5.11 Impacts of Transportation of Radioactive Materials

Transport of radioactive materials is an important activity associated with operating STP 3 & 4 at the STP site. The analysis in this section is based on the ~~ABWR~~ Advanced Boiling Water Reactor (ABWR) characteristics described in Section 3.2 and radioactive waste management systems described in Section 3.5. Information regarding preparation and packaging of the radioactive materials for transport offsite can be found in Section 3.8.

5.11.1 Transportation Assessment

The NRC regulations in 10 CFR 51.52 state that:

> "Every environmental report prepared for the construction permit stage of a light-water-cooled nuclear power reactor, and submitted after February 4, 1975, shall contain a statement concerning transportation of fuel and radioactive wastes to and from the reactor. That statement shall indicate that the reactor and this transportation either meet all of the conditions in paragraph (a) of this section or all of the conditions in paragraph (b) of this section."

NRC evaluated the environmental effects of transportation of fuel and waste for ~~LWRs~~ Light Water Reactors (LWR) in "Environmental Survey of Transportation of Radioactive Materials to and From Nuclear Power Plants," (WASH-1238, Reference 5.11-1) and Supplement 1 (NUREG-75/038, Reference 5.11-2) and found the impacts to be SMALL. These NRC analyses provided the basis for Table S-4 in 10 CFR 51.52 (see Table 5.11-1), which summarizes the environmental impacts of transportation of fuel and radioactive wastes to and from a reference reactor. The table addresses two categories of environmental considerations: (1) normal conditions of transport and (2) accidents in transport.

To analyze the impacts of transporting ABWR fuel and radioactive waste for comparison to Table S-4, the characteristics for the ABWR were normalized to a reference reactor-year. The reference reactor is an 1100 MWe reactor that has an 80% capacity factor, for an electrical output of 880 MWe. The advanced LWR technology being considered for the STP site is the ABWR. The proposed configuration for the new plant is two units. The standard configuration (a single unit) for the ABWR will be used to evaluate transportation impacts relative to the reference reactor.

Subparagraphs 10 CFR 51.52(a)(1) through (5) delineate specific conditions the reactor licensee must meet to use Table S-4 as part of its environmental report. Reactors not meeting all of the conditions in paragraph (a) of 10 CFR 51.52, paragraph (b) of 10 CFR 51.52 requires a further analysis of the transportation effects.

The conditions in paragraph (a) of 10 CFR 51.52 establishing the applicability of Table S-4 are reactor core thermal power, fuel form, fuel enrichment, fuel encapsulation, average fuel irradiation, time after discharge of irradiated fuel before shipment, mode of transport for unirradiated fuel, mode of transport for irradiated fuel, radioactive waste form and packaging, and mode of transport for radioactive waste other than irradiated fuel. The following subsections describe the characteristics of the ABWR relative to the conditions of 10 CFR 51.52 for use of Table S-4.

5.11.1.1 Reactor Core Thermal Power

Subparagraph 10 CFR 51.52(a)(1) requires that the reactor have a core thermal power level not exceeding 3800 megawatts. The reference ABWR has a thermal power rating of 3926 MWt (Reference 5.11-3) and exceeds this condition.

The core power level was established as a condition because, for the LWRs being licensed when Table S-4 was promulgated, higher power levels typically indicated the need for more fuel and therefore more fuel shipments than were evaluated for Table S-4. This is not the case for the new LWR designs due to the higher unit capacity and higher burnup for these reactors. The annual fuel reloading for the reference reactor analyzed in WASH-1238 was 30 metric tons of uranium (MTU). The annual fuel loading for the ABWR is approximately 42 MTU. When normalized to equivalent electric output, the annual fuel requirement for the ABWR is approximately 29 MTU, roughly equal to that of the reference LWR.

5.11.1.2 Fuel Form

Subparagraph 10 CFR 51.52(a)(2) requires that the reactor fuel be in the form of sintered uranium dioxide (UO2) pellets. The reference ABWR uses a sintered UO2 pellet fuel form (Reference 5.11-3) and meets this condition.

5.11.1.3 Fuel Enrichment

Subparagraph 10 CFR 51.52(a)(2) requires that the reactor fuel have a U-235 enrichment not exceeding four percent by weight. For the ABWR, the enrichment of the initial core averages approximately 2.2% (Reference 5.11-3) and the average for reloads is approximately 3.2%. The ABWR fuel meets the four percent U-235 condition.

5.11.1.4 Fuel Encapsulation

Subparagraph 10 CFR 51.52(a)(2) requires that the reactor fuel pellets be encapsulated in Zircaloy rods. The ABWR fuel uses Zircaloy-2 cladding (Reference 5.11-3) and meets this condition.

5.11.1.5 Average Fuel Irradiation

Subparagraph 10 CFR 51.52(a)(3) requires that the average burnup not exceed 33,000 MW-days per MTU. The average burnup is 32,300 MW-days per MTU for the ABWR, which meets this condition.

5.11.1.6 Time after Discharge of Irradiated Fuel before Shipment

Subparagraph 10 CFR 51.52(a)(3) requires that no irradiated fuel assembly be shipped until at least 90 days after it is discharged from the reactor. The WASH-1238 analysis for Table S-4 assumes 150 days of decay time before shipment of any irradiated fuel assemblies. NUREG/CR-6703 (Reference 5.11-4), which updated this analysis to extend Table S-4 to burnups of up to 62,000 MW-days per MTU, assumes a minimum of five years between removal from the reactor and shipment. Five years is the minimum decay time expected before shipment of irradiated fuel assemblies. The U.S. Department of Energy's (DOE's) contract for acceptance of spent fuel, as set forth in 10 CFR 961, Appendix E, requires a five-year minimum cooling time. In addition, NRC specifies five years as the minimum cooling period when it issues certificates of compliance for casks used for shipment of power reactor fuel (Reference 5.11-5). As described in Section 3.5, the ABWR units will have storage capacity exceeding that needed to accommodate five-year cooling of irradiated fuel prior to transport off site. The ABWR meets the minimum 90-day storage condition.

5.11.1.7 Radioactive Waste Form and Packaging

Subparagraph 10 CFR 51.52(a)(4) requires that, with the exception of spent fuel, radioactive waste shipped from the reactor be packaged and in a solid form. As described in Subsection 3.5.4, STPNOC will process to a solid form, if required, and package the radioactive waste generated by the ABWR. STPNOC will comply with NRC (10 CFR 71) and DOT (49 CFR 173 and 178) packaging and transportation regulations for the shipment of radioactive material. Therefore, the ABWR meets this condition.

5.11.1.8 Transportation of Unirradiated Fuel

Subparagraph 10 CFR 51.52(a)(5) requires that unirradiated fuel be shipped to the reactor site by truck. Fuel is currently transported to STP 1 & 2 by truck. STPNOC will receive fuel via truck shipments for STP 3 & 4.

Table S-4 includes a condition that the truck shipments not exceed 73,000 pounds as governed by federal or state gross vehicle weight restrictions. The fuel shipments to the STP site will comply with federal and state weight restrictions. Therefore, the ABWR meets this condition.

5.11.1.9 Transportation of Irradiated Fuel

Subparagraph 10 CFR 51.52(a)(5) allows for truck, rail, or barge transport of irradiated fuel. DOE is responsible for spent fuel transportation from reactor sites to the repository and will make the decision on transport mode as specified in 10 CFR 961. For the impacts analysis described in Subsection 5.11.2, STP assumed that all spent fuel shipments will be made using legal weight trucks, which is a conservative assumption for this analysis. Therefore, the ABWR meets this condition.

5.11.1.10 Transportation of Radioactive Waste other than Irradiated Fuel

Subparagraph 10 CFR 51.52(a)(5) requires that the mode of transport of radioactive waste other than irradiated fuel be either truck or rail. STPNOC will ship this radioactive waste from the ABWR units by truck.

Radioactive waste shipments are subject to a weight limitation of 73,000 pounds per truck. Radioactive waste from the ABWR will comply with federal or state weight restrictions. Therefore, the ABWR meets this condition.

5.11.1.11 Number of Truck Shipments

Table S-4 limits traffic density to less than one truck shipment per day or three rail cars per month. STP has estimated the number of truck shipments that will be required assuming that all radioactive materials (fuel and waste) are received at the site or transported offsite via truck.

Table 5.11-2 summarizes the number of truck shipments of unirradiated fuel. The table also normalizes the number of shipments to the electrical output for the reference reactor analyzed in WASH-1238. When normalized for electrical output, the number of truck shipments of unirradiated fuel for the ABWR is approximately equal to the number of truck shipments estimated for the reference LWR.

For the ABWR, the initial core load is approximately 151 MTU per unit and the annual reload requirements are estimated at approximately 42 MTU per year per unit. This equates to about 872 fuel assemblies in the initial core (assuming 0.17388 MTU per fuel assembly) and 244 fuel assemblies per year for refueling. The fuel assemblies would be packaged two per container. Truck shipments would be able to accommodate 14 containers for a total of 28 fuel assemblies per shipment. The capacity of a truck shipment would be the same for the initial core and the reloads.

The numbers of spent fuel shipments were estimated as follows. For the reference LWR analyzed in WASH-1238, NRC assumed that 60 shipments per year will be made, each carrying 0.5 MTU of spent fuel. This amount is equivalent to the annual refueling requirement of 30 MTU per year for the reference LWR. For this transportation analysis, STP assumed that it would also ship spent fuel from the ABWR at a rate equal to the annual refueling requirement. The shipping cask capacities used to calculate annual spent fuel shipments were assumed to be the same as those for the reference LWR (0.5 MTU per legal weight truck shipment). This results in 85 shipments per year for one ABWR. After normalizing for electrical output, the number of spent fuel shipments is 59 per year for the ABWR. The normalized spent fuel shipments for the ABWR would be approximately the same as the reference reactor that was the basis for Table S-4.

Table 5.11-3 presents estimates of annual waste volumes and numbers of truck shipments. The values are normalized to the reference LWR analyzed in WASH-1238. The normalized annual waste volumes and waste shipments for the ABWR will be less than the reference reactor that was the basis for Table S-4.

The normalized total numbers of truck shipments of fuel and radioactive waste to and from the reactor are estimated at 96 per year for the ABWR. These radioactive material transportation estimates are well below the one truck shipment per day condition given in 10 CFR 51.52, Table S-4. Doubling the estimated number of truck shipments to account for empty return shipments still results in number of shipments well below the one-shipment-per-day condition. Therefore, the ABWR meets this condition.

5.11.1.12 Summary

Table 5.11-4 summarizes the reference conditions in paragraph (a) of 10 CFR 51.52 for use in Table S-4, and the values for the ABWR. The ABWR does not meet the condition for rated thermal power. Therefore, Subsection 5.11.2 and Section 7.4 present additional analyses of fuel transportation effects for normal conditions and accidents, respectively. Transportation of radioactive waste is consistent with the conditions assumed in References 5.11-1 and 5.11-2 and no further analysis is required.

5.11.2 Incident-Free Transportation Impacts Analysis

Environmental impacts of incident-free transportation of fuel are discussed in this section. Transportation accidents are discussed in Section 7.4.

NRC analyzed the transportation of radioactive materials in its assessments of environmental impacts for the proposed/approved ESP sites at North Anna, Clinton, and Grand Gulf (Reference 5.11-6, 5.11-7, and 5.11-8). The NRC analyses were reviewed for guidance in assessing transportation impacts for the ABWR units at the STP site.

5.11.2.1 Transportation of Unirradiated Fuel

Table S-4 of 10 CFR 51.52 includes conditions related to radiological doses to transport workers and members of the public along transport routes. These doses, based on calculations in WASH-1238, are a function of the radiation dose rate emitted from the unirradiated fuel shipments, the number of exposed individuals and their locations relative to the shipment, the time of transit (including travel and stop times), and the number of shipments to which the individuals are exposed. In its assessments of environmental impacts for proposed ESP sites, NRC calculated the radiological dose impacts of unirradiated fuel transportation using the RADTRAN 5 computer code. The RADTRAN 5 calculations estimated worker and public doses associated with annual shipments of unirradiated fuel.

One of the key assumptions in WASH-1238 for the reference LWR unirradiated fuel shipments is that the radiation dose rate at one meter from the transport vehicle is about 0.1 millirem per hour. This assumption was also used by NRC to analyze advanced LWR unirradiated fuel shipments for the proposed ESP sites. This assumption is reasonable for all of the advanced LWR types because the fuel materials will all be low-dose-rate uranium radionuclides and will be packaged similarly (inside a metal container that provides little radiation shielding). The per-shipment dose estimates are “generic” (i.e., independent of reactor technology) because they were calculated based on an assumed external radiation dose rate rather than the specific characteristics of the fuel or packaging. Thus, the results can be used to evaluate the impacts for any of the advanced LWR designs. Other input parameters used in the NRC radiation dose analysis for advanced LWR unirradiated fuel shipments are summarized in Table 5.11-5. The results for this “generic” fresh fuel shipment based on the RADTRAN 5 analyses are as follows:

Population Component	Dose
Transport workers	0.00171 person-rem/shipment
General public (Onlookers – persons at stops and sharing the highway)	0.00665 person-rem/shipment
General public (Along Route – persons living near a highway)	1.61×10^{-4} person-rem/shipment

From a review of the NRC analysis, it was concluded that these unit dose values could be used to estimate the impacts of transporting unirradiated fuel to an ABWR at the STP site. Based on the parameters used in the analysis, these per-shipment doses are expected to conservatively estimate the impacts for fuel shipments to a site in the STP region of interest. For example, the average shipping distance of 2000 miles used in the NRC analyses is likely to exceed the shipping distance for fuel deliveries to the STP site. The fuel shipments are expected to originate at a fabrication facility located in Columbia, South Carolina and travel less than 1200 miles to the STP site.

The unit dose values were combined with the average annual shipments of unirradiated fuel to calculate annual doses to the public and workers that can be compared to Table S-4 conditions. The numbers of unirradiated fuel shipments were normalized to the reference reactor analyzed in WASH-1238. The numbers of shipments per year were obtained from Table 5.11-2. The results are presented in Table 5.11-6. As shown, the calculated radiation doses for transporting unirradiated fuel to the STP site are a small fraction of the Table S-4 conditions that apply to all radioactive materials transportation.

Although radiation may cause cancers at high doses and high dose rates, currently there are no data that unequivocally establish the occurrence of cancer following exposures to low doses, below about 10 rem. However, radiation protection experts conservatively assume that any amount of radiation may pose some risk of causing cancer or a severe hereditary effect and that the risk is higher for higher radiation exposures. Therefore, a linear, no-threshold dose response relationship is used to describe the relationship between radiation dose and detriments such as cancer induction. Simply stated, any increase in dose, no matter how small, results in an incremental increase in health risk. This theory is accepted by the NRC as a conservative model for estimating health risks from radiation exposure, recognizing that the model may overestimate those risks. A recent review by the National Academy of Sciences Committee to Assess Health Risks from Exposure to Low Levels of Ionizing Radiation supports the linear no-threshold model (Reference 5.11-9).

Based on this model, the risk to the public from radiation exposure is estimated using the nominal probability coefficient for total detriment (730 fatal cancers, nonfatal cancers, and severe hereditary effects per million person-rem) from International Commission on Radiation Protection Publication 60 (Reference 5.11-10). All the public collective doses presented in Table 5.11-6 are less than 0.1 person-rem per year. Therefore, the total detriment estimates associated with these doses will all be less than 1 × 10-4 fatal cancers, nonfatal cancers, and severe hereditary effects per year. These risks are very small compared to the fatal cancers, nonfatal cancers, and severe hereditary effects that the same population will incur annually from exposure to natural sources of radiation.

5.11.2.2 Transportation of Spent Fuel

This section provides the environmental impacts of transporting spent fuel from the STP site to a spent fuel disposal facility, using Yucca Mountain, Nevada as a possible location for a geologic repository. The impacts of the transportation of spent fuel to a potential repository in Nevada provides a reasonable bounding estimate of the transportation impacts to a monitored retrievable storage facility because of the distances involved and the representative exposure of members of the public in urban, suburban, and rural areas (Reference 5.11-6, 5.11-7, and 5.11-8).

Incident-free transportation refers to transportation activities in which the shipments reach their destination without releasing any of their radioactive cargo to the environment. Impacts from these shipments will be from the low levels of radiation that penetrate the heavily shielded spent fuel shipping cask. Radiation doses will occur to (1) persons residing along the transportation corridors between the STP site and the proposed repository, (2) persons in vehicles passing a spent-fuel shipment, (3) persons at vehicle stops for refueling, rest, and vehicle inspections, and (4) transportation crew workers.

This analysis is based on shipment of spent fuel by legal-weight trucks in casks with characteristics similar to casks currently available (i.e., massive, heavily shielded, cylindrical metal pressure vessels). Each shipment is assumed to consist of a single shipping cask loaded on a modified trailer. These assumptions are consistent with assumptions made in evaluating the environmental impacts of spent fuel transportation in Addendum 1 to NUREG-1437 (Reference 5.11-5). As discussed in NUREG-1437, these assumptions are conservative because the alternative assumptions involve rail transportation or heavy-haul trucks, which will reduce the overall number of spent fuel shipments.

The environmental impacts of spent fuel transportation were estimated using the RADTRAN 5 computer code (Reference 5.11-11). This analysis assumed the spent fuel will be transported by legal weight trucks to the potential Yucca Mountain repository over designated highway route-controlled quantity (HRCQ) routes. The route used for this analysis of the STP site is similar to the STP-Yucca Mountain legal weight truck route evaluated in the Yucca Mountain EIS (Reference 5.11-12). The STP-Yucca Mountain route analyzed in the Yucca Mountain EIS traveled a total of 1,871 miles (3,010 km) (Reference 5.11-12, Table J-10). STP evaluated a route that was consistent with HRCQ requirements but which traveled a total of 1,838 miles (2,957 km).

Although shipping casks have not been designed for the advanced LWR fuels, the advanced LWR fuel designs will most likely not be significantly different from existing LWR designs. Current shipping cask designs were used for analysis.

Radiation doses are a function of many parameters, including vehicle speed, traffic count, dose rate at one meter from the vehicle, packaging dimensions, number in the truck crew, stop time, and population density at stops. The values of the key variables used in this analysis are presented in Table 5.11-7. Most of the variables are extracted from the literature and are considered to be standard values used in many RADTRAN applications, including environmental impact statements and regulatory analyses.

The transportation route selected for a shipment determines the total potentially exposed population and the expected frequency of transportation-related accidents. For truck transportation, the route characteristics most important to the risk assessment include the total shipping distance between each origin-destination pair of sites and the population density along the route.

Representative shipment routes for the proposed STP site and alternative sites were identified using the TRAGIS (Version 1.5.4) routing model (Reference 5.11-13). The highway data network in TRAGIS is a computerized road atlas that includes a complete description of the interstate highway system and of all U.S. highways. The TRAGIS database version used was Highway Data Network 4.0. The population densities along a route are derived from 2000 census data from the U.S. Bureau of the Census. This transportation route information is summarized in Table 5.11-8.

Based on the transportation route information shown in Table 5.11-8, the impacts of spent fuel shipments originating at the STP site are expected to be similar to the impacts for the alternative sites (Limestone, Malakoff, Parish). The impacts of transportation of spent fuel from a greenfield site (assumed to be ~~in Allens~~ Allen's Creek) located in the STP region of interest will also be similar to the transportation impacts for the STP site.

The radiation dose estimates to the transport workers and the public for spent fuel shipments from the STP site and alternative sites are as follows:

	Population Dose (person-rem per shipment)		
Site	Transport workers	General public (Onlookers)	General Public (Along Route)
STP	0.0388	0.269	5.45×10^{-3}
Allens Creek	0.0378	0.237	5.36×10^{-3}
Limestone	0.0376	0.236	4.50×10^{-3}
Malakoff	0.0370	0.236	4.43×10^{-3}
Parish	0.0385	0.237	5.74×10^{-3}

These per-shipment dose estimates are independent of reactor technology because they were calculated based on an assumed external radiation dose rate emitted from the cask, which was fixed at the regulatory maximum of 10 millirem per hour at two meters. For the purpose of this analysis, the transportation crew consists of two drivers. Stop times were assumed to accrue at the rate of 30 minutes per 4-hour driving time. TRAGIS output was used to determine the number of stops.

The numbers of spent fuel shipments for the transportation impacts analysis were derived as described in Subsection 5.11.1. The normalized annual shipments values and corresponding population dose estimates per reactor-year are presented in Table 5.11-9. The population doses were calculated by multiplying the number of spent fuel shipments per year by the per-shipment doses. For comparison to Table S-4, the population doses were normalized to the reference LWR analyzed in WASH-1238.

As shown in Table 5.11-9, population doses to the onlookers for both the ABWR and the reference LWR exceed Table S-4 values, but the population doses to onlookers for the ABWR are less than those for the reference LWR. Two key reasons for these higher population doses relative to Table S-4 are the number of spent fuel shipments and the shipping distances assumed for these analyses relative to the assumptions used in WASH-1238.

- Shipping distance — The analyses in WASH-1238 used a “typical” distance for a spent fuel shipment of 1000 miles. The shipping distance used in this assessment is about 1838 miles.
- Cask capacity — The numbers of spent fuel shipments are based on shipping casks designed to transport shorter-cooled fuel (i.e., 150 days out of the reactor). This analysis assumed that the shipping cask capacities are 0.5 MTU per legal-weight truck shipment. Newer cask designs are based on longer-cooled spent fuel (i.e., five years out of reactor) and have larger capacities. For example, spent fuel shipping cask capacities used in the Yucca Mountain EIS (Reference 5.11-12, Table J-2) were approximately 1.8 MTU per legal-weight truck shipment. Use of the newer shipping cask designs will reduce the number of spent fuel shipments and decrease the associated environmental impacts (since the dose rates used in the impacts analysis are fixed at the regulatory limit rather than based on the cask design and contents).

Other conservative assumptions in the spent fuel transportation impacts calculation include:

- Use of the regulatory maximum dose rate (10 millirem per hour at 2 meters) in the RADTRAN 5 calculations — The shipping casks assumed in the Yucca Mountain EIS (Reference 5.11-12) transportation analyses were designed for spent fuel that has cooled for five years. In reality, most spent fuel will have cooled for much longer than five years before it is shipped to a possible geologic repository. NRC developed a probabilistic distribution of dose rates based on fuel cooling times that indicates that approximately three-fourths of the spent fuel to be transported to a possible geologic repository will have dose rates less than half of the regulatory limit (Reference 5.11-14). Consequently, the estimated population doses in Table 5.11-9 could be divided in half if more realistic dose rate projections are used for spent fuel shipments from the STP site.

- Use of 30 minutes as the average time at a truck stop in the calculations — Many stops made for actual spent fuel shipments are short duration stops (i.e., 10 minutes) for brief visual inspections of the cargo (checking the cask tie-downs). These stops typically occur in minimally populated areas, such as an overpass or freeway ramp in an unpopulated area. Based on data for actual truck stops, NRC concluded that the assumption of a 30-minute stop for every 4 hours of driving time used to evaluate potential ESP sites will overestimate public doses at stops by at least a factor of two (Reference 5.11-6, 5.11-7, and 5.11-8). Consequently, the doses to onlookers given in Table 5.11-9 could be reduced by a factor of two to reflect more realistic truck shipping conditions.

5.11.2.3 Maximally Exposed Individuals Under Normal Transport Conditions

STPNOC also considered incident-free radiation doses to maximally exposed individuals (MEIs) for fuel and waste shipments to and from the STP site. An MEI is a person who may receive the highest radiation dose from a shipment to and/or from the STP site. The radiological doses to the workers who would load casks, drive trucks, and inspect vehicles in transit would be higher than doses to individuals in the general public. Radiological protection programs would manage and limit doses to workers whose jobs would cause them to receive the greatest exposures.

Truck crew members would receive the highest radiation doses because of their proximity to the loaded shipping container for an extended period of time. It was assumed that crew member doses would be limited to two rem per year, which is the DOE administrative control level (Reference 5.11-15). DOE will take title to the spent fuel at the reactor site. Consequently, the DOE administrative control level is expected to apply to spent fuel shipments from the STP site to a disposal facility. Spent fuel represents the majority of the radioactive materials shipments to and from reactor sites, and comprises those shipments with the highest radiation dose rates as specified in 10 CFR 961. Crew doses from unirradiated fuel and radioactive waste shipments will be lower than the spent fuel shipments. STPNOC also assumed a maximally exposed individual worker on the truck crew could receive a dose as high as two rem per year for each of the 40 years of reactor operation, for a total of 80 rem for one ABWR over the 40-year license term.

The dose received by members of the public would be less than that described for the truck crew due to decreases in the exposure times, dose rates, and number of times an individual may be exposed to an offsite shipment. For example:

- Inspectors — Radioactive shipments are inspected by federal or state vehicle inspectors at state ports of entry. DOE (Reference 5.11-12) assumed that inspectors would be exposed for one hour at a distance of one meter from the shipping containers. The dose rate at one meter is about 14 millirem per hour, assuming the dose rate from the shipping containers is 10 millirem per hour at 2 meters from the side of the transport vehicle. (This is the maximum dose rate allowed by U.S. DOT regulations.) Therefore, the dose per shipment is about 14 millirem. Based on this conservative value, the maximum annual dose to vehicle inspectors would be approximately 1900 millirem per year, assuming the same person inspects all shipments of fuel and waste to and from the reactor site in a year. This is less than the two rem per year DOE administrative control level on individual doses.

- Resident — A resident living along the transportation route could be exposed to each shipment that passes their residence. Given the distance separating the residence from the radioactive material transport vehicle on the roadway and the short duration of each exposure, the potential radiation doses to maximally exposed residents would be much less than those of the truck crew or inspectors.
- Individual stuck in traffic — Potential traffic interruptions could lead to a person being exposed to a loaded radioactive material shipment for some period of time. Because this exposure scenario would occur only one time to any individual and their exposure is relatively short (on the order of an hour), the dose to these members of the public sharing the route would be much less than those of the truck crew or inspectors.
- Person at a truck service station — An employee at a service station could be exposed when truck shipments to and from the reactor stop. DOE (Reference 5.11-12) assumed this person could be exposed for 49 minutes at a distance of 52 feet (15.9 meters) from the loaded shipping container. This results in a dose of about 0.07 millirem per shipment for an annual dose of approximately 10 millirem, assuming that a single individual services all unirradiated fuel, spent fuel, and radioactive waste shipments to and from the site in a year. This dose is much less than those of the truck crew or inspectors.

5.11.2.4 Conclusion

STPNOC has evaluated incident-free transportation of unirradiated and spent fuel to and from the STP site, including potential impacts to MEIs. The impacts of accident-free transportation will be SMALL and do not warrant additional mitigation.

5.11.2.5 References

5.11-1 “Environmental Survey of Transportation of Radioactive Materials to and from Nuclear Power Plants, WASH-1238,” AEC (U.S. Atomic Energy Commission), December 1972.

5.11-2 “Environmental Survey of Transportation of Radioactive Materials to and from Nuclear Power Plants,” NUREG-75/038, Supplement 1, April 1975.

5.11-3 “ABWR Design Control Document, Revision 4,” GE (GE Nuclear Energy) March 1997.

5.11-4 “Environmental Effects of Extending Fuel Burnup Above 60 GWd/MTU, NUREG/CR-6703,” January 2001.

5.11-5 “Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Section 6.3, “Transportation” and Table 9-1, “Summary of findings on NEPA issues for license renewal of nuclear power plants,” NUREG-1437, Volume 1, Addendum 1,” August 1999.

5.11-6 "Environmental Impact Statement for an Early Site Permit (ESP) at the North Anna ESP Site, NUREG-1811," December 2006.

5.11-7 "Environmental Impact Statement for an Early Site Permit (ESP) at the Exelon ESP Site," NUREG-1815, July 2006.

5.11-8 "Environmental Impact Statement for an Early Site Permit (ESP) at the Grand Gulf ESP Site, NUREG-1817," April 2006.

5.11-9 "Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII – Phase 2," NAS (National Academy of Sciences), Committee to Assess Health Risks From Exposure to Low Levels of Ionizing Radiation, Board on Radiation Effects Research, Division of Earth and Life Studies, National Research Council, National Academy Press, 2005. Available at http://www.nap.edu/books/030909156X/html.

5.11-10 "Recommendations of the International Commission on Radiological Protection, ICRP Publication 60," ICRP (International Commission on Radiological Protection), 1991.

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5.11-13 "Transportation Routing Analysis Geographic Information System (WebTRAGIS) User's Manual, ORNL/TM-2000/86," Johnson, P. E. and R. D. Michelhaugh, Oak Ridge National Laboratory, 2000. Available at http://www.ornl.gov/~webworks/cpr/v823/rpt/106749.pdf.

5.11-14 "Reexamination of Spent Fuel Shipment Risk Estimates," NUREG/CR-6672, Volume 1, March 2000.

5.11-15 "DOE Standard, Radiological Control, DOE-STD-1098-99," DOE (U.S. Department of Energy) 2005, March 2005. Available at http://www.hss.energy.gov/NuclearSafety/techstds/standard/std1098/doe-std-1098-99cn1a.pdf.

5.11-16 "A Resource Handbook on DOE Transportation Risk Assessment, DOE/EM/NTP/HB-01," DOE (U.S. Department of Energy), Office of Environmental Management, National Transportation Program, 2002.

Table 5.11-1 Summary of Environmental Impacts of Transportation of Fuel and Waste to and from One LWR, Taken from 10 CFR 51.52 Table S-4 [1]

Normal Conditions of Transport

	Environmental Impact
Heat (per irradiated fuel cask in transit)	250,000 Btu/hr.
Weight (governed by Federal or State restrictions)	73,000 lbs. per truck; 100 tons per cask per railcar.
Traffic density:	
Truck	Less than 1 per day
Rail	Less than 3 per month

Exposed Population	Estimated Number of Persons Exposed	Range of Doses to Exposed Individuals [2] (per reactor year)	Cumulative Dose to Exposed Population (per reactor year) [3]
Transportation workers	200	0.01 to 300 millirem	4 man-rem
General public:			
Onlookers	1,100	0.003 to 1.3 millirem	3 man-rem
Along Route	600,000	0.0001 to 0.06 millirem	

Accidents in Transport

Types of Effects	Environmental Risk
Radiological effects	Small [4]
Common (nonradiological) causes	1 fatal injury in 100 reactor years; 1 nonfatal injury in 10 reactor years; $475 property damage per reactor year.

[1] Data supporting this table are given in the Commission's "Environmental Survey of Transportation of Radioactive Materials to and from Nuclear Power Plants," WASH-1238, December 1972, and Supp. 1 NUREG-75/038, April 1975.

[2] The Federal Radiation Council has recommended that the radiation doses from all sources of radiation other than natural background and medical exposures should be limited to 5000 millirem per year for individuals as a result of occupational exposure and should be limited to 500 millirem per year for individuals in the general population. The dose to individuals due to average natural background radiation is about 130 millirem per year.

[3] Man-rem is an expression for the summation of whole body doses to individuals in a group. Thus, if each member of a population group of 1000 people were to receive a dose of 0.001 rem (1 millirem), or if 2 people were to receive a dose of 0.5 rem (500 millirem) each, the total man-rem dose in each case will be 1 man-rem.

[4] Although the environmental risk of radiological effects stemming from transportation accidents is currently incapable of being numerically quantified, the risk remains small regardless of whether it is being applied to a single reactor or a multi-reactor site.

Table 5.11-2 Number of Truck Shipments of Unirradiated Fuel

Reactor Type	Number of Shipments per Unit			Unit Electric Generation, MW(e)	Capacity Factor	Normalized Shipments Total [3]	Normalized Shipments Annual [3]
	Initial Core [1]	Annual Reload	Total [2]				
Reference LWR	18[5]	6.0	252	1100	0.8	252	6.3
ABWR	32	8.7	371	1300	0.95	255	6.4

[1] Shipments of the initial core have been rounded up to the next highest whole number.

[2] Total shipments of fresh fuel over 40-year plant lifetime (i.e., initial core load plus 39 years of average annual reload quantities).

[3] Normalized to electric output for WASH-1238 reference plant (i.e., 1100 MW[e] plant at 80 percent or an electrical output of 880 MW[e]).

[4] Annual average for 40-year plant lifetime

[5] The initial core load for the reference BWR in WASH-1238 was 150 MTU, that resulted in 18 truck shipments of fresh fuel per reactor.

Table 5.11-3 Number of Radioactive Waste Shipments

Reactor Type	Waste Generation, ft^3/yr (m^3/yr), per unit	Electrical Output, MW(e), per unit	Capacity Factor	Normalized Waste Generation Rate, ft^3/ Reactor-Year (m^3/Reactor-Year) [1]	Normalized Shipments/ Reactor-Year [2]
Reference LWR	3800 (108)	1100	0.80	3800 (108)	46
ABWR	3500 (99)	1300	0.95	2400 (68)	30

[1] Annual waste generation rates normalized to equivalent electrical output of 880 MWe for reference LWR analyzed in WASH-1238.

[2] The number of shipments was calculated assuming the average waste shipment capacity of 82.6 ft3 per shipment (3800 ft3/yr divided by 46 shipments/yr) used in WASH-1238.

Table 5.11-4 ABWR Comparisons to Table S-4 Reference Conditions

Characteristic	Table S-4 Condition	ABWR
Thermal Power Rating (MWt)	not exceeding 3800 per reactor	3926
Fuel Form	sintered UO2 pellets	sintered UO2 pellets
U235 Enrichment (%)	Not exceeding 4	Initial Core Average: 2.2; Reload Average: 3.2
Fuel Rod Cladding	Zircaloy rods; NRC has also accepted ZIRLO™ per 10 CFR 50.46	Zircaloy-2
Average burnup (MWd/MTU)	Not exceeding 33,000	32,300
	Unirradiated Fuel	
Transport Mode	truck	truck
No. of shipments for initial core loading [1]	No comparison	32
No. of reload shipments per year [1]	No comparison	8.7
	Irradiated Fuel	
Transport mode	truck, rail or barge	truck, rail
Decay time prior to shipment	Not less than 90 days is a condition for use of Table S-4; 5 years is per contract with DOE	Minimum 5 years
No. of spent fuel shipments by truck [1]	No comparison	85 per year
No. of spent fuel shipments by rail	No comparison	not analyzed
	Radioactive Waste	
Transport mode	truck or rail	truck
Waste form	solid	solid
Packaged	yes	yes
No. of waste shipments by truck[1]	No comparison	43 per year
	Traffic Density	
Trucks per day [2] (normalized total)	Less than 1	Less than 1 (96 per year)
Rail cars per month	Less than 3	not analyzed

[1] Table provides the total numbers of truck shipments of fuel and waste for the ABWR. These values are then normalized based on electric output and summed for comparison to the traffic density condition in Table S-4.

[2] Total truck shipments per year calculated after normalization of estimated fuel and waste shipments for equivalent electrical output to the reference reactor analyzed in WASH-1238.

Table 5.11-5 RADTRAN 5 Input Parameters for NRC Analysis of Unirradiated Fuel Shipments

Parameter	RADTRAN 5 Input Value
Shipping distance, miles [1] (km)	2,000 (3,218)
Travel Fraction – Rural	0.90
Travel Fraction – Suburban	0.05
Travel Fraction – Urban	0.05
Population Density – Rural, persons/mi^2 (persons/km^2)	25.9 (67)
Population Density – Suburban, persons/mi^2 (persons/km^2)	904 (2,341)
Population Density – Urban, persons/mi^2 (persons/km^2)	5850 (15,152)
Vehicle speed – Rural, miles/hr (km/hr)	55 (89)
Vehicle speed – Suburban, miles/hr (km/hr)	55 (89)
Vehicle speed – Urban, miles/hr (km/hr)	55 (89)
Traffic count – Rural, vehicles/hr	530
Traffic count – Suburban, vehicles/hr	760
Traffic count – Urban, vehicles/hr	2,400
Dose rate at 1 meter from vehicle, mrem/hr	0.1
Packaging length, ft (m)	22 (6.7)
Number of truck crew	2
Stop time, hr/trip	4.5
Population density at stops, persons/mi^2 (persons/km^2)	166,500 (431,235)

Source: Reference 5.11-1.

[1] WASH-1238 had a range of shipping distances between 25 and 3000 miles for unirradiated fuel shipments. A 2000-mile “average” shipping distance was used in NRC analyses of ESP sites in Reference 5.11-6, 5.11-7, 5.11-8.

Table 5.11-6 Radiological Impacts of Transporting Unirradiated Fuel to the STP Site by Truck

Reactor Type	Normalized Average Annual Shipments	Cumulative Annual Dose, person-rem per reference reactor year		
		Transport Workers	**General Public - onlookers**	**General Public - along route**
Reference LWR (WASH-1238)	6.3	0.011	0.042	0.0010
ABWR	6.4	0.011	0.042	0.0010
10 CFR 51.52 Table S-4 condition [1]	365 (<1 per day)	4	3	3

[1] Table S-4 conditions apply to all types of radioactive material transportation. The impacts of unirradiated fuel shipments constitute a small fraction of the overall cumulative annual dose limit.

Table 5.11-7 RADTRAN 5 Incident-free Exposure Parameters

Parameter	RADTRAN 5 input value	Source
Vehicle speed – Rural (miles/hr)	55	Based on average speed in rural areas given in Reference 5.11-16. Because most travel is on interstate highways, the same vehicle speed is assumed in rural, suburban, and urban areas. No speed reductions were assumed for travel at rush hour.
Vehicle speed – Suburban (miles/hr)	55	
Vehicle speed – Urban (miles/hr)	55	
Traffic count – Rural (vehicles/hr)	530	Reference 5.11-16
Traffic count – Suburban (vehicles/hr)	760	Reference 5.11-16
Traffic count – Urban (vehicles/hr)	2400	Reference 5.11-16
Dose rate at 1 m from vehicle (mrem/hr)	13	Approximate rate at 1 m that is equivalent to maximum dose rate allowed by Federal regulations (i.e., 10 mrem/hr at 2 m from the side of a transport vehicle)
Packaging dimensions, m	Length = 5.2 Diameter = 1.0	Reference 5.11-12
Number of truck crew	2	Reference 5.11-16
Stop time (hr/trip)	4	Route specific
Population density at Stops (person/km^2)	30,000	Reference 5.11-14
Min/Max Radii of Annular Area Surrounding Vehicle at Stops (m)	1 to 10	Reference 5.11-14
Shielding Factor Applied to Annular Area Surrounding Vehicle at Stops	1 (no shielding)	Reference 5.11-14
Population Density Surrounding Truck Stops (persons/km^2)	340	Reference 5.11-14
Min/Max Radii of Annular Area Surrounding Truck Stop (m)	10 to 800	Reference 5.11-14
Shielding Factor Applied to Annular Area Surrounding Truck Stop	0.2	Reference 5.11-14

Table 5.11-8 Transportation Route Information for Spent Fuel Shipments to the Potential Yucca Mountain Disposal Facility [1]

Reactor Site	One-way Shipping Distance, miles				Population Density, persons per square mile			Stop Time per trip, hr
	Total	**Rural**	**Suburban**	**Urban**	**Rural**	**Suburban**	**Urban**	
STP	1838	1509	277	53	20.8	915	6300	4
Allens Creek	1793	1466	275	53	20.8	906	6294	3.5
Limestone	1784	1518	220	47	19.7	929	6291	3.5
Malakoff	1753	1494	214	46	19.8	940	6332	3.5
Parish	1827	1478	293	57	21.2	918	6267	3.5

[1] Transportation route information obtained from TRAGIS. Routing of legal weight truck shipments from STP site differs slightly from that analyzed in the Yucca Mountain EIS (Reference 5.11-12).

Table 5.11-9 Population Doses from Spent Fuel Transportation, Normalized to Reference LWR

Exposed Population	Cumulative dose limit specified in Table S-4, person-rem per reactor year [1]	Reactor Type	
		Reference LWR (WASH-1238)	ABWR
		Normalized Number of Spent Fuel Shipments per year	
		60	59
		Environmental Effects, person-rem per reactor year	
Crew [2]	4	2.33	2.29
Onlookers	3	16.2	15.9
Along route	3	0.327	0.322

[1] Table S-4 conditions apply to all types of radioactive material transportation.

[2] The entries represent the annual population dose incurred by the crew. In evaluating the dose to maximally exposed individuals (see Subsection 5.11.2.3), STP assumed that individual crew member doses would be limited to 2 rem per year.