	1,997	7,499
2059	4,992	511	0	0	1,997	7,499
2060	5,005	510	0	0	2,002	7,518
2061	4,992	511	0	0	1,997	7,499
2062	4,992	511	0	0	1,997	7,499
2063	4,992	511	0	0	1,997	7,499
2064	5,005	510	0	0	2,002	7,518
2065	4,992	511	0	0	1,997	7,499
2066	4,992	511	0	0	1,997	7,499
2067	4,992	511	0	0	1,997	7,499
2068	5,005	510	0	0	2,002	7,518
2069	4,992	511	0	0	1,997	7,499
2070	4,934	338	0	0	1,997	7,269
2071	4,992	511	0	0	1,997	7,499
2072	5,005	510	0	0	2,002	7,518
2073	4,992	511	0	0	1,997	7,499

TABLE 3.1b (continued)
DECON ALTERNATIVE
SPENT FUEL MANAGEMENT EXPENDITURES
(thousands, 2019 dollars)

Year	Labor	Equipment & Materials	Energy	Burial	Other	Total
2074	4,992	511	0	0	1,997	7,499
2075	4,934	338	0	0	1,997	7,269
2076	5,005	510	0	0	2,002	7,518
2077	4,992	511	0	0	1,997	7,499
2078	4,992	511	0	0	1,997	7,499
2079	4,992	511	0	0	1,997	7,499
2080	4,820	511	0	0	1,939	7,270
2081	0	0	0	0	0	0
Total	180,701	100,677	0	0	69,795	351,173

TABLE 3.1c
DECON ALTERNATIVE
SITE RESTORATION EXPENDITURES
(thousands, 2019 dollars)

Year	Labor	Equipment & Materials	Energy	Burial	Other	Total
2043	0	0	0	0	0	0
2044	30	0	0	0	0	30
2045	830	0	0	0	0	830
2046	1,292	24	0	0	0	1,315
2047	555	45	0	0	0	600
2048	1,298	64	0	0	0	1,361
2049	1,531	70	0	0	0	1,601
2050	709	32	0	0	0	741
2051	7,869	4,493	70	0	893	13,324
2052	19,460	11,110	172	0	2,209	32,951
2053	7,231	4,128	64	0	821	12,244
2054-80	0	0	0	0	0	0
2081	3,190	1,208	28	0	673	5,099
Total	43,994	21,173	333	0	4,597	70,097