6.2 Transportation Impacts

This section addresses both the radiological and nonradiological environmental impacts from normal operating and accident conditions resulting from (1) shipment of unirradiated fuel to the LNP site and alternative sites, (2) shipment of spent fuel to a monitored retrievable storage facility or a permanent repository, and (3) shipment of low-level radioactive waste and mixed waste to offsite disposal facilities. For the purposes of these analyses, the NRC staff considered the proposed Yucca Mountain, Nevada, site as a surrogate destination for a permanent repository. The impacts evaluated in this section for two new nuclear generating units at the LNP site are appropriate to characterize the alternative sites discussed in Section 9.3 of this EIS. Alternative sites evaluated in this EIS include the LNP site (proposed), and alternative sites at Crystal River, Dixie, Highlands, and Putnam. There is no meaningful differentiation among the proposed and the alternative sites regarding the radiological and nonradiological environmental impacts from normal operating and accident conditions and these conditions are not discussed further in Chapter 9.

NRC performed a generic analysis of the environmental effects of the transportation of fuel and waste to and from LWRs in the *Environmental Survey of Transportation of Radioactive Materials To and From Nuclear Power Plants*, WASH-1238 (AEC 1972) and in a supplement to WASH-1238, NUREG-75/038 (NRC 1975), and found the impact to be small. These documents provided the basis for Table S–4 in 10 CFR 51.52 that summarizes the environmental impacts of transportation of fuel and waste to and from one LWR of 3000 to 5000 MW(t) (1000 to 1500 MW[e]). Impacts are provided for normal conditions of transport and accidents in transport for a reference 1100-MW(e) LWR.[(a)] Dose to transportation workers during normal transportation operations was estimated to result in a collective dose of 4 person-rem per reference reactor-year. The combined dose to the public along the route and dose to onlookers were estimated to result in a collective dose of 3 person-rem per reference reactor-year.

Environmental risks of radiological effects during accident conditions, as stated in Table S–4, are SMALL. Nonradiological impacts from postulated accidents were estimated as one fatal injury in 100 reference reactor-years and one nonfatal injury in 10 reference reactor-years. Subsequent reviews of transportation impacts in NUREG-0170 (NRC 1977a) and NUREG/CR-6672 (Sprung et al. 2000) concluded that impacts were bounded by Table S–4 in 10 CFR 51.52.

(a) The transportation impacts associated with the LNP site were normalized for a reference 1100-MW(e) LWR at an 80-percent capacity factor for comparisons to Table S–4. Note that the basis for Table S–4 is an 1100 MW(e) LWR at an 80-percent capacity factor (AEC 1972; NRC 1975). The basis for Table S–3 in 10 CFR 51.51(b) that was discussed in Section 6.1 of this EIS is a 1000 MW(e) LWR with an 80-percent capacity factor (NRC 1976). However, because fuel cycle and transportation impacts are evaluated separately, this difference does not affect the results and conclusions in this EIS.

In accordance with 10 CFR 51.52(a), a full description and detailed analysis of transportation impacts is not required when licensing an LWR (i.e., impacts are assumed to be bounded by Table S–4) if the reactor meets the following criteria:

- The reactor has a core thermal power level that does not exceed 3800 MW(t).
- Fuel is in the form of sintered uranium oxide pellets having a uranium-235 enrichment not exceeding 4 percent by weight; and pellets are encapsulated in zircalloy-clad fuel rods.
- The average level of irradiation of the fuel from the reactor does not exceed 33,000 MWd/MTU, and no irradiated fuel assembly is shipped until at least 90 days after it is discharged from the reactor.
- With the exception of irradiated fuel, all radioactive waste shipped from the reactor is packaged and in solid form.
- Unirradiated fuel is shipped to the reactor by truck; irradiated (spent) fuel is shipped from the reactor by truck, railcar, or barge; and radioactive waste other than irradiated fuel is shipped from the reactor by truck or railcar.

The environmental impacts of the transportation of fuel and radioactive wastes to and from nuclear power facilities are resolved generically in 10 CFR 51.52, provided that the specific conditions in the rule (see above) are met. The NRC may consider requests for licensed plants to operate at conditions above those in the facility's licensing basis, for example, higher burnups (above 33,000 MWd/MTU), enrichments (above 4 weight percent uranium-235), or thermal power levels (above 3800 MW[t]). Departures from the conditions itemized in 10 CFR 51.52(a) are to be supported by a full description and detailed analysis of the environmental effects, as specified in 10 CFR 51.52(b). Departures found to be acceptable for licensed facilities cannot serve as the basis for initial licensing of new reactors.

In its application, PEF requested combined construction permits and operating licenses (COLs) for two proposed reactors at its LNP site in Florida. Both proposed new reactors would be Westinghouse AP1000 advanced LWRs. The Westinghouse AP1000 reactor has a thermal power rating of 3400 MW(t), with a minimum net electrical output of 1115 MW(e). The Westinghouse AP1000 reactors are expected to operate with a 93-percent capacity factor, yielding a net electrical output (annualized) of about 1037 MW(e). Fuel for the units would be enriched up to about 4.51 weight percent uranium-235, which exceeds the 4-percent condition given in 10 CFR 51.52(a). In addition, the expected peak irradiation level of about 62,000 MWd/MTU exceeds the 33,000 MWd/MTU condition given in 10 CFR 51.52(a). Therefore, a full description and detailed analysis of transportation impacts is required.

In its ER (PEF 2009a), PEF provided a full description and detailed analyses of transportation impacts. In these analyses, the radiological impacts of transporting fuel and waste to and from the proposed LNP site and alternative sites were calculated using the RADTRAN 5.6 computer code (Weiner et al. 2006). RADTRAN 5.6 was used in this EIS and is the most commonly used transportation impact analysis software in the nuclear industry.

Comments on four previous early site permit EISs also were considered when developing the scope of this EIS. The most significant change is that this EIS includes an explicit analysis of the nonradiological impacts of transporting unirradiated fuel, spent fuel, and radioactive waste to and from the LNP site and alternative sites. Nonradiological impacts of transporting construction workers and materials (see Section 4.8.3) and operations workers (Section 5.8.6) are addressed elsewhere in this EIS. Publicly available information about traffic accident, injury, and fatality rates was used to estimate nonradiological impacts. In addition, the radiological impacts on maximally exposed individuals (MEIs) are evaluated.

6.2.1 Transportation of Unirradiated Fuel

The NRC staff performed an independent evaluation of the environmental impacts of transporting unirradiated (i.e., fresh) fuel to the LNP site and alternative sites. Radiological impacts of normal conditions and transportation accidents as well as nonradiological impacts are discussed in this section. Radiological impacts on populations and MEIs are presented. Because the specific fuel fabrication plant for LNP unirradiated fuel is not known at this time, the NRC staff's analysis assumes a "representative" route between the fuel fabrication facility and LNP site and alternative sites. This means that there are no substantive differences between the impacts calculated, for the purposes of Chapter 9, for the LNP site and the four alternative sites. The site-specific differences are minor because the radiation doses from unirradiated fuel transport are minute and the differences in shipping distances between potential fuel fabrication plants and the LNP site and alternative sites are small.

6.2.1.1 Normal Conditions

Normal conditions, sometimes referred to as "incident-free" transportation, are transportation activities during which shipments reach their destination without releasing any radioactive material to the environment. Impacts from these shipments would be from the low levels of radiation that penetrate the unirradiated fuel shipping containers. Radiation exposures at some level would occur to the following individuals: (1) persons residing along the transportation corridors between the fuel fabrication facility and the LNP or alternative sites; (2) persons in vehicles traveling on the same route as an unirradiated fuel shipment; (3) persons at vehicle stops for refueling, rest, and vehicle inspections; and (4) transportation crew workers.

Truck Shipments

Table 6-3 provides an estimate of the number of truck shipments of unirradiated fuel for the Westinghouse AP1000 reactor design compared to those of the reference 1100-MW(e) reactor specified in WASH-1238 (AEC 1972) operating at 80-percent capacity (880 MW[e]). After normalization, the NRC staff found that the number of truck shipments of unirradiated fuel to the

LNP site or alternative sites would be fewer than the number of truck shipments of unirradiated fuel estimated for the reference LWR in WASH-1238. The results are consistent with the estimates provided in PEF's ER (PEF 2009a).

Shipping Mode and Weight Limits

In 10 CFR 51.52, a condition is identified that states all unirradiated fuel is shipped to the reactor by truck. PEF specifies that unirradiated fuel would be shipped to the proposed reactor site by truck. Section 10 CFR 51.52, Table S–4, includes a condition that the truck shipments not exceed 73,000 lb as governed by Federal or State gross vehicle weight restrictions. PEF states in its ER that the unirradiated fuel shipments to the LNP site and alternative sites would comply with applicable weight restrictions (PEF 2009a).

Table 6-3. Number of Truck Shipments of Unirradiated Fuel for the Reference LWR and a Single AP1000 Reactor at the LNP Site

Reactor Type	Number of Shipments per Reactor Unit			Unit Electric Generation, MW(e)[(c)]	Capacity Factor[(c)]	Normalized, Shipments per 1100 MW(e)[(d)]
	Initial Core[(a)]	Annual Reload	Total[(b)]			
Reference LWR (WASH-1238)	18	6	252	1100	0.8	252
LNP Westinghouse AP1000	23	5.4	233	1115	0.93	198

(a) Shipments of the initial core have been rounded up to the next highest whole number.
(b) Total shipments of unirradiated fuel over a 40-year plant lifetime (i.e., initial core load plus 39 years of average annual reload quantities).
(c) Unit capacities and capacity factors were taken from WASH-1238 for the reference LWR and from the ER (PEF 2009a) for the Westinghouse AP1000 reactor.
(d) Normalized to net electric output for WASH-1238 reference LWR (i.e., 1100-MW[e] plant at an 80-percent or net electrical output of 880 MW[e]).

Radiological Doses to Transport Workers and the Public

Section 10 CFR 51.52, Table S–4, includes conditions related to radiological dose to transport workers and members of the public along transport routes. These doses are a function of many variables, including the radiation dose rate emitted from the unirradiated fuel shipments, the number of exposed individuals and their locations relative to the shipment, the time in transit (including travel and stop times), and the number of shipments to which the individuals are exposed. For this EIS, the radiological dose impacts of the transportation of unirradiated fuel were calculated by the NRC staff for the worker and the public using the RADTRAN 5.6 computer code (Weiner et al. 2006).

One of the key assumptions in WASH-1238 (AEC 1972) for the reference LWR unirradiated fuel shipments is that the radiation dose rate at 3.3 ft from the transport vehicle is about 0.1 mrem/hr. This assumption also was used in the NRC staff's analysis of the Westinghouse

AP1000 reactor unirradiated fuel shipments. This assumption is reasonable because the Westinghouse AP1000 reactor fuel materials would be low-dose-rate uranium radionuclides and would be packaged similarly to those described in WASH-1238 (i.e., inside a metal container that provides little radiation shielding). The numbers of shipments per year were obtained by dividing the normalized shipments in Table 6-3 by 40 years of reactor operation. Other key input parameters used in the radiation dose analysis for unirradiated fuel are shown in Table 6-4.

Table 6-4. RADTRAN 5.6 Input Parameters for Reference LWR Fresh Fuel Shipments

Parameter	RADTRAN 5.6 Input Value	Source
Shipping distance, km	3200	AEC (1972)[a]
Travel fraction – Rural	0.90	Rural, suburban, and urban travel fractions are taken from NRC (1977a)
Travel fraction – Suburban	0.05	
Travel fraction – Urban	0.05	
Population density – Rural, persons/km^2	10	Rural, suburban, and urban population densities are taken from DOE (2002a)
Population density – Suburban, persons/km^2	349	
Population density – Urban, persons/km^2	2260	
Vehicle speed – km/hr	88.49	Conservative in-transit speed of 55 mph assumed; predominantly interstate highways used.
Traffic count – Rural, vehicles/hr	530	Rural, suburban, and urban traffic counts are taken from DOE (2002a)
Traffic count – Suburban, vehicles/hr	760	
Traffic count – Urban, vehicles/hr	2400	
Dose rate at 1 m from vehicle, mrem/hr	0.1	AEC (1972)
Packaging length, m	7.3	Approximate length of two LWR fuel element packages placed on end (DOE 1997)
Number of truck crew	2	AEC (1972), NRC (1977a), and DOE (2002a)
Stop time, hr/trip	4	Based on one 30-minute stop per 4-hour driving time
Population density at stops, persons/km^2	See Table 6-14 for truck stop parameters	

(a) AEC (1972) provides a range of shipping distances between 40 km (25 mi) and 4800 km (3000 mi) for unirradiated fuel shipments. A 3200-km (2000-mi) "representative" shipping distance was assumed here.

The RADTRAN 5.6 results for this "generic" unirradiated fuel shipment are as follows:

- worker dose: 1.71×10^{-3} person-rem/shipment
- general public dose (onlookers/persons at stops and sharing the highway): 2.91×10^{-3} person-rem/shipment
- general public dose (along route/persons living near a highway or truck stop): 4.12×10^{-5} person-rem/shipment.

These values were combined with the average annual shipments of unirradiated fuel for the Westinghouse AP1000 reactor to calculate annual doses to the public and workers. Table 6-5 presents the annual radiological impacts on workers, public onlookers (persons at stops and sharing the road), and members of the public along the route (i.e., residents within 0.5 mi of the highway) for transporting unirradiated fuel to the LNP site and alternative sites for a single AP1000 reactor. The cumulative annual dose estimates in Table 6-5 were normalized to 1100 MW(e) (880 MW[e] net electrical output). The NRC staff performed an independent review and determined that all dose estimates are bounded by the Table S–4 conditions of 4 person-rem/yr to transportation workers, 3 person-rem/yr to onlookers, and 3 person-rem/yr to members of the public along the route.

Table 6-5. Radiological Impacts Under Normal Conditions of Transporting Unirradiated Fuel to the LNP Site or Alternative Sites for a Single AP1000 Reactor

Plant Type	Normalized Average Annual Shipments	Cumulative Annual Dose; person-rem/yr per 1100 MW(e)[a] (880 MW(e) net		
		Workers	Public – Onlookers	Public – Along Route
Reference LWR (WASH-1238)	6.3	1.1×10^{-2}	1.8×10^{-2}	2.6×10^{-4}
Reference Westinghouse AP1000	5.0	8.5×10^{-3}	1.4×10^{-2}	2.0×10^{-4}
LNP	5.0	3.1×10^{-3}	7.6×10^{-3}	2.9×10^{-4}
Crystal River	5.0	3.1×10^{-3}	7.6×10^{-3}	2.9×10^{-4}
Dixie	5.0	3.0×10^{-3}	7.5×10^{-3}	2.5×10^{-4}
Highlands	5.0	3.6×10^{-3}	1.1×10^{-2}	3.5×10^{-4}
Putnam	5.0	2.7×10^{-3}	7.4×10^{-3}	2.6×10^{-4}
10 CFR 51.52, Table S–4 Condition	<1 per day	4.0×10^{0}	3.0×10^{0}	3.0×10^{0}

(a) Divide person-rem/yr by 100 to obtain doses in person-Sv/yr.

In its ER (PEF 2009a), PEF assumed that unirradiated fuel would be shipped from a fuel fabrication facility located near Lynchburg, Virginia, rather than the "generic" location assumed in WASH-1238. The NRC staff evaluated PEF's analysis by attempting to duplicate a sample of the impact calculations. RADTRAN 5.6 calculations were performed using the route information and other input parameters specified in the ER. No significant differences were identified. Based on this confirmatory analysis, the NRC staff concluded that PEF's analysis of unirradiated fuel transportation impacts is sufficient to meet the requirements of 10 CFR 51.52(b).

Radiation protection experts 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. A recent report by the National Research Council (2006), the BEIR VII report, uses the linear, no-threshold dose response model as a basis for estimating the risks from low doses. This approach is accepted by the NRC as a conservative method for estimating health risks from radiation exposure, recognizing that the model may overestimate those risks. Based on this method, the NRC staff estimated the risk to the public from radiation exposure using the nominal probability coefficient for total detriment. This coefficient has the value of 570 fatal cancers, nonfatal cancers, and severe hereditary effects per 1,000,000 person-rem (10,000 person-Sv), equal to 0.00057 effects per person-rem. The coefficient is taken from ICRP Publication 103 (ICRP 2007).

Both the NCRP and ICRP suggest that when the collective effective dose is smaller than the reciprocal of the relevant risk detriment (in other words, less than 1/0.00057, which is less than 1754 person-rem), the risk assessment should note that the most likely number of excess health effects is zero (NCRP 1995; ICRP 2007). The largest annual collective dose estimate for transporting unirradiated fuel to the LNP site and alternative sites was less than 2×10^{-2} person-rem, which is less than the 1754 person-rem value that ICRP and NCRP suggest would most likely result in zero excess health effects.

To place these impacts in perspective, the average U.S. resident receives about 311 mrem/yr effective dose equivalent from natural background radiation (i.e., exposures from cosmic radiation, naturally occurring radioactive materials such as radon, and global fallout from testing of nuclear explosive devices) (NCRP 2009). Using this average effective dose, the collective population dose from natural background radiation to the population along the generic representative route would be about 2.2×10^{5} person-rem. Therefore, the radiation doses from transporting unirradiated fuel to the LNP site and alternative sites are minimal compared to the collective population dose to the same population from exposure to natural sources of radiation.

Maximally Exposed Individuals Under Normal Transport Conditions

A scenario-based analysis was conducted by the NRC staff to develop estimates of incident-free radiation doses to MEIs for fuel and waste shipments to and from the LNP site and alternative sites. The following discussion applies to unirradiated fuel shipments to, and spent fuel and radioactive waste shipments from, the LNP and any of the alternative sites. The analysis is based on data from DOE (2002b) and incorporates data about exposure times, dose rates, and the number of times an individual may be exposed to an offsite shipment. Adjustments were made where necessary to reflect the normalized fuel and waste shipments addressed in this EIS. In all cases, the NRC staff assumed that the dose rate emitted from the shipping containers is 10 mrem/hr at 2 m (6.6 ft) from the side of the transport vehicle. This assumption is conservative, in that the assumed dose rate is the maximum dose rate allowed by U.S. Department of Transportation (DOT) regulations (49 CFR 173.441). Most unirradiated fuel and radioactive waste shipments would have much lower dose rates than the regulations allow (AEC 1972; DOE 2002a). An MEI is a person who may receive the highest radiation dose from a shipment to and/or from the LNP site and alternative sites. The analysis of MEIs is described below.

Truck Crew Member

Truck crew members would receive the highest radiation doses during incident-free transport because of their proximity to the loaded shipping container for an extended period. The analysis assumed that crew member doses are limited to 2 rem/yr, which is the DOE administrative control level presented in DOE-STD-1098-99, *DOE Standard, Radiological Control*, Chapter 2, Article 211 (DOE 2005). The NRC staff anticipates this limit would apply to spent nuclear fuel shipments to a disposal facility, because DOE would take title to the spent fuel at the reactor site. There would be more shipments of spent nuclear fuel from the LNP site (or alternative sites) than there would be shipments of unirradiated fuel to and radioactive waste other than spent fuel from, these sites. This is because the capacities of spent fuel shipping casks are limited due to their substantial radiation shielding and accident resistance requirements. Spent fuel shipments also have significantly higher radiation dose rates than unirradiated fuel and radioactive waste (DOE 2002a). As a result, crew doses from unirradiated fuel and radioactive waste shipments would be lower than the doses from spent nuclear fuel shipments. The DOE administrative limit of 2 rem/yr (DOE 2005) is less than the NRC limit for occupational exposures of 5 rem/yr (see 10 CFR Part 20).

The U.S. DOT does not regulate annual occupational exposures. It does recognize that air crews are exposed to elevated cosmic radiation levels and recommends dose limits to air crew members from cosmic radiation (DOT 2003). Air passengers are less of a concern because they do not fly as frequently as air crew members. The recommended limits are a 5-year effective dose of 2 rem/yr with no more than 5 rem in a single year (DOT 2003). As a result of this recommendation, a 2-rem/yr MEI dose to truck crews is a reasonable estimate to apply to shipments of fuel and waste from the LNP site and alternative sites.

Inspectors

Radioactive shipments are inspected by Federal or State vehicle inspectors, for example, at State ports of entry. The Yucca Mountain Final EIS (DOE 2002a) assumed that inspectors would be exposed for 1 hour at a distance of 1 m (3.3 ft) from the shipping containers. Assuming conservatively that the external dose rate at 2 m (6.6 ft) is at the maximum allowed by regulations (10 mrem/hr), the dose rate at 1 m (3.3 ft) is about 14 mrem/hr (Weiner et al. 2006). Therefore, the dose per shipment is about 14 mrem. This is independent of the location of the reactor site. Based on this conservative external dose rate and the assumption that the same person inspects all shipments of fuel and waste to and from the LNP site and alternative sites, the annual doses to vehicle inspectors were calculated to be about 0.9 rem/yr, based on a combined total of 66 shipments of unirradiated fuel, spent fuel, and radioactive waste per year. This value is about one-half of the 2-rem/yr DOE administrative control level on individual doses (DOE 2005) and one-fifth of the 5-rem/yr NRC occupational dose limit (see 10 CFR Part 20). Doses to State inspectors would be doubled for a site with two Westinghouse AP1000 reactors, like the LNP site and the alternative sites, which would bring their annual dose to approximately the DOE administrative limit.

Residents

The analysis assumed that a resident lives adjacent to a highway where a shipment would pass and would be exposed to all shipments along a particular route. Exposures to residents on a per-shipment basis were obtained from the NRC staff's RADTRAN 5.6 output files. These dose estimates are based on an individual located 100 ft from the shipments that are traveling 15 mph. The potential radiation dose to the maximally exposed resident is about 0.043 mrem/yr for shipments of fuel and waste to and from the LNP site and alternative sites with a single AP1000 reactor. This dose would be doubled for a site with two Westinghouse AP1000 reactors, like the LNP site and the alternative sites.

Individuals Stuck in Traffic

This scenario addresses potential traffic interruptions that could lead to a person being exposed to a loaded shipment for 1 hour at a distance of 4 ft. The NRC staff's analysis assumed this exposure scenario would occur only one time to any individual, and the dose rate was at the regulatory limit of 10 mrem/hr at 2 m (6.6 ft) from the shipment, so the dose rate would be higher at the assumed exposure distance of 4 ft. The dose to the MEI was calculated to be 16 mrem in DOE's Yucca Mountain Final EIS (DOE 2002b). These doses would not be doubled for a site with two Westinghouse AP1000 reactors, because it was assumed that this scenario would occur only once to any individual.

Persons at a Truck Service Station

This scenario estimates doses to an employee at a service station where all truck shipments to and from the LNP site and alternative sites are assumed to stop. The NRC staff's analysis assumed this person is exposed for 49 minutes at a distance of 52 ft from the loaded shipping container (DOE 2002b). The exposure time and distance were based on the observations discussed by Griego et al. (1996). This results in a dose of about 0.34 mrem/shipment and an annual dose of about 22 mrem/yr for the LNP site and alternative sites, assuming that a single individual services all unirradiated fuel, spent fuel, and radioactive waste shipments to and from the LNP site and alternative sites with a single AP1000 reactor. This dose would be doubled for a site with two Westinghouse AP1000 reactors, like the LNP site and the alternative sites.

6.2.1.2 Radiological Impacts of Transportation Accidents

Accident risks are a combination of accident frequency and consequence. Accident frequencies for transportation of unirradiated fuel to the LNP site and alternative sites are expected to be lower than those used in the analysis in WASH-1238 (AEC 1972), which forms the basis for Table S–4 of 10 CFR 51.52, because of improvements in highway safety and security, and an overall reduction in traffic accident, injury, and fatality rates since WASH-1238 was published. There is no significant difference in the consequences of transportation accidents severe enough to result in a release of unirradiated fuel particles to the environment between the Westinghouse AP1000 and current-generation LWRs because the fuel form, cladding, and packaging are similar to those analyzed in WASH-1238. Consequently, consistent with the conclusions of WASH-1238 (AEC 1972), the impacts of accidents during transport of unirradiated fuel to a Westinghouse AP1000 reactor at the LNP site and alternative sites are expected to be negligible.

6.2.1.3 Nonradiological Impacts of Transportation Accidents

Nonradiological impacts are the human health impacts projected to result from traffic accidents involving shipments of unirradiated fuel to the LNP site and alternative sites; that is, the analysis does not consider the radiological or hazardous characteristics of the cargo. Nonradiological impacts include the projected number of traffic accidents, injuries, and fatalities that could result from shipments of unirradiated fuel to the site and return shipments of empty containers from the site.

Nonradiological impacts are calculated using accident, injury, and fatality rates from published sources. The rates (i.e., impacts per vehicle-km traveled) are then multiplied by estimated travel distances for workers and materials. The general formula for calculating nonradiological impacts is as follows:

Impacts = (unit rate) × (round-trip shipping distance) × (annual number of shipments).

In this formula, impacts are presented in units of the number of accidents, number of injuries, and number of fatalities per year. Corresponding unit rates (i.e., impacts per vehicle-km traveled) are used in the calculations.

Accident, injury, and fatality rates were taken from Table 4 in ANL/ESD/TM-150 *State-Level Accident Rates for Surface Freight Transportation: A Reexamination* (Saricks and Tompkins 1999). Nationwide median rates were used for shipments of unirradiated fuel to the site. The data are representative of traffic accident, injury, and fatality rates for truck shipments similar to those to be used to transport unirradiated fuel to the LNP site and alternative sites. In addition, the DOT Federal Motor Carrier Safety Administration evaluated the data underlying the Saricks and Tompkins (1999) rates, which were taken from the Motor Carrier Management Information System, and determined that the rates were under-reported. Therefore, the accident, injury, and fatality rates in Saricks and Tompkins (1999) were adjusted using factors derived from data provided by the University of Michigan Transportation Research Institute (UMTRI 2003). The UMTRI data indicate that accident rates for 1994 to 1996, the same data used by Saricks and Tompkins (1999), were under-reported by about 39 percent. Injury and fatality rates were under-reported by 16 percent and 36 percent, respectively. As a result, the accident, injury, and fatality rates were increased by factors of 1.64, 1.20, and 1.57, respectively, to account for the under-reporting.

The nonradiological accident impacts for transporting unirradiated fuel to (and empty shipping containers from) the LNP site and alternative sites are shown in Table 6-6. The nonradiological impacts associated with the WASH-1238 reference LWR are also shown for comparison purposes. Note that there are only small differences between the impacts calculated for an AP1000 reactor at the LNP site and alternative sites and the reference LWR in WASH-1238 due entirely to the estimated annual number of shipments. Overall, the impacts are minimal and there are no substantive differences among the LNP site and alternative sites. The impacts would be doubled for a site with two AP1000 reactors like the LNP site and the alternative sites.

Table 6-6. Nonradiological Impacts of Transporting Unirradiated Fuel to the LNP Site and Alternative Sites with a Single AP1000 Reactor, Normalized to Reference LWR

Plant Type	Annual Shipments Normalized to Reference LWR	One-Way Shipping Distance (km)	Annual Round-trip Distance (km)	Annual Impacts		
				Accidents per Year	Injuries per Year	Fatalities per Year
Reference LWR (AEC 1972)	6.3	3200	4.0×10^{4}	1.9×10^{-2}	9.3×10^{-3}	5.8×10^{-4}
Reference Westinghouse AP1000	5.0	3200	3.2×10^{4}	1.5×10^{-2}	7.3×10^{-3}	4.6×10^{-4}
LNP	5.0	1166	1.2×10^{4}	6.9×10^{-3}	3.8×10^{-3}	3.1×10^{-4}
Crystal River	5.0	1152	1.1×10^{4}	6.9×10^{-3}	3.8×10^{-3}	3.1×10^{-4}
Dixie	5.0	1131	1.1×10^{4}	6.9×10^{-3}	3.8×10^{-3}	3.1×10^{-4}
Highlands	5.0	1349	1.3×10^{4}	7.1×10^{-3}	3.9×10^{-3}	3.3×10^{-4}
Putnam	5.0	1020	1.0×10^{4}	6.7×10^{-3}	3.7×10^{-3}	2.9×10^{-4}

6.2.2 Transportation of Spent Fuel

The NRC staff performed an independent analysis of the environmental impacts of transporting spent fuel from the LNP site and alternative sites to a spent fuel disposal repository. For the purposes of these analyses, the NRC staff considered the proposed Yucca Mountain site in Nevada as a surrogate destination. Currently, NRC has not made a decision on the proposed geologic repository at Yucca Mountain. However, the NRC staff considers that an estimate of the impacts of the transportation of spent fuel to a possible repository in Nevada to be a reasonable bounding estimate of the transportation impacts on a storage or disposal facility because of the distances involved and the representativeness of the distribution of members of the public in urban, suburban, and rural areas (i.e., population distributions) along the shipping routes. Radiological and nonradiological environmental impacts of normal operating conditions and transportation accidents, as well as nonradiological impacts, are discussed in this section.

This NRC staff's analysis is based on shipment of spent fuel by legal-weight trucks in shipping casks with characteristics similar to casks currently available (i.e., massive, heavily shielded, cylindrical metal pressure vessels). Due to the large size and weight of spent fuel shipping casks, each shipment is assumed to consist of a single shipping cask loaded on a modified trailer. These assumptions are consistent with those made in the evaluation of the environmental impacts of transportation of spent fuel in Addendum 1 to NUREG-1437 (NRC 1999). Because the alternative transportation methods involve rail transportation or heavy-haul trucks, which would reduce the overall number of spent fuel shipments (NRC 1999), thereby reducing impacts, these assumptions are conservative. Also, the use of current shipping cask designs for this analysis results in conservative impact estimates because the current designs are based on transporting short-cooled spent fuel (approximately 120 days out of reactor). Future shipping casks would be designed to transport longer-cooled fuel (greater than 5 years out of reactor) and would require much less shielding to meet external dose limitations. Therefore, future shipping casks are expected to have higher cargo capacities, thus reducing the numbers of shipments and associated impacts.

Radiological impacts of transportation of spent fuel were calculated by the NRC staff using the RADTRAN 5.6 computer code (Weiner et al. 2006). Routing and population data used in RADTRAN 5.6 for truck shipments were obtained from the TRAGIS routing code (Johnson and Michelhaugh 2003). The population data in the TRAGIS code are based on the 2000 census. Nonradiological impacts were calculated using published traffic accident, injury, and fatality data (Saricks and Tompkins 1999) in addition to route information from TRAGIS (Johnson and Michelhaugh 2003). Traffic accident rates input to RADTRAN 5.6 and nonradiological impact calculations were adjusted to account for under-reporting, as discussed in Sections 4.8.3 and 6.2.1.3.

6.2.2.1 Normal Conditions

Normal conditions, sometimes referred to as "incident-free" transportation, are transportation activities in which shipments reach their destination without an accident occurring en route. Impacts from these shipments would be from the low levels of radiation that penetrate the heavily shielded spent fuel shipping cask. Radiation exposures would occur to the following populations: (1) persons residing along the transportation corridors between the LNP site and alternative sites and the proposed repository location; (2) persons in vehicles traveling on the same route as a spent fuel shipment; (3) persons at vehicle stops for refueling, rest, and vehicle inspections; and (4) transportation crew workers (drivers). For purposes of this analysis, it was assumed that the destination for the spent fuel shipments is the proposed Yucca Mountain disposal facility in Nevada. This assumption is conservative, because it tends to maximize the shipping distance from the LNP site and alternative sites.

Shipping casks have not been designed for the spent fuel from advanced reactor designs such as the Westinghouse AP1000. Information in the *Early Site Permit Environmental Report Sections and Supporting Documentation* (INEEL 2003) indicated that advanced LWR fuel designs would not be significantly different from existing LWR designs; therefore, current shipping cask designs were used for the analysis of Westinghouse AP1000 reactor spent fuel shipments. The NRC staff assumed that the capacity of a truck shipment of Westinghouse AP1000 reactor spent fuel was 0.5 MTU/shipment, the same capacity as that used in WASH-1238 (AEC 1972). In its ER (PEF 2009a), PEF assumed a shipping cask capacity of 0.5 MTU/shipment.

Input to RADTRAN 5.6 includes the total shipping distance between the origin and destination sites and the population distributions along the routes. This information was obtained by running the TRAGIS computer code (Johnson and Michelhaugh 2003) for highway routes from the LNP site and alternative sites to the proposed Yucca Mountain facility. The resulting route characteristics information is shown in Table 6-7. Note that for truck shipments, all of the spent fuel is assumed to be shipped to the proposed Yucca Mountain facility over designated highway-route controlled quantity routes. In addition, TRAGIS data were used in RADTRAN 5.6 on a state-by-state basis. This increases precision and could allow the results to be presented for each state along the route between the LNP site and alternative sites and Yucca Mountain.

Table 6-7. Transportation Route Information for Shipments from the LNP Site and Alternative Sites to the Yucca Mountain Spent Fuel Disposal Facility[(a)]

Reactor Site	One-Way Shipping Distance, km				Population Density, persons/km^2			Stop Time per Trip, hr
	Total	**Rural**	**Suburban**	**Urban**	**Rural**	**Suburban**	**Urban**	
Levy County	4520.3	3479.8	935.2	105.4	9.9	318.5	2271.4	5.5
Crystal River	4506.5	3466.0	935.2	105.4	9.9	318.5	2271.4	5.5
Dixie	4407.8	3439.6	866.5	101.9	9.8	320.3	2268.2	5.5
Highlands	4867.9	3745.7	1005.0	117.4	9.9	327.6	2243.6	6.0
Putnam	4529.9	3504.3	915.2	110.6	9.8	327.0	2259.1	5.5

Source: Johnson and Michelhaugh 2003

(a) This table presents aggregated route characteristics given in the TRAGIS (Johnson and Michelhaugh 2003), including estimated distances from the LNP and alternative sites to the nearest TRAGIS highway node. Input to the RADTRAN 5.6 computer code was disaggregated to a state-by-state level.

Radiation doses are a function of many parameters, including vehicle speed, traffic count, dose rate, packaging dimensions, number in the truck crew, stop time, and population density at stops. A list of the values for these and other parameters and the sources of the information is provided in Table 6-8.

Table 6-8. RADTRAN 5.6 Normal (Incident-Free) Exposure Parameters

Parameter	RADTRAN 5.6 Input Value	Source
Vehicle speed, km/hr	88.49	Based on the average speed in rural areas given in DOE (2002a). Conservative in-transit speed of 55 mph assumed; predominantly interstate highways used.
Traffic count – Rural, vehicles/hr	State-specific	State-specific rural, suburban, and urban traffic counts are taken from Weiner et al. (2006)
Traffic count – Suburban, vehicles/hr	State-specific	
Traffic count – Urban, vehicles/hr	State-specific	
Vehicle occupancy, persons/vehicle	1.5	DOE (2002a)
Dose rate at 1 m from vehicle, mrem/hr	14	DOE (2002a, b) – approximate dose rate at 1 m that is equivalent to the 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 – 5.82 Diameter – 1.0	DOE (2002b)
Packaging dimensions, m	Length – 5.82 Diameter – 1.0	DOE (2002b)

Number of truck crew	2	AEC (1972), NRC (1977a), and DOE (2002a, b)
Stop time, hr/trip	Route-Specific	See Table 6-5
Population density at stops, persons/km^2	30,000	Sprung et al. (2000). Nine persons within 10 m of vehicle. See Figure 6-2.
Min/max radii of annular area around vehicle at stops, m	1 to 10	Sprung et al. (2000)
Shielding factor applied to annular area surrounding vehicle at stops, dimensionless	1 (no shielding)	Sprung et al. (2000)
Population density surrounding truck stops, persons/km^2	340	Sprung et al. (2000)
Min/max radius of annular area surrounding truck stop, m	10 to 800	Sprung et al. (2000)
Shielding factor applied to annular area surrounding truck stop, dimensionless	0.2	Sprung et al. (2000)

For the purposes of this analysis, the transportation crew for spent fuel shipments delivered by truck is assumed to consist of two drivers. Escort vehicles and drivers were considered, but they were not included because their distance from the shipping cask would reduce the dose rates to levels well below the dose rates experienced by the drivers and would be negligible (DOE 2002b). Stop times for refueling and rest were assumed to occur at the rate of 30 minutes per 4 hours of driving time. TRAGIS outputs were used to determine the number of stops. Doses to the public at truck stops have been significant contributors to the doses calculated in previous RADTRAN 5.6 analyses. For this analysis, doses to the public at refueling and rest stops (“stop doses”) are the sum of the doses to individuals located in two annular rings centered at the stopped vehicle, as illustrated in Figure 6-2. The inner ring represents persons who may be at the truck stop at the same time as a spent fuel shipment and extends 1 to 10 m from the edge of the vehicle. The outer ring represents persons who reside near a truck stop and it extends from 10 to 800 m from the vehicle. This scheme is similar to that used by Sprung et al. (2000). Population densities and shielding factors were also taken from Sprung et al. (2000), which were based on the observations of Griego et al. (1996).

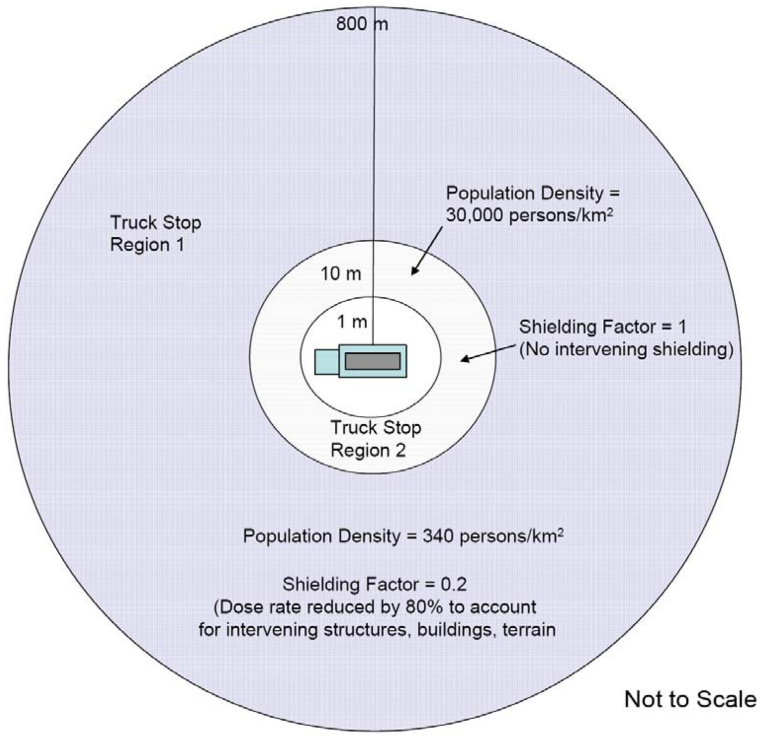

Figure 6-2. Illustration of Truck Stop Model

The results of these normal (incident-free) exposure calculations are shown in Table 6-9 for the LNP site and alternative sites. Population dose estimates are given for workers (i.e., truck crew members), onlookers (doses to persons at stops and persons on highways exposed to the spent fuel shipment), and persons along the route (persons living near the highway).

Shipping schedules for spent fuel generated by the proposed new units have not been determined. The NRC staff determined that it is reasonable to calculate annual doses assuming the annual number of spent fuel shipments is equivalent to the annual refueling requirements. Population doses were normalized to the reference LWR in WASH-1238 (880 net MW[e]). This corresponds to an 1100-MW(e) LWR operating at 80-percent capacity. Note that the impacts in Table 6-9 would be doubled for a site with two AP1000 reactors like the LNP site and the alternative sites.

Table 6-9. Normal (Incident-Free) Radiation Doses to Transport Workers and the Public from Shipping Spent Fuel from the LNP Site and Alternative Sites to the Proposed High-Level Waste Repository at Yucca Mountain

	Normalized Impacts, Person-rem/yr[a]		
Site and Reactor Type	Worker (Crew)	Onlookers	Along Route

Reference LWR (WASH-1238)[b]	1.2×10^{1}	3.0×10^{1}	6.4×10^{-1}
Levy County AP1000[c]	8.2×10^{0}	2.0×10^{1}	4.2×10^{-1}
Crystal River AP1000[c]	8.2×10^{0}	2.0×10^{1}	4.2×10^{-1}
Dixie AP1000[c]	8.0×10^{0}	2.0×10^{1}	4.0×10^{-1}
Highlands AP1000[c]	8.9×10^{0}	2.2×10^{1}	4.7×10^{-1}
Putnam AP1000[c]	8.2×10^{0}	2.0×10^{1}	4.3×10^{-1}
Table S–4 Condition	4×10^{0}	3×10^{0}	3×10^{0}

(a) To convert person-rem to person-Sv, divide by 100.
(b) Based on 60 shipments per year.
(c) Based on 40 shipments per year after normalizing to the reference LWR.

The small differences in transportation impacts among the LNP site and four alternative sites evaluated are not substantive and the differences among sites are relatively minor and are less than the uncertainty in the analytical results.

The bounding cumulative doses to the exposed population given in Table S–4 are as follows:

- 4 person-rem/reactor-year to transport workers
- 3 person-rem/reactor-year to general public (onlookers) and members of the public along the route.

The calculated population doses to the crew and onlookers for the reference LWR and the LNP and alternative site shipments exceed Table S–4 values. A key reason for the higher population doses relative to Table S–4 is the longer shipping distances assumed for this COL analysis (i.e., to a proposed repository in Nevada) than the distances used in WASH-1238 (AEC 1972). WASH-1238 assumed that each spent fuel shipment would travel a distance of 1000 mi, whereas the shipping distances used in this EIS were about 2700 mi to 3000 mi. If the shorter distance were used to calculate the impacts for the LNP and alternative sites spent fuel shipments, the doses would be reduced by about 60 percent. Other important differences are the stop model described above and the additional precision that results from incorporating state-specific route characteristics and vehicle densities on highways (vehicles per hour).

Where necessary, the NRC staff made conservative assumptions to calculate impacts associated with the transportation of spent fuel. Some of the key conservative assumptions are as follows:

- <u>Use of the regulatory maximum dose rate (10 mrem/hr at 2 m) in the RADTRAN 5.6 calculations</u>. The shipping casks assumed in the EIS prepared by DOE in support of the application for a geologic repository at the proposed Yucca Mountain repository (DOE 2002b) would transport spent fuel that has cooled for a minimum of 5 years (see 10 CFR Part 961, Subpart B). Most spent fuel would have cooled for much longer than

5 years before it is shipped to a possible geologic repository. Based on this, shipments from the LNP site and alternative sites also are expected to be cooled for longer than 5 years. Consequently, the estimated population doses in Table 6-9 could be further reduced if more realistic dose rate projections are used.

- Use of the shipping cask capacity used in WASH-1238. The WASH-1238 analyses that form the basis for Table S–4 assumed that spent fuel would be shipped at least 90 days after discharge from a current LWR. The spent fuel shipping casks described in WASH-1238 were designed to transport 90-day-cooled fuel, so their shielding and containment designs must accommodate this highly radioactive cargo. Shipping-cask capacities assumed in WASH-1238 were approximately 0.5 MTU per truck cask. In the Yucca Mountain Supplemental EIS (DOE 2008), DOE assumed a 10-year cooling period for spent fuel to be shipped to the repository. This allowed DOE to increase the assumed shipping-cask capacity to about 1.8 MTU per truck shipment of un-canistered spent fuel. The NRC staff believes this is a reasonable projection for future spent fuel truck shipping cask capacities. If this assumption were to be used in this EIS, the number of shipments of spent fuel would be reduced by about one-third with a similar reduction in radiological incident-free impacts.

- Use of 30 minutes as the average time at a truck stop in the calculations. Many stops made for actual spent fuel shipments are of short duration (i.e., 10 minutes) for brief visual inspections of the cargo (e.g., checking the cask tie-downs). These stops typically occur in minimally populated areas, such as an overpass or freeway ramp in an unpopulated area. Furthermore, empirical data provided by Griego et al. (1996) indicate that a 30-minute duration is toward the high end of the stop time distribution. Average stop times observed by Griego et al. (1996) are on the order of 18 minutes. More realistic stop times would further reduce the population doses in Table 6-9.

A sensitivity study was performed by the NRC staff to demonstrate the effects of using more realistic dose rates and stop times on the incident-free population dose calculations. For this sensitivity study, the dose rate was reduced to 5 mrem/hr, the approximate 50-percent confidence interval of the dose rate distribution estimated by Sprung et al. (2000) for future spent fuel shipments. The stop time was reduced to 18 minutes per stop. All other RADTRAN 5.6 input values were unchanged. The result is that the annual crew doses were reduced to 4.9 person-rem/yr, or about 60 percent of the annual dose shown in Table 6-9. The annual onlooker doses were reduced to 5.3 person-rem/yr (about 27 percent) and the annual doses to persons along the route were reduced to 1.5×10^{-1} person-rem/yr (about 36 percent).

In its ER (PEF 2009a), PEF describes the results of a RADTRAN 5.6 analysis of the impacts of incident-free transport of spent fuel to Yucca Mountain. The PEF analysis and this EIS used similar methods and input parameters. The NRC staff concluded that the results produced by PEF are similar to those calculated by the NRC staff and reported in this EIS.

Using the linear no-threshold dose response relationship discussed in Section 6.2.1.1, the annual public dose impacts for transporting spent fuel from the LNP or alternative sites to Yucca Mountain are about 22 person-rem, which is less than the 1754 person-rem value that ICRP (2007) and NCRP (1995) suggest would most likely result in no excess health effects. This dose is very small compared to the estimated 2.5×10^5 person-rem that the same population along the route from the LNP site to Yucca Mountain would incur annually from exposure to natural sources of radiation. Note that the estimated population dose along the LNP-to-Yucca-Mountain route from natural background radiation is different than the natural background dose calculated by the NRC staff for unirradiated fuel shipments in Section 6.2.1.1 of this EIS because the route characteristics are different. A generic route and actual highway routes were used in Section 6.2.1.1 for unirradiated fuel shipments and actual highway routes were used in this section for spent fuel shipments.

Dose estimates to the MEI from transport of unirradiated fuel, spent fuel, and wastes under normal conditions are presented in Section 6.2.1.1.

6.2.2.2 Radiological Impacts of Accidents

As discussed previously, the NRC staff used the RADTRAN 5.6 computer code to estimate the impacts of transportation accidents involving spent fuel shipments. RADTRAN 5.6 considers a spectrum of postulated transportation accidents, ranging from those with high frequencies and low consequences (e.g., “fender benders”) to those with low frequencies and high consequences (i.e., accidents in which the shipping container is exposed to severe mechanical and thermal conditions).

Radionuclide inventories are important parameters in the calculation of accident risks. The radionuclide inventories used in this analysis were from *Early Site Permit Environmental Report Sections and Supporting Documentation* (INEEL 2003) and are the same as those presented in PEF’s ER (PEF 2009a). The Idaho National Engineering and Environmental Laboratory (INEEL) report includes 140 radionuclides for Westinghouse AP1000 reactor spent fuel. The NRC staff conducted a screening analysis to select the dominant contributors to accident risks to simplify the RADTRAN 5.6 calculations. The screening identified the radionuclides that would contribute more than 99.999 percent of the dose from inhalation of radionuclides released following a transportation accident. Spent fuel inventories used in the NRC staff analysis are listed in Table 6-10. The list includes all of the radionuclides that were included in the analysis conducted by Sprung et al. (2000). However, INEEL (2003) did not provide radionuclide source terms for radioactive material deposited on the external surfaces of LWR spent fuel rods (commonly called “crud”). Because crud is deposited from corrosion products generated elsewhere in the reactor cooling system and the complete reactor design and operating parameters are uncertain, the quantities and characteristics of crud deposited on Westinghouse AP1000 reactor spent fuel are not available at this time. The Westinghouse AP1000 reactor spent fuel transportation accident impacts were calculated by the NRC staff assuming that the cobalt-60 inventory in the form of crud is 4.4 TBq/MTU (120 Ci/MTU), based on information provided by Sprung et al. (2000). PEF also included the impacts of crud in its spent fuel transportation impact analysis (PEF 2009a).

Table 6-10. Radionuclide Inventories Used in Transportation Accident Risk Calculations for the Westinghouse AP1000 Reactor[a,b]

Radionuclide	Ci/MTU	Bq/MTU
Pu-241	6.96×10^{4}	2.57×10^{15}
Pu-238	6.07×10^{3}	2.24×10^{14}
Cm-244	7.75×10^{3}	2.87×10^{14}
Am-241	7.27×10^{2}	2.69×10^{13}
Pu-240	5.43×10^{2}	2.01×10^{13}
Pu-239	2.55×10^{2}	9.44×10^{12}
Sr-90	6.19×10^{4}	2.29×10^{15}
Cs-137	9.31×10^{4}	3.44×10^{15}
Am-243	3.34×10^{1}	1.24×10^{12}
Cm-243	3.07×10^{1}	1.13×10^{12}
Am-242m	1.31×10^{1}	4.85×10^{11}

Table 6-10. (contd)

Radionuclide	Ci/MTU	Bq/MTU
Ru-106	1.55×10^{4}	5.72×10^{14}
Eu-154	9.13×10^{3}	3.38×10^{14}
Cs-134	4.80×10^{4}	1.78×10^{15}
Ce-144	8.87×10^{3}	3.28×10^{14}
Sb-125	3.83×10^{3}	1.42×10^{14}
Pu-242	1.82×10^{0}	6.72×10^{10}
Cm-242	2.83×10^{1}	1.05×10^{12}
Pm-147	1.76×10^{4}	6.52×10^{14}
Cm-245	1.21×10^{0}	4.46×10^{10}
Y-90	6.19×10^{4}	2.29×10^{15}
Eu-155	4.62×10^{3}	1.71×10^{14}
Co-60[b]	1.20×10^{2}	4.40×10^{12}

Source: INEEL 2003 except where otherwise indicated.
(a) Divide becquerel/metric ton uranium (Bq/MTU) by 3.7×10^{10} to obtain curies/MTU.
(b) Cobalt-60 is the key radionuclide constituent of fuel assembly crud. The inventory was derived using data given by Sprung et al. (2000).

Robust shipping casks are used to transport spent fuel because of the radiation shielding and accident resistance required by 10 CFR Part 71. Spent fuel shipping casks must be certified Type B packaging systems, meaning they must withstand a series of severe postulated accident conditions with essentially no loss of containment or shielding capability. These casks also are designed with fissile material controls to ensure that the spent fuel remains subcritical under normal and accident conditions. According to Sprung et al. (2000), the probability of encountering accident conditions that would lead to shipping cask failure is less than 0.01 percent (i.e., more than 99.99 percent of all accidents would result in no release of radioactive material from the shipping cask). The NRC staff assumed that shipping casks approved for transportation of Westinghouse AP1000 reactor spent fuel would provide equivalent mechanical and thermal protection of the spent fuel cargo.

Accident frequencies are calculated in RADTRAN 5.6 using user-specified accident rates and conditional shipping cask failure probabilities. State-specific accident rates were taken from Saricks and Tompkins (1999) and used in the RADTRAN 5.6 calculations. The state-specific accident rates were then adjusted to account for under-reporting, as described in Section 6.2.1.3. Conditional shipping cask failure probabilities (that is, the probability of cask failure as a function of the mechanical and thermal conditions applied in an accident) were taken from Sprung et al. (2000).

The RADTRAN 5.6 accident risk calculations were performed using the radionuclide inventories (Ci/MTU) in Table 6-10 multiplied by the shipping cask capacity (0.5 MTU). The resulting risk estimates were then multiplied by assumed annual spent fuel shipments (shipments/yr) to derive estimates of the annual accident risks associated with spent fuel shipments from the LNP site and alternative sites to the proposed repository at Yucca Mountain in Nevada. As was done for routine exposures, the NRC staff assumed that the numbers of shipments of spent fuel per year are equivalent to the annual discharge quantities.

For this assessment, release fractions for current-generation LWR fuel designs (Sprung et al. 2000) were used to approximate the impacts from the Westinghouse AP1000 reactor spent fuel shipments. This assumes that the fuel materials and containment systems (i.e., cladding, fuel coatings) behave similarly to current LWR fuel under applied mechanical and thermal conditions.

The NRC staff used RADTRAN 5.6 to calculate the population dose from the released radioactive material from four of five possible exposure pathways.[(a)] These pathways areas follows:

- external dose from exposure to the passing cloud of radioactive material (cloudshine).
- external dose from the radionuclides deposited on the ground by the passing plume (groundshine). The NRC staff's analysis included the radiation exposure from this pathway even though the area surrounding a potential accidental release would be evacuated and decontaminated, thus preventing long-term exposures from this pathway.
- internal dose from inhalation of airborne radioactive contaminants (inhalation).
- internal dose from resuspension of radioactive materials that were deposited on the ground (resuspension). The NRC staff's analysis included the radiation exposures from this pathway even though evacuation and decontamination of the area surrounding a potential accidental release would prevent long-term exposures.

Table 6-11 presents the environmental consequences of transportation accidents when shipping spent fuel from the LNP site and alternative sites to the proposed Yucca Mountain repository. The shipping distances and population distribution information for the routes were the same as those used for the normal "incident-free" conditions (see Section 6.2.2.1). The results are normalized to the WASH-1238 reference reactor (880-MW[e] net electrical generation, 1100-MW[e] reactor operating at 80-percent capacity) to provide a common basis for comparison to the impacts listed in Table S–4. Although there are slight differences in impacts among alternative sites, none of the alternative sites would be clearly favored over the LNP site. The impacts would be doubled for two AP1000 reactors at the LNP site or alternative sites.

Table 6-11. Annual Spent Fuel Transportation Accident Impacts for an AP1000 Reactor at the LNP Site and Alternative Sites, Normalized to Reference 1100-MW(e) LWR Net Electrical Generation

Site, Reactor Type	Normalized Population Impacts, Person-rem/yr[(a)]
Reference LWR (WASH-1238)[(b)]	1.4×10^{-4}
Levy County AP1000[(c)]	9.2×10^{-5}
Crystal River AP1000[(c)]	9.2×10^{-5}
Dixie AP1000[(c)]	9.1×10^{-5}
Highlands AP1000[(c)]	9.4×10^{-5}

(a) Internal dose from ingestion of contaminated food was not considered because the NRC staff assumed evacuation and subsequent interdiction of foodstuffs following a postulated transportation accident.

Putnam AP1000[c]	9.2×10^{-5}

(a) Divide person-rem/yr by 100 to obtain person-Sv/yr.
(b) Based on 60 shipments per year.
(c) Based on 40 shipments per year after normalizing to the reference LWR.

The transportation accident impact analysis conducted by PEF (PEF 2009a) used methods and data that are similar to those used in this EIS. Differences are insignificant in terms of the overall results.

Using the linear no-threshold dose response relationship discussed in Section 6.2.1.1, the annual collective public dose estimate for transporting spent fuel from the LNP and alternative sites to Yucca Mountain is less than 1×10^{-4} person-rem, which is less than the 1754 person-rem value that ICRP (2007) and NCRP (1995) suggest would most likely result in zero excess health effects. The collective population dose from natural background radiation to the population along the representative routes from the LNP and alternative sites to Yucca Mountain would be about 2.5×10^{5} person-rem. Therefore, the radiation doses from transporting spent fuel to Yucca Mountain are minimal compared to the collective population dose to the same population from exposure to natural sources of radiation.

6.2.2.3 Nonradiological Impact of Spent Fuel Shipments

The general approach used to calculate the nonradiological impacts of spent fuel shipments is the same as that used for unirradiated fuel shipments. State-by-state shipping distances were obtained from the TRAGIS output file and combined with the annual number of shipments and accident, injury, and fatality rates by state from Saricks and Tompkins (1999) to calculate nonradiological impacts. In addition, the accident, injury, and fatality rates from Saricks and Tompkins (1999) were adjusted to account for under-reporting (see Section 6.2.1.3). The results are shown in Table 6-12 for a single AP1000 reactor. The impacts would be doubled for a site with two AP1000 reactors like the LNP site and the alternative sites. Overall, the impacts are minimal and there are no substantive differences among the alternative sites.

Table 6-12. Nonradiological Impacts of Transporting Spent Fuel from the LNP Site and Alternative Sites to Yucca Mountain for a Single AP1000 Reactor, Normalized to Reference LWR

Site	One-Way Shipping Distance, km	Nonradiological Impacts, per year		
		Accidents	**Injuries**	**Fatalities**
Levy County	4520.3	1.5×10^{-1}	8.7×10^{-2}	6.2×10^{-3}
Crystal River	4506.5	1.5×10^{-1}	8.7×10^{-2}	6.2×10^{-3}
Dixie	4407.8	1.4×10^{-1}	8.7×10^{-2}	6.1×10^{-3}
Highland	4867.9	1.5×10^{-1}	8.9×10^{-2}	6.6×10^{-3}

Putnam	4529.9	1.5×10^{-1}	8.7×10^{-2}	6.2×10^{-3}

Note: The number of shipments of spent fuel assumed in the calculations is 40/yr after normalizing to the reference LWR.

6.2.3 Transportation of Radioactive Waste

This section discusses the environmental effects of transporting radioactive waste other than spent fuel from the LNP site and alternative sites. The environmental conditions listed in 10 CFR 51.52 that apply to shipments of radioactive waste are as follows:

- Radioactive waste (except spent fuel) would be packaged and in solid form.
- Radioactive waste (except spent fuel) would be shipped from the reactor by truck or railcar.
- The weight limitation of 33,100 kg (73,000 lb) per truck and 90.7 MT (100 T) per cask per railcar would be met.
- Traffic density would be less than the condition of one truck shipment per day or three railcars per month.

Radioactive waste other than spent fuel from the Westinghouse AP1000 reactor is expected to be capable of being shipped in compliance with Federal or State weight restrictions. Table 6-13 presents estimates of annual waste volumes and annual waste shipment numbers for a Westinghouse AP1000 reactor at the LNP site normalized to the reference 1100-MW(e) LWR defined in WASH-1238 (AEC 1972). The expected annual waste volumes and waste shipments for the Westinghouse AP1000 reactor were less than the 1100-MW(e) reference reactor that was the basis for Table S–4. The maximum projected waste-generation rates for the Westinghouse AP1000 reactor (5717 ft^3 per year is the maximum estimated rate given by Westinghouse (2008) could exceed the reference LWR waste-generation rate. However, projections of the rate of waste generation are uncertain and are a function of PEF’s radioactive waste-management practices. Therefore, waste-generation rates for the proposed LNP reactors are anticipated to be much closer to the expected rate, shown in Table 6-13, than the maximum rate.

Table 6-13. Summary of Radioactive Waste Shipments from the LNP Site and Alternative Sites for a Single AP1000 Reactor

Reactor Type	Waste-Generation Information	Annual Waste Volume, m^3/yr per Unit	Electrical Output, MW(e) per Unit	Normalized Rate, m^3/1100 MW(e) Unit (880 MW[e] Net)[a]	Shipments/ 1100 MW(e) (880 MW[e] Net) Electrical Output[b]
Reference LWR (WASH-1238)	3800 ft^3/yr per unit	108	1100	108	46

Levy County Westinghouse AP1000, expected	1964 ft^3/yr per unit[(c)]	56	1115[(c)]	47	21

Conversions: 1 m^3 = 35.31 ft^3. Drum volume = 210 L (0.21 m^3).
(a) Capacity factors used to normalize the waste-generation rates to an equivalent electrical generation output are 80 percent for the reference LWR (AEC 1972) and 93 percent for the proposed LNP Westinghouse AP1000 (PEF 2009a). Waste generation for the Westinghouse AP1000 is normalized to 880 MW(e) net electrical output (1100-MW[e] unit with an 80-percent capacity factor).
(b) The number of shipments per 1100 MW(e) was calculated assuming the WASH-1238 average waste shipment capacity of 2.34 m^3 (82.6 ft^3 per shipment [108 m^3/yr divided by 46 shipments/yr]).
(c) This value was taken from the PEF ER (PEF 2009a).

The sum of the daily shipments of unirradiated fuel, spent fuel, and radioactive waste is well below the one-truck-shipment-per-day condition given in 10 CFR 51.52, Table S–4, for a Westinghouse AP1000 reactor located at the LNP site and alternative sites. Doubling the shipment estimates to account for empty return shipments of fuel and waste is included in the results. An additional doubling to account for a second reactor at the LNP site or alternative sites is also less than the one-shipment-per-day condition.

Dose estimates to the MEI from transport of unirradiated fuel, spent fuel, and waste under normal conditions are presented in Section 6.2.1.1.

The nonradiological impacts of radioactive waste shipments were calculated using the same general approach used for unirradiated and spent fuel shipments. For this EIS, the shipping distance was assumed to be 500 mi one way (AEC 1972). Because the actual destination is uncertain, national median accident, injury, and fatality rates were used in the calculations (Saricks and Tompkins 1999). These rates were adjusted to account for under-reporting, as described in Section 6.2.1.3. The results are presented in Table 6-14. As shown, the calculated nonradiological impacts for transportation of radioactive waste other than spent fuel from the LNP site and alternative sites to waste disposal facilities are less than the impacts calculated for the reference LWR in WASH-1238.

Table 6-14. Nonradiological Impacts of Radioactive Waste Shipments from the LNP Site and Alternative Sites with a Single AP1000 Reactor

	Shipments per Year	**One-Way Distance, km**	**Accidents per Year**	**Injuries per Year**	**Fatalities per Year**
Reference LWR (WASH-1238)	46	800	3.4×10^{-2}	1.7×10^{-2}	1.1×10^{-3}
LNP and Alternative Sites, Westinghouse AP1000	21	800	1.6×10^{-2}	7.8×10^{-3}	4.9×10^{-4}

Note: The shipments and impacts have been normalized to the reference LWR.

6.2.4 Conclusions for Transportation

The NRC staff performed an independent confirmatory analysis of the impacts under normal operating and accident conditions of transporting fuel and wastes to and from a Westinghouse AP1000 reactor to be located at the LNP site. Four alternative sites also were evaluated, including Crystal River, Dixie, Highlands, and Putnam (see PEF 2009a). To make comparisons to Table S–4, the environmental impacts were adjusted (i.e., normalized) to the environmental impacts associated with the reference LWR in WASH-1238 (AEC 1972) by multiplying the AP1000 reactor impact estimates by the ratio of the total electric output for the reference reactor to the electric output of the proposed reactor.

Because of the conservative approaches and data used to calculate impacts, the NRC staff does not expect the actual environmental effects to exceed those calculated in this EIS. Thus, the NRC staff concludes that the environmental impacts of the transportation of fuel and radioactive wastes to and from the LNP site and alternative sites would be SMALL, and would be consistent with the environmental impacts associated with the transportation of fuel and radioactive wastes to and from current-generation reactors presented in Table S–4 of 10 CFR 51.52.

The NRC staff notes that on March 3, 2010, DOE (2010) submitted a motion to the Atomic Safety and Licensing Board to withdraw with prejudice its application for a permanent geologic repository at Yucca Mountain, Nevada. Regardless of the outcome of this motion, the NRC staff concludes that transportation impacts are roughly proportional to the distance from the reactor site to the repository site, in this case Florida to Nevada. The distance from the LNP site or any of the alternative sites to any new planned repository in the contiguous United States would be no more than double the distance from the LNP site or alternative sites to Yucca Mountain. Doubling the environmental impact estimates from the transportation of spent reactor fuel, as presented in this section, would provide a reasonable bounding estimate of the impacts to meet the needs of the National Environmental Policy Act of 1969, as amended (NEPA). The NRC staff concludes that the environmental impacts of these doubled estimates would still be SMALL.