APPENDIX A
DETAILED EVALUATION OF NORMAL OPERATIONS AND ADJACENT CONDITIONS DURING LOADING, STORAGE, AND UNLOADING OPERATIONS

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APPENDIX A

A. DETAILED EVALUATION OF NORMAL OPERATIONS AND ACCIDENT CONDITIONS DURING LOADING, STORAGE, AND UNLOADING OPERATIONS

This section presents estimated environmental consequences, event probabilities, and risks (a product of probability and consequence) for both normal operations and postulated accident scenarios related to the loading, storage, and unloading of naval spent nuclear fuel. Normal operations and accidents are evaluated to estimate the potential for releases of radioactive material. The results of these analyses are presented in terms of the predicted health effects to facility workers and the public due to the release of radioactive materials into the environment. Effects on environmental factors are also presented, based on the amount of land which could be affected due to postulated accidents.

Analytical results for loading are presented for two locations at the Department of Energy's (DOE's) Idaho National Engineering Laboratory (INEL), the Naval Reactors Facility and the Idaho Chemical Processing Plant, which hold all of the naval spent nuclear fuel. Analytical results for dry storage are presented for these same two locations in addition to a location on the INEL site near Birch Creek (hereafter referred to as the Birch Creek Area), which is representative of a hypothetical dry storage location which is not immediately above the Snake River Plain Aquifer. It is expected that other areas on the western boundary of the INEL site which may not be located above the Snake River Plain Aquifer, like the Lemhi Range Area, would have radiological impacts similar to those presented in this Appendix for the Birch Creek Area. For more detailed information on alternative dry storage locations, see Appendix F. Analytical results for surface facility unloading operations are presented for a hypothetical mined deep geologic repository or a centralized interim storage facility.

A.1 Summary

Analyses of normal operations, and design basis and beyond design basis hypothetical accidents, were performed to estimate the potential consequences due to release of radioactive materials. The analytical results for radiological operations have been summarized by the locations and alternatives being considered in this Environmental Impact Statement (EIS).

A.1.1 Historical Accident Record

The Naval Nuclear Propulsion Program has a well documented nuclear safety record. In more than 4,600 reactor-years of operation and more than 350 refuelings and defuelings of naval reactors, there has never been a nuclear reactor accident or criticality accident. Moreover, there has never been a transportation accident that has resulted in any significant release of radioactivity to the environment.

A.1.2 Normal Operations

Table A.1 presents the estimated number of annual latent cancer fatalities to the general population living within a 50-mi (approximately 80-km) radius of each facility due to radiological releases from normal operations. The results in this table were calculated using the methods described in Section A.2.3. The number of latent cancer fatalities is very low at all locations and for all alternatives. The number of total health effects (deaths, nonfatal cancers, genetic effects, and other impacts on human health) may be obtained by multiplying the latent cancer fatalities by the factor of 1.46, as described in Section A.2.3. For normal operations, the impacts on the general population are similar for both Multi-Purpose Canisters, the Dual-Purpose Canister, and the Transportable Storage Cask Alternatives for loading and dry storage at INEL; however, for the No-Action and Current Technology/Rail Alternatives, the impacts are greater since the dry storage containers must be opened at INEL to load the spent nuclear fuel into the M-140 shipping containers. At a repository or centralized interim storage facility, the Multi-Purpose Canister Alternatives result in a lower risk than the other container alternatives since the canisters are not opened to remove the spent nuclear fuel.

TABLE A.1 Annual Latent Cancer Fatalities from Normal Operations[a]

Alternative	Latent Cancer Fatalities to General Population within 50-Mile Radius of Site: NRF	ICPP	Repository or Storage Facility
Multi-Purpose Canister Alternatives	5.4×10^{-8}	7.2×10^{-7}	N/A[b]
Transportable Storage Cask and Dual-Purpose Canister Alternatives	5.4×10^{-8}	7.2×10^{-7}	1.2×10^{-5}
No-Action and Current Technology/Rail Alternatives	4.6×10^{-6}	5.3×10^{-6}	1.2×10^{-5}

[a] Notation: ICPP = Idaho Chemical Processing Plant; NRF= Naval Reactors Facility.

[b] Multi-Purpose Canisters are not opened at a repository or centralized interim storage facility, thus there is no release of radiological materials to the environment.

A.1.3 Hypothetical Accident Evaluations

Several hypothetical accidents were analyzed at each facility for each of the alternatives. The results are summarized in Tables A.2 and A.3. The results in these tables were calculated using the methods described in Section A.2.3. Both latent cancer fatalities from the maximum foreseeable accident at each location and the most severe risk from a facility accident at each location are presented. Risk is defined as the product of the consequences of an event multiplied by the probability of that event. The risks associated with the accidents analyzed have not been added together because the occurrences of the postulated accidents are independent events. The risks presented in this appendix cover the complete range of accidents which might make a detectable contribution to overall risk and additional analyses would not be expected to result in increases in calculated risk. Due to low altitude testing of commercial jetliners near to the Idaho Chemical Processing Plant, the facility accident which results in the highest number of latent cancer fatalities (consequences) is an airplane crash into either a multi-purpose canister or a high-capacity M-140 cask at the Idaho Chemical Processing Plant. The facility accident which results in the highest risk (a product of probability and consequence) is a drained water pool at the Idaho Chemical Processing Plant. The risk is higher at the Idaho Chemical Processing Plant than at the Expended Core Facility due to the large amount of naval spent nuclear fuel stored in the Building 666 water pools. As was the case for the normal operations evaluation, the accident risk is very low at all locations and for all alternatives. In addition, as discussed in Section A.2.7, due to conservative analysis techniques (e.g., worst case meteorological conditions, conservative source terms, no mitigative measures, etc.), the risks presented in this Appendix are believed to be at least 10 to 100 times larger than would actually occur.

TABLE A.2 Latent Cancer Fatalities from a Maximum Foreseeable Facility Accident[a]

	Latent Cancer Fatalities per Accident to General Population within a 50-Mile Radius of Site over 50 Years		
Alternative	NRF[b]	ICPP[c]	Repository or Storage Facility[d]
Multi-Purpose Canister	1.7×10^{-2}	2.6	1.5×10^{-3}
No-Action	1.7×10^{-2}	1.6	1.0×10^{-3}
Current Technology/Rail	1.7×10^{-2}	2.4	1.8×10^{-3}
Transportable Storage Cask	1.7×10^{-2}	2.4	1.8×10^{-3}
Dual-Purpose Canister	1.7×10^{-2}	2.4	1.8×10^{-3}
Small Multi-Purpose Canister	1.7×10^{-2}	1.3	1.0×10^{-3}

[a] Notation: ICPP = Idaho Chemical Processing Plant; NRF= Naval Reactors Facility.
[b] Drained water pool.
[c] Airplane crash.
[d] Wind-driven projectile.

TABLE A.3 Most Severe Risk from a Facility Accident[a]

	Annual Risk of Latent Cancer Fatalities to General Population within a 50-Mile Radius of Site		
Alternative	NRF[b]	ICPP[b]	Repository or Storage Facility[c]
Multi-Purpose Canister	1.7×10^{-7}	2.4×10^{-6}	1.5×10^{-8}
No-Action and Small Multi-Purpose Canister	1.7×10^{-7}	2.4×10^{-6}	1.0×10^{-8}
All others	1.7×10^{-7}	2.4×10^{-6}	1.8×10^{-8}

[a] Notation: ICPP = Idaho Chemical Processing Plant; NRF= Naval Reactors Facility.
[b] Drained water pool.
[c] Wind-driven projectile.

Table A.4 presents a summary of the risk of latent cancer fatalities by alternative for normal operations and most severe facility accident for each alternative. Consistent with the detailed tables, this summary table shows that all alternatives and all locations associated have very low risk.

TABLE A.4 Risk of Latent Cancer Fatalities by Alternative

Alternative	Annual Risk of Latent Cancer Fatalities to General Population within a 50-Mile Radius of Site	
	Normal Operations[a]	Facility Accident
Multi-Purpose Canister Alternatives	7.7×10^{-7}	2.4×10^{-6}
Transportable Storage Cask and Dual-Purpose Canister Alternatives	1.3×10^{-5}	2.4×10^{-6}
No-Action and Current Technology/Rail Alternatives	2.2×10^{-5}	2.4×10^{-6}

[a] The normal operations risk presented here is a summation of the risks at INEL and a geologic repository or centralized interim storage facility.

A.1.4 Other Radiological Impacts

The radiological impact of accidents on the environs of a facility was determined by examining the area that could be contaminated following such an event. Calculations using average meteorological conditions were performed for each accident scenario. These calculations determined the extent of the contamination which might cause an increase over the background radiation from naturally occurring sources. For the accidents evaluated, the contaminated area would be confined within the boundaries of the site. The impact of this contamination would be temporary while the area was isolated and remediation efforts completed. Although not specifically analyzed due to a probability of less than 1×10^{-7}, an airplane crash into a new dry storage facility near the Birch Creek Area at INEL could result in about 500 acres becoming contaminated outside the boundary of INEL due to its location close to the site boundary. However, even in this case the level of contamination would be low and the impact temporary.

A.2 Radiological Issues from Naval Spent Nuclear Fuel Loading, Storage, and Unloading

Naval spent nuclear fuel is currently held in water pools at the Idaho Chemical Processing Plant and at the Naval Reactors Facility's Expended Core Facility, both located on the INEL. The Expended Core Facility is a large laboratory facility used to receive, examine, and prepare for shipment, naval spent nuclear fuel and irradiated test specimen assemblies. Enclosed work areas at the Expended Core Facility include an array of interconnected reinforced concrete water pools which permit visual observation of naval spent nuclear fuel during handling and inspection while shielding workers from radiation. Adjacent to the water pools are shielded cells used for operations which must be performed dry. From 1953 to 1992 the Idaho Chemical Processing Plant recovered usable uranium from spent nuclear fuel; however, in 1992, DOE shutdown the reprocessing operation.

A.2.1 Normal Operations

Loading Operations. The activities analyzed in this EIS for naval spent nuclear fuel loading operations are those that would take place at INEL. These activities include handling and removal of the spent nuclear fuel from the water pools at either the Expended Core Facility or the Idaho Chemical Processing Plant and loading the spent nuclear fuel into a container. The loading operations analyses cover operations at these facilities which could take place while handling spent nuclear fuel both in the water pools and in a dry cell facility, and encompassing all operations to load the containers and prepare them for either dry storage at INEL or transportation to a repository. Since loading operations involve handling individual spent fuel assemblies and are similar for all alternatives, the container hardware system has no impact on the expected radiological releases due to normal operations. Separate analyses were performed for the Expended Core Facility and the Idaho Chemical Processing Plant.

Dry Storage. The activities analyzed in this EIS for naval spent nuclear fuel dry storage are those that take place at INEL. These activities include dry storage in the container hardware system selected for use at either the Expended Core Facility, the Idaho Chemical Processing Plant, or the Birch Creek Area. Since similar amounts of spent nuclear fuel will be stored at each location under the various alternatives and no airborne releases are expected from the sealed containers, the alternative container designs do not impact the normal operations analyses results.

Unloading Operations. The activities analyzed in this EIS for naval spent nuclear fuel unloading operations are those that would take place at a repository surface facility. These activities include receipt of and preparation for disposal of the naval spent nuclear fuel shipments from INEL. For the purpose of this EIS, it has been assumed that under the alternatives which result in spent nuclear fuel arriving in multi-purpose canisters, the fuel will not be removed from the canister; however, for all other alternatives, the containers will be opened to remove the spent nuclear fuel and to place it in a separate disposal container. For all alternatives, the unloading operations will take place in dry, heavily shielded transfer rooms within the surface facility waste handling building.

A.2.2 Screening/Selection of Accidents for Detailed Examination

Accidents were considered for inclusion in detailed analyses if they were expected to contribute substantially to risk. Accidents were categorized into three types as either Abnormal Events, Design-Basis Accidents, or Beyond Design-Basis Accidents. These categories are characterized by their probability of occurrence as described further in Section A.2.3. Construction and industrial accidents are included in these categories.

In selecting accidents to include in detailed analyses, several considerations were utilized. Initiating events included natural phenomena (earthquakes, volcanic activity, tornadoes, hurricanes, and other natural events) and human-induced events (human error, equipment failures, fires, explosions, plane crashes, transportation accidents, and terrorism). Guiding principles were established, such as, the radioactive materials involved must be available in a dispersible form; there must be a mechanism available for release of such materials from the facility; and, there must be a mechanism available for off-site dispersion of the released materials. The pathways whereby members of the public can be affected from the radiological aspects of spent nuclear fuel operations are direct exposure to radiation, inhalation of radioactive materials, and ingestion of radioactive materials.

Recognizing these fundamental processes and pathways, accidents involving the following basic phenomena were identified:

- Loss of shielding of radioactive materials,
- Release of radioactive products to the environment due to overheating of fuel,
- Release of radioactive products to the environment due to mechanical shock or damage, or inadvertent breaching of fuel cladding or containment,
- An unplanned criticality, and
- Transportation accidents.

After the basic phenomena were identified, other references were consulted to ensure that all important accidents were considered. These included safety analysis reports, court decisions, other EISs, and summary documents such as the "Final Generic Environmental Impact Statement on Handling and Storage of Spent Light Water Reactor Power Reactor Fuel" (Nuclear Regulatory Commission (NRC 1979a)) and "The Safety of the Nuclear Fuel Cycle" (Nuclear Energy Agency 1993).

Examining the kinds of accidents which could result in release of radioactive material to the environment or an increase in radiation levels shows that they can only occur if an accident produces severe conditions. Some types of accidents, such as procedure violations, spills of small volumes of water containing radioactive particles, and most other types of common human error, may occur more frequently than the more severe accidents analyzed. However, they do not involve enough radioactive material or radiation to result in a significant release to the environment or a meaningful increase in radiation levels. Stated another way, the very low consequences associated with these events produce smaller risks than those for the accidents analyzed, even when combined with a higher probability of occurrence. Consequently, they have not been included in the results presented in this EIS.

Acts of terrorism are expected to result in consequences which are bounded by the results of accidents which are evaluated. Naval spent nuclear fuel is not considered to be attractive to terrorists due to the bulk of the fuel containers and due to high radiation fields involved with unshielded spent nuclear fuel. However, terrorist attacks on naval fuel during shipment were evaluated. The massive structure of the containers used for naval spent nuclear fuel makes them an unlikely target of a terrorist attack. No such attacks have occurred in the nearly 40 years of rail shipments which have now traveled about 2 million kilometers. Thus, the probability of a terrorist attack on a shipment is judged to be no more than the probability of a rail accident which is listed in Section B.5.2 of this Environmental Impact Statement. The consequences of a terrorist attack are also judged to be no more severe than those listed for the transportation accidents. Therefore, the same conclusions reached for transportation accidents apply to the risk to the extremely rugged shipping containers from terrorist attack during a shipment. In addition, during shipment, all naval spent nuclear fuel containers are accompanied by escorts who remain in contact with the communications center. In the event of an emergency, state and federal resources would be quickly summoned to stabilize the situation.

For an act of war, sabotage, or terrorist attack, it is likely the risk would be lower than calculated for an airplane crash because it should be less probable that a force would exist to disperse radioactive products into the atmosphere from a weapon as compared to the motive force of the fire assumed in the case of an airplane crash. For example, attacks on containers using anti-tank weapons would be less severe than the accidents analyzed because: (a) anti-tank weapons would cause a self-sealing penetration in the metal of a container, unlike that which is assumed from the airplane crash (impact from a 50-inch diameter engine rotor); (b) there is no explosive material inside the container, so it will not "blow-up" as a tank would if hit by such a weapon (in a tank attack, the tank shells inside the turret detonate); (c) there would be no fire to disperse the radioactivity that is released when the container is breached, unlike an aircraft crash where the jet fuel will burn creating such a fire. The rugged design of containers reduces the effects of other types of explosive charges. It is not credible that a terrorist attack would result in a criticality or meltdown of spent nuclear fuel; however, in Section A.2.5, the consequences of a hypothetical criticality accident are presented. The risks associated with an accidental criticality are less than those associated with a drained water pool or an airplane crash into dry storage containers.

The effect of a terrorist attack or an act of sabotage is expected to be conservatively bounded by the limiting accident discussed at each facility under each alternative. For example, the most limiting accident involving naval spent nuclear fuel is described in this attachment to be an airplane crash into a 125-ton multi-purpose canister at the Idaho Chemical Processing Plant. This accident could lead to 2.6 latent fatal cancers over the next 50 years in the population within 50 miles of the site. Since the probability of the event is one chance in 2,500,000 per year, the risk would be 0.00000104 latent cancer fatalities per year or, in other words, about one chance in 960,000 of a single fatal cancer fatality over a year. This risk is shared among the approximately 120,000 people residing within 50 miles of the site who would be expected to have over 300 cancer fatalities from all causes every year. For an act of war, sabotage, or terrorist attack, it is likely the risk would be lower than calculated because it should be less probable that a force would exist to disperse radioactive products into the atmosphere from a weapon as compared to the motive force of the fire assumed in the case of an airplane crash.

Accidents initiated at nearby facilities, by other activities unrelated to spent nuclear fuel handling or storage, or during construction of a facility, would not produce effects more severe than the sequences of events described in this EIS. This is because naval spent nuclear fuel undergoing loading, storage, or unloading under the conditions associated with the alternatives evaluated would not need special conditions or uninterrupted operator attention to prevent overheating, failure of containment, or loss of shielding. Therefore, evacuation in response to an accident at some other facility would not compromise safety. This inherent safety, combined with the distance between naval spent nuclear fuel facilities and any other activities which might suffer a catastrophic accident, means that the accidents analyzed in this document produce conditions at a naval spent nuclear fuel facility which would be more severe than those for any hypothetical synergistic combination of events resulting from accidents at other, unrelated facilities. Therefore, such analyses have not been included in this evaluation.

The existence of common cause accidents at a facility has been considered. In general, only one spent nuclear fuel facility is located at a particular site. However, it is possible for natural phenomena, like an earthquake, to produce more than one accident at some sites causing the release of radioactive material into the atmosphere or an increase in radiation levels due to loss of shielding. However, the probability of two or more accidents having maximum consequences occurring concurrently is less than the probability of the individual events. For example, if an earthquake affected the Naval Reactors Facility at INEL, a crane might fail causing damage to stored spent nuclear fuel, and the water pool might drain. The impacts for this could conservatively be estimated by summing the consequences. A combined total of 1.7×10^{-2} latent cancer fatalities is estimated. Similarly, consequences from several spent nuclear fuel facilities within a large site like INEL could be combined to estimate sitewide impacts conservatively. Once again, the probability of a common cause event resulting in this number of consequences is lower than the probability of the individual accidents because the severity of impact will vary between facilities due to separation distances.

Several accident scenarios were developed for the loading, storage, and unloading of naval spent nuclear fuel. All potential accidents were not evaluated, but cases which are considered to be more severe than all other reasonably foreseeable accidents were analyzed. Like the evaluations for normal operations, population and meteorology data specific to each site were used to estimate health effects.

It should be noted that this EIS does not evaluate the possibility of hydrogen ignition during container welding, as was recently experienced at a commercial nuclear power facility. That occurrence was caused by a chemical reaction between boric acid in the water within the container and the container's interior zinc coating. This situation cannot exist for loading operations involving naval spent nuclear fuel because the Naval Nuclear Propulsion Program does not use boric acid for this purpose.

Loading Operations. For completeness, several hypothetical accident scenarios were evaluated for naval spent nuclear fuel loading operations at both the Expended Core Facility and the Idaho Chemical Processing Plant. Since the procedures for loading spent nuclear fuel into a container will be similar for all container alternatives, the container hardware system involved has no impact on the accident analytical results. These hypothetical sequences of events include a drainage of the water pool caused by an earthquake, an accidental criticality, mechanical damage due to operator error or crane failure, an airplane crash into the water pool facility, a fire in a high-efficiency particulate air (HEPA) filter, minor water pool leakage, and a dropped fuel unit during loading operations in a Dry Cell Facility. Radiation dose to on-site individuals, an individual at the site boundary, and the general population was estimated for airborne releases of radioactivity, water releases, and direct radiation exposure.

Dry Storage. Several hypothetical accident scenarios were evaluated for naval spent nuclear fuel stored in containers at the Naval Reactors Facility, the Idaho Chemical Processing Plant, and a possible new facility near Birch Creek. Since the alternatives result in differing amounts of spent nuclear fuel in the containers, the hardware system does have an impact on the accident analyses. The first scenario postulates that a wind-driven projectile crashes into a storage cask, with mechanical damage causing a release of corrosion products into the environment. It is expected that the consequences from this scenario exceed those which would result from a container or canister drop during handling. The second hypothetical scenario is based on an airplane crash into the dry storage area at the Idaho Chemical Processing Plant. Once again, radiation dose to on-site individuals, an individual at the site boundary, and the general population was estimated for airborne releases, water releases, and direct radiation dose.

Unloading Operations. Several hypothetical accident scenarios were evaluated for naval spent nuclear fuel unloading operations at a repository surface facility. Since the alternatives result in differing amounts of spent nuclear fuel in the containers, the hardware system does have an impact on the accident analyses. These hypothetical sequences of events include mechanical damage to a container and a dropped transfer container.

A.2.3 Analytical Methods for Evaluation of Radiation Exposure

General. Evaluations of normal operations and hypothetical accidents at the sites were performed to assess the possible radiation exposure to individuals due to the release of radioactive materials. For the Naval Reactors Facility and the Idaho Chemical Processing Plant, the analyses are based on the same operations carried out at each location and the same accidents at both sites. With this approach, it is possible to compare the incremental effect of the alternatives or the different impacts of the postulated accidents at the different locations.

Exposures Calculated. Radiation exposure to the following different individuals and the general population is calculated for normal operation of the spent nuclear fuel facility and for accident conditions:

- Facility Worker (worker). An individual located 328 ft (approximately 100 m) from the radioactive material release point. (The impact of accidents on close-in workers is not calculated numerically but is discussed qualitatively for each accident in Section A.2.6.) |

- Maximally exposed off-site individual (MEI). A theoretical individual living at the site boundary receiving the maximum exposure.

- Nearest public access (NPA) individual. At INEL, highways used by the public cross the federal reservation which includes the facility where naval spent nuclear fuel operations could be conducted. Consequently, these analyses included evaluation of the exposure to a theoretical motorist who might be stranded on such a highway at the time of an accident. Based on experience from emergency exercises, emergency response teams would be able to evacuate such an individual within 2 hours, so this was the exposure time used in the calculations. No nearest public access value was calculated for a geologic repository location because there are no public roads which cross this hypothetical site, there are no residents on the site, and there are no other public accesses.

- General population within a 50-mi (approximately 80-km) radius of the facility. |

Exposure is calculated to result from direct radiation from the facility and exposure to radioactive contamination released to the air. The exposure pathways are described in detail in the Programmatic SNF and INEL EIS (DOE 1995 Volume 1, Appendix D, Attachment F, Section F.1.3.2) and include all internal and external pathways for exposures, including food and water.

Evaluation of Health Effects. Health effects are calculated from the exposure results. The risk factors used for calculations of health effects are taken from Publication 60 of the International Commission on Radiological Protection (ICRP 1991). Table A.5 lists the appropriate factors used in the analysis of both the normal operations and the hypothetical accident scenarios.

TABLE A.5 Risk Estimators for Health Effects from Ionizing Radiation

Effect	Nuclide	Risk Factor[a] (probability per rem) Worker	General Population
Fatal cancer (all organs)	All	4.0×10^{-4}	5.0×10^{-4}
Weighted nonfatal cancer[b]	All	8.0×10^{-5}	1.0×10^{-4}
Weighted genetic effects[b]	All	8.0×10^{-5}	1.3×10^{-4}
Weighted total effects[b]	All	5.6×10^{-4}	7.3×10^{-4}

[a] For high individual doses (≥20 rem), the above risk factors are multiplied by a factor of two. General population doses were not modified because the large drop in exposure with increasing distances results in average exposure rates well below 20 rem.

[b] In determining a means of assessing health effects from radiation exposure, the ICRP has developed a weighting method for nonfatal cancers and genetic effects to obtain a total weighted effect, or "health detriment."

Cancer fatalities were used to summarize and compare the results in this EIS since this effect was viewed to be of the greatest interest to most people. The number of total health effects (deaths, nonfatal cancers, genetic effects, and other impacts on human health) may be easily obtained by multiplying the latent cancer fatalities by the factor of 1.46, which is the ratio of 7.3×10^{-4} divided by 5.0×10^{-4} from Table A.5 above.

The numerical estimates of cancer deaths and other health detriments presented were obtained by the practice of linear extrapolation. Other methods of extrapolation to the low-dose region could yield higher or lower numerical estimates of cancer deaths. Studies of human populations exposed at low doses are inadequate to demonstrate the actual level of risk. There is scientific uncertainty about cancer risk in the low-dose region below the range of epidemiologic observation, and the possibility of no risk cannot be excluded (Committee on Interagency Radiation Research and Policy Coordination 1992). In this appendix, the doses have been provided in all cases to allow independent evaluation using any relation between exposure and health effects.

Population. Population distributions specific to INEL (the Expended Core Facility, the Idaho Chemical Processing Plant, and Test Area North (TAN) for Birch Creek Area) were used and were obtained from 1990 U.S. Census data. The population information was obtained in 16 compass directions and 5 equal radial distances from the likely location of a naval spent nuclear fuel site to a 50 mi (approximately 80 km) total distance.

For calculation purposes, a population density of 45 persons/mi^2 (17 persons/km^2) was used for distances from 3 mi (approximately 4.8 km) to 50 mi (approximately 80 km) at the representative geologic repository site. This density is equivalent to the average in the western United States. At distances closer than 3 mi (approximately 4.8 km), it was assumed that there were no members of the general public. The population was assumed to be uniform in all radial directions.

Meteorology.The Naval Reactors Facility tower meteorological data for the years 1987-1991 were used for both Naval Reactors Facility and Idaho Chemical Processing Plant analyses. The

TAN tower meteorological data for the years 1987-1991 were used for the Birch Creek analyses. The data were used to develop a joint frequency distribution of 6 wind speed intervals, 16 wind directions, and 6 stability categories for the GENII program, described below, to evaluate normal operations. The data were also used to calculate the 50% and 95% meteorological conditions for the accident analyses. The 50% condition represents the average meteorological condition. This condition is defined as that for which more severe conditions with respect to accident consequences occur less than 50% of the time. The 95% condition represents the meteorological conditions which could produce the highest calculated exposures. This is defined as that condition which is not exceeded more than 5% of the time or is the worst combination of weather stability category and wind speed. Each of these conditions is evaluated for 16 wind directions.

For the hypothetical geologic repository site, the meteorology used in all directions was Pasquill Class D with a wind speed of 13.2 ft/s (approximately 4 m/s) for normal conditions (50%) and Pasquill Class F with a wind speed of 3.3 ft/s (approximately 1 m/s) for severe weather conditions (95%). These values are consistent with national averages for the above conditions.

Computer Programs. Five computer programs were used to evaluate the radiation exposures to the specified individuals and general population: GENII, RSAC-5, ORIGEN, SPAN and WATER RELEASE. These codes are discussed in detail in the Programmatic SNF and INEL EIS (DOE 1995 Volume 1, Appendix D, Attachment F, Section F.1.3.6).

Categorization of Accidents. For this analysis, accidents have been categorized in terms of abnormal events, design-basis accidents, and beyond design-basis accidents.

Abnormal Events. Abnormal events are unplanned or improper events which result in little or no consequence. Abnormal events include industrial accidents and accidents that occur during normal operations, such as skin contamination with radioactive materials, spills of radioactive liquids, or exposure to direct radiation due to improper placement of shielding. The occurrence of these unplanned events has been anticipated and mitigative procedures are in place which promptly detect and eliminate the events and limit the effects of these events on individuals. As a result, there is little hazard to the general population from abnormal events. Such events are considered to occur in the probability range of 1 to 10^{-3} per year or greater. The probability referred to here is the total probability of occurrence and includes the probability that the event occurs times other probabilities required for the consequences. For accidents included in this range, results are presented for both the 50% meteorological condition (average meteorology) and the 95% meteorological condition.

Design-Basis Accident Range. Accidents which have a probability of occurrence in the range of 10^{-3} to 10^{-6} per year are included in the range called the design-basis accident range. The terminology "design-basis accident," which normally refers to facilities to be constructed, also includes the "evaluation" basis accident which applies to existing facilities. For accidents included in this range, results are presented for both the 50% meteorological condition (average meteorology) and the 95% meteorological condition. Risk calculations for accidents in this range utilize the consequences associated with 95% meteorological conditions.

Beyond Design-Basis Accidents. This range of accidents includes those which are less likely to occur than design-basis accidents but which may have very large or catastrophic consequences. Accidents included in this range typically have a total probability of occurrence in the range of 10^{-6} to 10^{-7} per year. Accidents which are less likely than 10^{-7} per year typically are not discussed since they are not expected to contribute in any substantial way to the risk. For these beyond design-basis accidents, consequences are presented for 50% and 95% meteorological conditions. Risk calculations for accidents in this range utilize the consequences associated with 95% meteorological conditions.

Evaluation of Impacted Area. The impacted area surrounding a facility following an accident was determined for each scenario evaluated. The impacted area was defined as that area in which the plume deposited radioactive material to such a degree that an individual standing on the boundary of the fallout area would receive approximately 0.01 mrem/h of exposure. If this individual spends 24 hours per day at this location, that person would receive about 88 mrem/yr from the ground surface shine. This is within the 100 mrem/yr limit of 10 CFR Part 20.

To best characterize the affected areas for each casualty, a typical 50% meteorology was chosen (Pasquill-Gifford Class D, wind speed 4 mph) and applied to each accident scenario. The dispersion of a plume of ionizing radiation and the downwind fallout footprint it produces, is dependent upon the stability of the atmosphere and the associated wind speeds. A very stable atmosphere with low wind speeds would mix the plume into a very much smaller volume than an unstable atmosphere and stronger wind speeds which would dilute the plume into a very much larger volume and thereby reduce the potential negative health effects. The RSAC-5 results for ground surface dose were interpolated to determine the distance downwind where the centerline dose had dropped to approximately 88 mrem/yr based on 24 hours per day exposure. For the wind class chosen, the plume remains within a single 22.5 degree sector. The area affected by the plume is determined as the entire sector contaminated to the calculated downwind distance. Table A.6 lists each facility accident analyzed and the contaminated footprint associated with the accident.

TABLE A.6 Footprint Estimates for Facility Accidents

Accident Scenario	Footprint Length (miles)	Footprint Area[a] (acres)
Drained water pool	1.2	11
Criticality	0.25	8
Loading mechanical damage	<0.06	<0.5
Loading airplane crash	0.27	9
Dry storage mechanical damage[b]	0.11	1.4
Dry storage airplane crash[b]	2.2	629
Unloading mechanical damage[b]	0.11	1.4
Dropped transfer container	<0.06	<0.5

[a] Based on contamination of a single sector.

[b] Results for these accident scenarios vary by container alternative. The numbers presented here are for the container alternatives which would contain the most spent nuclear fuel.

With the exception of the Birch Creek Area dry storage location, the footprint length does not extend beyond the site boundary for any accident so the contaminated area would be on-site. However, for the Birch Creek Area location, the boundary of INEL would be about 1 mile from the dry storage location. Although not specifically evaluated due to the low probability, for an accident such as the dry storage airplane crash, about 500 of the 629 acres would be off-site if the wind were blowing in the most unfavorable direction.

Although the plume would be contained within a single sector, the direction of the wind is unknown. Therefore, each site was examined for impacts in all directions around the facility site out to a distance equal to the footprint length. Since the postulated accidents would occur over a short duration of time, the acreage of the sector quoted is still an accurate indication of the total contaminated area. Identification of the potential impacts is contained in Table A.7.

TABLE A.7 Secondary Impacts of Facility Accidents at Idaho National Engineering Laboratory or the Hypothetical Geologic Repository

Parameter	Impact
Biotic resources	Plants and animals on the site and around the site will experience no long-term impacts.
Water resources	The water used for drinking and industrial purposes is monitored and use may be temporarily suspended during cleanup operations. No enduring impacts are expected.
Economic impacts	A small number of individuals may experience temporary job loss due to temporary restrictions on support activities near the facility during cleanup operations. Some costs would also be incurred for the actual cleanup operation.
National defense	No impacts.
Environmental contamination	Except for the Birch Creek dry storage location, contamination would remain within the site boundaries. Table A.6 lists the amount of area that could be contaminated.
Endangered species	The facility accident would not result in the extermination of any species, nor would it affect the long-term potential for survival of any species.
Land use	Access to some areas may be temporarily restricted until cleanup is completed.
Treaty rights	Some temporary restrictions on access may be required until cleanup is completed. No enduring impacts are expected.

Emergency Preparedness and Mitigative Measures. Emergency plans are in effect at the INEL site to ensure that workers and the public would be properly protected in the event of an accident. In addition, emergency plans are in effect for accidents involving the transportation of radioactive materials. These response plans include the activation of emergency response teams provided by the site and a site emergency control center, as well as activation of a command and control network with Naval Reactor Headquarters and support laboratories. The long standing emergency planning program that exists within the Naval Nuclear Propulsion Program includes the ability to utilize the comprehensive and extensive emergency response resources of the site and provides for coordination with appropriate civil authorities. In addition to the Naval Nuclear Propulsion Program resources, extensive federal emergency response resources are available as needed to support state or local response.

Emergency response measures include provisions for immediate response to any emergency at the site, identification of the accident conditions, and communications with civil authorities providing radiological data and recommendations for any appropriate protective actions. In the event of an accident involving radioactive or toxic materials, workers in the vicinity of the accident would promptly evacuate the immediate area. This evacuation can typically be accomplished within minutes of the accident and would reduce the hazard to workers.

Exercises are conducted periodically at the site in order to test the ability of personnel to respond to accidents. These exercises include realistic tests of people, equipment, and communications involved in all aspects of the plans, and the plans are regularly reviewed and modified to incorporate experience gained from the exercises. These exercises also periodically include steps to verify the adequacy of interactions with local hospitals and emergency personnel and state officials.

For members of the general public residing at the site boundary or beyond, no credit is taken for any preventive or mitigative actions that would limit their exposure. These individuals are calculated as being exposed to the entire contaminated plume as it travels downwind from the accident site. Similarly, no action is taken to prevent these people from continuing their normal day-to-day routine, and ingestion of terrestrial food and animal products continues on a yearly basis. If needed, action would be taken to prevent the public from exceeding a Protective Action Guideline. No reduction of exposure due to these actions is accounted for in this analysis. The public is assumed to spend approximately 30% of the day within their homes or other buildings, and the exposure to ground surface radiation is therefore reduced appropriately on a yearly basis.

Individuals that reside or work on-site, or those that may be traversing the site in a vehicle would be evacuated from the affected area within 2 hours. This is based on the availability of security personnel at all locations to oversee the removal of residents, collocated workers, and travelers in a safe and efficient manner. Periodic training and evaluation of the security personnel is conducted to ensure that correct actions are taken during an actual casualty. Therefore, residents, collocated workers, and travelers would be exposed to the entire contaminated plume as it travels downwind for a period not to exceed 2 hours. Similarly, the radiation shine from the deposited radioactive materials would be limited to a 2-hour period. No ingestion of contamination is calculated for these individuals.

Facility workers all undergo training to take quick, decisive action during a casualty. These individuals quickly evacuate the area and move to previously defined "relocation" areas on the facility site. Workers could be exposed to a full 5 minutes of the radioactive plume as they move to the "relocation" centers. Once the immediate threat of the plume has moved off-site and downwind, the workers would be instructed to walk to vehicles waiting to evacuate them from the site. An additional 15 minutes would be required to evacuate the workers from the contaminated area and therefore the workers receive a total of 20 minutes of groundshine. No ingestion of contamination is calculated for these individuals.

The individual exposure times utilized in the accident analyses presented in Section A.2.5 are summarized in Table A.8.

TABLE A.8 Estimated Time an Individual Might Be Exposed[a]

Receptor	Estimated Exposure Time per Exposure Pathway: Plume	Fallout on Ground Surface	Food
Worker at 100 m	5 min	20 min	N/A
NPA	100% of release time up to 120 min	120 min	N/A
MEI	100% of release time	0.7 yr	1 yr

[a] Notation: MEI = individual at nearest site boundary; NPA = nearest public access individual.

Perspective on Calculations of Cancer Fatalities and Risk. The topics of human health effects caused by radiation and the risks associated with normal operations or postulated accidents associated with spent nuclear fuel management are discussed many times throughout this EIS. It is important to understand these concepts and how they are used in order to understand the information presented in this document. It is also valuable to have some frame of reference or comparison for understanding how the risks compare to the risks of daily life.

The method used to calculate the risk of any impact is fundamental to all of the evaluations presented and follows standard accepted practices. The first step is to determine the probability that a specific event will occur. For example, the probability that a routine task, such as operating a crane, will be performed sometime during a year of normal operations at a facility would be 1.0. That means that the action would certainly occur. The probability that an accident might occur is less than 1.0. This is true because accidents occur only infrequently and some of the more severe accidents, such as a catastrophic earthquake, might occur at any location only once in hundreds, thousands, or millions of years.

Once the probability of an event has been determined, the next step is to predict what the consequences of the event being considered might be. One important measure of consequences chosen for this EIS is the number of human fatalities from cancer induced by radiation. This was chosen because this document deals with radioactive materials. The number of cancer fatalities that might be caused by any routine operation or any postulated accident can be calculated using a standard technique based on the amount of radiation exposure that might occur from all conceivable pathways and the number of people who might be affected.

A couple of examples should serve to illustrate the calculation of risk. A summary of these examples is presented in Table A.9. In the first, the lifetime risk of dying in a motor vehicle accident can be computed from the likelihood of an individual being in an automobile accident and the consequences or number of fatalities per accident. There were 10,000,000 motor vehicle accidents during 1992 in the United States resulting in about 40,000 deaths (National Safety Council 1993). Thus, the probability of a person being in an automobile accident is 10,000,000 accidents divided by approximately 250,000,000 persons in the United States, or 0.04 per year. The number of fatalities per accident, 0.004 (40,000 deaths divided by 10,000,000 accidents), is less than 1.0 since many accidents do not cause fatalities. Multiplying the probability of the accident (0.04 per year) by the consequences of the accident (0.004 deaths per accident) by the number of years the person is exposed to the risk (72 years is considered to be an average lifetime) gives the risk for any individual being killed in an automobile accident. From this calculation, the overall risk of someone dying in a motor vehicle accident is about 1 chance in 87 over a lifetime.

A second example illustrates the calculation of risk for another event which occurs daily. Fossil fuels, such as natural gas or coal, contain naturally occurring radioactive material that is released into the air during combustion. This radioactivity in the air finds its way into our bodies through our food and the air we breathe. This radioactivity has been estimated to produce about 0.5 mrem of radiation dose to the average U.S. resident each year (NCRP 1987b). The probability of this happening is essentially 1.0 since these fuels are burned every day all over the country. The number of fatal cancers from exposure to 0.5 mrem/yr is calculated by taking 0.5 mrem/yr times the 72 years considered to be an average lifetime times the 0.0005 fatal cancers estimated to be caused by each rem (0.5 mrem/yr × 72 years × 0.0005 fatal cancers per rem = 0.000018 fatal cancers per individual lifetime). The risk is the probability (1.0) times the consequences (0.000018 cancer fatalities) which equals about 1 chance in 55,000 of death from this cause over a lifetime.

These risks and others from everyday life can be used to gain a perspective on the risks associated with the alternatives in this EIS. As illustrated, the risk of death from cancer from the radioactivity released daily from combustion of fossil fuels is about 1 chance in 55,000 for the average U.S. resident. As a further comparison, the naturally occurring radioactive materials in agricultural fertilizer contribute about 1 to 2 mrem/yr to an average U.S. resident's exposure to radiation (NCRP 1987b). A calculation similar to the one in the preceding paragraph shows that the use of fertilizer to produce food crops in the United States results in a risk of death from cancer between 1 chance in 12,500 and 1 chance in 25,000. Finally, the average U.S. resident's risk of dying from cancer from all causes is 1 chance in 5 over his or her lifetime. These risks can be compared, for example, to the average individual risk of less than 1 chance in 30 billion for a resident in the vicinity of the INEL developing a fatal cancer due to normal operations at the Expended Core Facility (see the data in Section A.2.4).

A frame of reference for the risks from accidents associated with spent nuclear fuel management alternatives can be developed in the same way. For an average resident in the vicinity of the INEL, the individual risk of death from cancer caused by the water leaking from the Idaho Chemical Processing Plant after a large earthquake would be approximately 1 chance in 600 million. This individual risk was determined by dividing the risk value to the population within 50 mi (approximately 80 km) (2.4×10^{-6} fatalities per year per accident from Table A.14) by the total population of 120,003 and multiplying by an average life span of 72 years. This risk can be compared to the risks of death from other accidental causes to gain a perspective (see Table A.9). For example, the risk of death for the average U.S. resident from fires is approximately 1 chance in 500, and for death from accidental poisoning the risk is about 1 chance in 1,000 (Crouch 1982).

TABLE A.9 Risk Comparisons[a]

Cause of Death	Individual Lifetime Risk of Dying
Cancer: All causes	1 Chance in 5
Cancer: Exposure to Fossil Fuel Emissions	1 Chance in 55,000
Cancer: Naturally Occurring Radiation	1 Chance in 93
Cancer: INEL/ECF Operations	1 Chance in 30,000,000,000
Cancer: Incident-Free Transportation	1 Chance in 9,300,000
Automobile Accident	1 Chance in 87
Naval Spent Nuclear Fuel Transportation Accident	1 Chance in 39,000,000,000
Fire	1 Chance in 500
Poisoning	1 Chance in 1,000
Cancer: ICPP Water Pool Draining	1 Chance in 600,000,000

[a] Notation: ECF = Expended Core Facility; ICPP = Idaho Chemical Processing Plant

A.2.4 Analytical Results: Normal Operations

The purpose of this analysis is to determine the hypothetical health effects on workers and the public due to routine handling of naval spent nuclear fuel. Radioactive releases from facilities involved in routine handling of naval spent nuclear fuel are small. The releases at the Idaho Chemical Processing Plant are expected to be larger than those at the Expended Core Facility due to the larger storage capacity of the Idaho Chemical Processing Plant water pool. Meteorological and population data, as discussed in Section A.2.3, were used at each of the locations analyzed. For normal operations at INEL, exposure to the nearest public access individual is not estimated due to the short period of time that such an individual would spend on-site while driving on the public access road.

Loading Operations. The airborne release of radioactive materials from water pool storage of naval spent nuclear fuel units prior to loading into the containers for dry storage and subsequent shipment is extremely small. Only the corrosion product film on the fuel is capable of being released into the air under normal operations. Most of the nuclides in the corrosion film are solid elements and, thus, would not be released from the water pool into the air even if they can become released from the corrosion film. Since separate reporting of releases from water pool storage activities are not available for the Expended Core Facility or the Idaho Chemical Processing Plant, a calculated release was used to evaluate the potential exposure to workers and the public due to routine water pool storage and loading operations. At the Expended Core Facility, an annual release of 4.6×10^{-2} Ci of carbon-14 was used for the evaluation. A higher release of 6.1×10^{-1} Ci/yr was used for the Idaho Chemical Processing Plant since the Building 666 water pool has a much higher storage capacity and much more fuel than the Expended Core Facility. For the No-Action and Current Technology/Rail Alternatives only, an additional Carbon-14 release (3.9 Ci/yr) is expected when the dry storage containers are opened at INEL in preparation for loading the fuel and special case waste into the M-140 shipping containers, resulting in larger exposures for these two alternatives.

Table A.10 provides an indication of the incremental change at each location due to the addition of naval spent nuclear fuel loading operations.

TABLE A.10 Estimated Annual Health Effects from Naval Spent Nuclear Fuel and SCW: Loading Operations[a]

	Estimated Exposure					
	Facility Worker		MEI		General Population	
Activity/ Location	Dose (rem)	Latent Cancer Fatalities	Dose (rem)	Latent Cancer Fatalities	Collective Dose (person-rem)	Latent Cancer Fatalities
Loading operations - MPC, TSC, DPC, and SmMPC Alternatives						
NRF	2.8×10^{-6}	1.1×10^{-9}	1.7×10^{-8}	8.4×10^{-12}	1.1×10^{-4}	5.4×10^{-8}
ICPP	3.7×10^{-5}	1.5×10^{-8}	2.6×10^{-7}	1.3×10^{-10}	1.4×10^{-3}	7.2×10^{-7}
Loading operations - NAA and CTR Alternatives						
NRF	2.3×10^{-4}	9.4×10^{-8}	1.4×10^{-6}	7.0×10^{-10}	9.2×10^{-3}	4.6×10^{-6}
ICPP	2.7×10^{-4}	1.1×10^{-7}	1.9×10^{-6}	9.4×10^{-10}	1.1×10^{-2}	5.3×10^{-6}

[a] Notation: ICPP = Idaho Chemical Processing Plant; MEI = individual at nearest site boundary; NRF = Naval Reactors Facility; MPC = Multi-Purpose Canister; TSC = Transportable Storage Cask; DPC = Dual-Purpose Canister; SmMPC = Small Multi-Purpose Canister; NAA = No-Action Alternative; CTR = Current Technology/Rail.

Dry Storage. Another operation analyzed was the storage of naval spent nuclear fuel in containers in a safe array at three INEL locations. Shielding and physical boundaries would be established in accordance with existing regulations to protect facility workers. No routine airborne or water releases are expected from the dry storage activity; therefore, only direct radiation exposure was evaluated. The source term consists of an array of filled storage containers. Supplementary shielding would be provided as needed to ensure that there would be no measurable increase in radiation levels at the perimeter of the industrial area and that radiation levels within the industrial area but outside the storage area would not require occupational radiation exposure monitoring for workers. As containers are received over time, shielding will be provided to limit radiation exposure rates as discussed above. Distance falloff for radiation levels was determined using SPAN computer calculations as discussed in Section A.2.3.

Table A.11 provides an indication of the incremental change at each location due to the addition of dry storage areas. The health effect due to dry storage of spent nuclear fuel is extremely small at all locations.

TABLE A.11 Estimated Annual Health Effects from Naval Spent Nuclear Fuel and SCW: Dry Storage, All Alternatives[a]

	Estimated Exposure					
	Facility Worker		MEI		General Population	
Activity/ Location	Dose (rem)	Latent Cancer Fatalities	Dose (rem)	Latent Cancer Fatalities	Collective Dose (person-rem)	Latent Cancer Fatalities
Dry Storage						
NRF	1.1×10^{-2}	4.4×10^{-6}	6.5×10^{-14}	3.3×10^{-17}	1.7×10^{-12}	8.6×10^{-16}
ICPP	1.1×10^{-2}	4.4×10^{-6}	6.1×10^{-8}	3.1×10^{-11}	8.1×10^{-8}	4.1×10^{-11}
Birch Creek Area	1.1×10^{-2}	4.4×10^{-6}	4.7×10^{-4}	2.4×10^{-7}	5.1×10^{-5}	2.6×10^{-8}

[a] Notation: ICPP = Idaho Chemical Processing Plant; MEI = individual at nearest site boundary; NRF = Naval Reactors Facility.

Unloading Operations. The airborne release of radioactive materials from unloading naval spent nuclear fuel at a repository surface facility is expected to be extremely small. In addition, releases are not anticipated for all of the alternatives. The multi-purpose canisters will not be opened and, therefore, will not contribute any airborne releases. For the other container alternatives carbon-14 in the form of carbon dioxide gas will be generated during storage or shipping. The carbon-14 could be released to a repository surface facility and pass through the HEPA filters and into the environment. An annual release of 4.0 Ci of carbon-14 was used for the evaluation of all of these alternatives. It is expected that the actual releases of carbon-14 for any container alternative which is backfilled with an inert gas will be less than this value.

Table A.12 presents tabulated radiation exposure results for the unloading operations at the hypothetical geologic repository site.

Summary. Evaluations of environmental impacts at INEL are presented in the Programmatic SNF and INEL EIS (DOE 1995; Volume I, Appendix B). The radiological impacts at these sites are quite low in that latent cancer fatality projections to the population within 50 mi (approximately 80 km) from normal operations are well below 1.0. Hence, the addition of the above values due to normal operations related to naval spent nuclear fuel to those which may already exist at INEL result in total values which are still well below 1.0.

TABLE A.12 Estimated Annual Health Effects from Unloading Operations for Naval Spent Nuclear Fuel and SCW at a Hypothetical Geologic Repository Site: Normal Operations, All Container Alternatives Except MPCs[a]

	Estimated Exposure					
	Facility Worker		MEI		General Population	
Activity/ Location	Dose (rem)	Latent Cancer Fatalities	Dose (rem)	Latent Cancer Fatalities	Collective Dose (person-rem)	Latent Cancer Fatalities
Unloading Operations						
Repository	5.4×10^{-5}	2.2×10^{-8}	1.4×10^{-6}	7.2×10^{-10}	2.4×10^{-2}	1.2×10^{-5}

[a] Notation: MEI = individual at nearest site boundary.

A.2.5 Analytical Results: Accident Evaluation

The analysis of airborne releases at INEL from hypothetical accidents is evaluated with RSAC-5. Unless stated otherwise, the conditions listed in Table A.13 were used when performing calculations with RSAC-5. In most cases, these conditions are taken directly as defaults from the code. For airborne releases at a repository, the GENII code was used.

Loading Operations. Accidents during loading operations of naval spent nuclear fuel are considered for the Naval Reactors Facility and the Idaho Chemical Processing Plant at INEL. Six of the hypothetical accident scenarios evaluated during loading operations for this EIS are the same as those evaluated for water pool storage of naval spent nuclear fuel in the Programmatic SNF and INEL EIS (DOE 1995; Volume I, Appendix D, Attachment F, Section F.1.4.2.1). In addition, a dropped fuel unit scenario was evaluated for loading operations which would take place in a Dry Cell Facility. A prerequisite for a large release of radioactive material to the environment under more severe accident conditions is the damage of the cladding of a fairly large amount of stored fuel, with an accompanying release of gaseous and airborne particles of radioactive material from the fuel.

Drained Water Pool. In the hypothetical drained water pool scenario, a catastrophic event, like an earthquake, causes severe damage to the structure of the water pool, resulting in a complete loss of pool water. A thermal analysis of spent nuclear fuel in a water pool was conducted to demonstrate that clad failure or fuel melting is not possible in the event of an accidentally drained water pool. Air circulation through the fuel racks and fuel units was shown to be sufficient to prevent clad failure in the unlikely event of complete loss of pool water. However, the loss of water could result in increased direct radiation and a release of corrosion products.

TABLE A.13 Conditions Used as Input to the RSAC-5 Code for Estimating Airborne Releases from Hypothetical Accidents

Meteorological Data

- Wind speed, direction, and Pasquill stability are taken from 50% and 95% meteorology. See Section A.2.3 for a discussion of meteorological conditions.
- The release is calculated as occurring at ground level (0 ft or m).
- Mixing layer height is 1,320 ft (approximately 400 m). Airborne materials freely diffuse in the atmosphere near ground level in what is known as the mixing depth. A stable layer exists above the mixing depth which restricts vertical diffusion.
- Wet deposition is zero (no rain occurs to accelerate deposition and reduce the area affected).
- Dry deposition of the cloud is modeled. During movement of the radioactive plume, a fraction of the plume is deposited on the ground due to gravitational forces and becomes available for exposure by ground surface radiation and ingestion.
- The quantity of deposited radioactive material is proportional to the material size and speed. The following dry deposition velocities (m/s) were used:

  solids = 0.001 halogens = 0.01 noble gases = 0.0
  cesium = 0.001 ruthenium = 0.001.
- If radioactive releases occur through a stack, then additional plume dispersion can be accounted for by calculating a jet plume rise. In this analysis, jet plume rise is ignored.
- When released gases have a heat content, the plume can disperse more quickly. In this calculation, buoyant plume effects are ignored.

Inhalation Data

- Breathing rate is 3.33×10^{-4} m^3/s for worker and NPA; 2.66×10^{-4} m^3/s for people at site boundary and beyond.
- Particle size is 1.0 µm.
- The internal exposure period is 50 years for individual organs and tissues which have radionuclides committed.
- Exposure to the entire plume for the general public. The worker and NPA are exposed as discussed in Section A.2.3.
- Inhalation exposure factors are based on ICRP 30.

Ground Surface Exposure

- Exposed to contaminated soil for 1 year for the general public. See Section A.2.3 for additional details.
- Building shielding factor is 0.7 which exposes the individual to contaminated soil for 16 hours per day.

Ingestion Data

- Ingestion numbers will be reduced by a factor of 10 to account for only 10% of the food consumed being grown locally (such as in a person's garden).
- The following changes from RSAC-5 defaults were used (Rupp 1980):

  Annual Dietary Consumption Rates:

  177 kg/yr stored vegetables (produce)
  18.3 kg/yr fresh vegetables (leafy)
  94 kg/yr meat
  112 L/yr milk

Conditions used in developing the source term for the drained water pool accident are as follows:

- 300 naval fuel units would be in the water pool at the Expended Core Facility and 4,031 units at the Idaho Chemical Processing Plant.
- The thermal analysis demonstrates that no fission product release would occur during the accident.
- The amount of corrosion products on the fuel units is based on best estimate values.
- The release to the environment would occur at a constant rate over a 15-minute period.
- One percent of the original corrosion products from the fuel units might be released to the atmosphere due to thermal air currents. Additionally, 10% of the corrosion products could be released to the environment with the pool water.
- No filtration by HEPA filters is assumed.
- The following amounts of corrosion product nuclides might be released to the atmosphere. As noted above, the release to the water environment is 10 times these values. This listing includes nuclides that result in at least 99% of the exposure.

	Curies	
Nuclide	NRF	ICPP
Cobalt-60	3.6	48
Iron-55	6.6	89
Cobalt-58	1.3	17
Manganese-54	2.2×10^{-1}	2.9
Iron-59	1.9×10^{-2}	2.5×10^{-1}

The estimated health risks to the general population that might result from the hypothetical drained water pool accident at INEL are presented in Table A.14. The number of fatal cancers would be expected to occur over a 50-year period. "Risk" is defined as the number of fatal cancers times the probability of occurrence. The results are presented for the design basis accident with 50% and 95% meteorology. A probability of occurrence of 10^{-5} was used to develop the risk results in the table (DOE 1995; Volume 1, Appendix D, Part B, Section F.1.4.2.1.1.3).

The consequences calculated stem from the release of radioactive corrosion products within the pool water and would be the same for the design basis and beyond design basis seismic events.

Since the consequences are the same, the values shown in Table A.14 are based on the accident probability for the design-basis seismic event because that results in the larger risk.

For the hypothetical drained water pool scenario, the radioactive plume might result in contamination of the ground to a downwind distance of 0.29 mi (approximately 0.5 km) at the Naval Reactors Facility and 1.2 mi (approximately 1.9 km) at the Idaho Chemical Processing Plant. This would yield a total area impacted by the accident of approximately 11 acres (approximately 4.5 ha) and 175 acres (approximately 71 ha) respectively at the two sites. The calculated downwind distance would be contained within the boundaries of INEL.

TABLE A.14 Estimated Health Risks from a Drained Water Pool Accident at the Naval Reactors Facility or Idaho Chemical Processing Plant[a]

Site/ Individual	50% Meteorology		95% Meteorology	
	Dose (rem)	Latent Cancer Fatalities	Dose (rem)	Latent Cancer Fatalities
NRF				
Worker	7.5×10^{-1}	3.0×10^{-4}	2.1	8.3×10^{-4}
NPA	3.9×10^{-4}	2.0×10^{-7}	2.3×10^{-3}	1.2×10^{-6}
MEI	2.8×10^{-3}	1.4×10^{-6}	1.7×10^{-2}	8.5×10^{-6}
ICPP				
Worker	10	4.0×10^{-3}	28	2.2×10^{-2}
NPA	7.3×10^{-3}	3.6×10^{-6}	9.8×10^{-2}	4.9×10^{-5}
MEI	1.6×10^{-2}	8.2×10^{-6}	1.4×10^{-1}	7.0×10^{-5}

Population within 50-Mile Radius of Site	50% Meteorology		95% Meteorology		
	Collective Dose (person-rem)	Latent Cancer Fatalities	Collective Dose (person-rem)	Latent Cancer Fatalities	Annual Risk
NRF					
115,690	6.7	3.3×10^{-3}	35	1.7×10^{-2}	1.7×10^{-7}
ICPP					
120,003	91	4.6×10^{-2}	460	2.4×10^{-1}	2.4×10^{-6}

[a] Notation: ICPP = Idaho Chemical Processing Plant; MEI = individual at nearest site boundary; NPA = nearest public access individual; NRF = Naval Reactors Facility.

Accidental Criticality. In the hypothetical accidental criticality scenario, an accidental uncontrolled chain reaction producing 1×10^{19} fissions is postulated. The criticality occurs in the water pool which is not emptied by the event and does not subsequently empty. Release of fission products includes those specified in Regulatory Guide 3.34 (NRC 1979b) from the criticality, plus fission products remaining in the fuel as a result of the original use. Removal of fission products by the pool water is included.

Conditions used in developing the source term for the accidental criticality are as follows:

- The fraction of the fission products released to the building is 100% of the noble gases, 25% of the halogens, 0.1% of the ruthenium (Elder et al. 1986), and 0.05% of the cesium and remaining solids.

- The original inventory of fission products from two naval fuel units are available for release in addition to those created by the criticality event.

- A HEPA filter removes 99.9% of the solid fission products from the plume.

- The release to the environment occurs at a constant rate over a 15-minute period. This is conservative as compared to the 8-hour release allowed in Regulatory Guide 3.34.

- The following amounts of radionuclides are released to the environment. This listing includes nuclides that result in at least 99% of the possible exposure.

Nuclide	Curies	Nuclide	Curies
Tellurium-133	3.4×10^{3}	Iodine-132	1.7
Iodine-134	3.5×10^{2}	Strontium-90	1.9×10^{-2}
Iodine-135	1.2×10^{2}	Yttrium-91m	4.3×10^{-8}
Cesium-138	1.6×10^{-4}	Rubidium-88	1.7×10^{-5}
Rubidium-89	6.1×10^{-4}	Yttrium-91	1.1×10^{-2}
Plutonium-238	3.7×10^{-4}	Cesium-139	7.3×10^{-3}
Bromine-84	2.3×10^{2}	Barium-142	4.8×10^{-3}
Iodine-133	2.4	Yttrium-93	1.3×10^{-6}
Strontium-91	5.4×10^{-6}	Barium-137m	1.9×10^{-2}
Strontium-92	2.4×10^{-4}	Rubidium-106	7.6×10^{-3}
Barium-139	6.9×10^{-6}	Zirconium-95	1.4×10^{-2}
Barium-141	8.8×10^{-4}	Strontium-89	7.0×10^{-3}
Iodine-129	5.1×10^{-3}	Europium-154	1.3×10^{-3}
Iodine-131	3.2×10^{-1}	Cesium-137	2.0×10^{-2}
Tritium (H-3)	1.4×10^{2}	Cerium-144	4.5×10^{-2}
Cesium-134	1.5×10^{-2}	Niobium-95	2.7×10^{-2}
Barium-140	2.5×10^{-5}	Rubidium-90	2.2×10^{-2}
Iodine-136	1.1×10^{4}		

The estimated health risks to the general population that might result from the hypothetical criticality accident at each location are presented in Table A.15. The number of fatal cancers would be expected to occur over a 50-year period. An accidental criticality during spent nuclear fuel handling operations is extremely unlikely. The probability of occurrences of an accidental criticality at the Expended Core Facility is identified as 1×10^{-5} per year and as 1×10^{-4} per year in Building 666 at the Idaho Chemical Processing Plant (DOE 1995; Volume 1, Appendix D, Part B, Section F.1.4.2.1.2.3).

TABLE A.15 Estimated Health Risks from Accidental Criticality at the Naval Reactors Facility or Idaho Chemical Processing Plant[a]

Site/ Individual	50% Meteorology: Dose (rem)	50% Meteorology: Latent Cancer Fatalities	95% Meteorology: Dose (rem)	95% Meteorology: Latent Cancer Fatalities
NRF				
Worker	3.0	1.2×10^{-3}	8.0	3.2×10^{-3}
NPA	5.9×10^{-4}	2.9×10^{-7}	2.8×10^{-3}	1.4×10^{-6}
MEI	2.0×10^{-3}	1.0×10^{-6}	9.2×10^{-3}	4.6×10^{-6}
ICPP				
Worker	3.0	1.2×10^{-3}	8.0	3.2×10^{-3}
NPA	8.3×10^{-4}	4.1×10^{-7}	9.1×10^{-3}	4.6×10^{-6}
MEI	8.6×10^{-4}	4.3×10^{-7}	5.4×10^{-3}	2.7×10^{-6}

Population within 50-Mile Radius of Site	50% Meteorology: Collective Dose (person-rem)	50% Meteorology: Latent Cancer Fatalities	95% Meteorology: Collective Dose (person-rem)	95% Meteorology: Latent Cancer Fatalities	Annual Risk
NRF					
115,690	5.5	2.8×10^{-3}	13	6.4×10^{-3}	6.4×10^{-8}
ICPP					
120,003	5.6	2.8×10^{-3}	13	6.4×10^{-3}	6.4×10^{-7}

[a] Notation: ICPP = Idaho Chemical Processing Plant; MEI = individual at nearest site boundary; NPA = nearest public access individual; NRF = Naval Reactors Facility.

For the hypothetical criticality accident scenario, the radioactive plume might cause contamination of the ground to a downwind distance of 0.25 mi (approximately 0.4 km) at both the Naval Reactors Facility and the Idaho Chemical Processing Plant. This would yield a total area impacted by the accident of approximately 8 acres (approximately 3.2 ha). The calculated downwind distance would be contained within the boundaries of INEL.

Mechanical Damage from Operator Error, Crane Failure, or Similar Accidents. Accidental mechanical damage to spent nuclear fuel was evaluated. The hypothetical accident included damage to one fuel unit, allowing fission products within the assembly to escape through the clad failures. The cause was attributed to be crane failure, operator error, or a similar accident. All gas and some volatile and solid nuclides were calculated to be released to the pool. The release fractions are consistent with severe accident analyses and Nuclear Regulatory Commission Regulatory Guide 1.4. Due to the presence of pool water, no solids would be released into the air inside the facility.

Conditions used in developing the source term for the mechanical damage scenario are as follows:

- One fuel unit is damaged because only one fuel unit would be handled at a time and the storage facility design prevents damage to stored units from such events.
- One percent of the fuel is damaged and those fission products are available for release.
- All (100%) of the noble gases are released to the environment.
- Approximately 25% of the halogens are released to the pool and 90% of these fission products are absorbed in the water as they rise through the pool water. Therefore, 2.5% of the halogens are released to the air inside the facility.
- Due to the gaseous nature of the released fission products, installed HEPA filters would not remove them once they are released to the air in the building.
- The release to the environment occurs at a constant rate over a 15-minute period.
- There is no particulate fission product release to the atmosphere due to the presence of pool water.
- The following amounts of radionuclides could be released to the environment. This listing includes nuclides that result in at least 99% of the possible exposure.

Nuclide	Curies
Tritium (H-3)	1.4
Iodine-129	2.5×10^{-6}
Iodine-131	5.4×10^{-5}

The estimated health risks to the general population that might result from the hypothetical mechanical damage accident at each location are presented in Table A.16. The number of fatal cancers would be expected to occur over a 50-year period. The probability of the occurrence of fuel damage is small based on the conservative fuel handling rules. The probability of occurrence of such a mechanical damage accident for the INEL Expended Core Facility is 10^{-5} (DOE 1995; Volume 1,

Appendix D, Part B, Section F.1.4.2.1.3.3). The same value was assumed for the Idaho Chemical Processing Plant.

For the hypothetical wet storage mechanical damage accident scenario, the radioactive plume might cause contamination of the ground to a downwind distance of less than 0.06 mi (approximately 0.1 km). This would yield a total area impacted by the accident of less than 0.5 acre (approximately 0.2 ha) at both the Naval Reactors Facility and the Idaho Chemical Processing Plant. The calculated downwind distance would be contained within the boundaries of INEL.

TABLE A.16 Estimated Health Risks from a Mechanical Damage Accident (Fuel Unit Drop) at the Naval Reactors Facility or Idaho Chemical Processing Plant (All Alternatives)[a]

	50% Meteorology		95% Meteorology	
Site/ Individual	Dose (rem)	Latent Cancer Fatalities	Dose (rem)	Latent Cancer Fatalities
NRF				
Worker	1.9×10^{-4}	7.6×10^{-8}	5.2×10^{-4}	2.1×10^{-7}
NPA	1.5×10^{-7}	7.4×10^{-11}	8.3×10^{-7}	4.2×10^{-10}
MEI	5.7×10^{-7}	2.9×10^{-10}	2.6×10^{-6}	1.3×10^{-9}
ICPP				
Worker	1.9×10^{-4}	7.6×10^{-8}	5.2×10^{-4}	2.1×10^{-7}
NPA	2.1×10^{-7}	1.1×10^{-10}	2.7×10^{-6}	1.3×10^{-9}
MEI	2.5×10^{-7}	1.2×10^{-10}	1.5×10^{-6}	7.7×10^{-10}

	50% Meteorology		95% Meteorology		
Population within 50-Mile Radius of Site	Collective Dose (person-rem)	Latent Cancer Fatalities	Collective Dose (person-rem)	Latent Cancer Fatalities	Annual Risk
NRF					
115,690	5.0×10^{-3}	2.5×10^{-6}	1.1×10^{-2}	5.3×10^{-6}	5.3×10^{-11}
ICPP					
120,003	5.1×10^{-3}	2.6×10^{-6}	1.1×10^{-2}	5.3×10^{-6}	5.3×10^{-11}

[a] Notation: ICPP = Idaho Chemical Processing Plant; MEI = individual at nearest site boundary; NPA = nearest public access individual; NRF = Naval Reactors Facility.

Airplane Crash. Impact into water pools by aircraft with resulting damage to the naval fuel units stored inside the pool was evaluated. Based on the probability of occurrence, specific analyses were only performed for the Idaho Chemical Processing Plant. The hypothetical accident included damage to all fuel units stored at the water pool. Fission products and corrosion products are released from the fuel units into the water pool; however, the pool water is not released to the environment. An airplane crash into a water pool would not produce enough force to cause the pool to leak because the walls of the water pool are constructed of thick, reinforced concrete with earth surrounding them, making them very strong. In addition, it was considered unlikely that an airplane would impact the water pool at an angle steep enough to expose the floor of the pool or the walls of the pool below the water level to the direct impact. The presence of pool water results in only a release of gaseous fission products to the atmosphere.

Conditions used in developing the source term for the airplane crash scenario are as follows:

- One percent of the fission products from each of the fuel units stored inside the pool is available for release.
- Of the available fission products, 100% of the noble gases and 25% of the halogens are released to the pool water. Due to the presence of pool water, a reduction of the halogen release by a factor of 10 prior to release to the atmosphere occurs.
- No solid fission products or corrosion products are released to the environment due to the continued presence of pool water.
- The release to the environment occurs at a constant rate over a 15-minute period.
- 4,031 naval fuel units would be in the water pool.
- No filtration by high-efficiency particulate air (HEPA) filters is assumed.
- The following amounts of radionuclides could be released to the environment. This listing includes nuclides that result in at least 99% of the possible exposure.

Nuclide	Curies
Iodine-129	1.0×10^{-2}
Iodine-131	2.2×10^{-1}
Tritium (H-3)	5.7×10^{3}

The estimated health risks to the general population that might result from the hypothetical airplane crash accident at the Idaho Chemical Processing Plant are presented in Table A.17. The number of fatal cancers would be expected to occur over a 50-year period. At the Naval Reactors Facility, the likelihood of occurrence is 7×10^{-8} per year into the water pool and the probability at the Idaho Chemical Processing Plant is estimated to be 4 to 8 times greater (DOE 1995; Volume 1, Appendix D, Part B, Section F.3). The airplane crash probability is higher at the Idaho Chemical Processing Plant since low altitude testing of commercial jet airliners has been conducted near the National Oceanic and Atmospheric Administration tower, which is located about 1.5 miles from the Idaho Chemical Processing Plant. A probability of 6×10^{-7} is used for the probability of an airplane crash into the Building 666 water pool.

For the hypothetical airplane crash into a water pool facility accident scenario, the radioactive plume might result in contamination of the ground to a downwind distance of less than 0.27 mi (approximately 0.43 km). This would yield a total area impacted by the accident of less than 9 acres (approximately 3.6 ha). The calculated downwind distance would be contained within the boundaries of INEL.

TABLE A.17 Estimated Health Risks from an Airplane Crash at the Idaho Chemical Processing Plant[a]

	50% Meteorology		95% Meteorology		
Individual	Dose (rem)	Latent Cancer Fatalities	Dose (rem)	Latent Cancer Fatalities	
Worker	7.6×10^{-1}	3.1×10^{-4}	2.1	6.4×10^{-5}	
NPA	8.8×10^{-4}	4.4×10^{-7}	1.1×10^{-2}	5.4×10^{-6}	
MEI	9.8×10^{-4}	4.9×10^{-7}	5.9×10^{-3}	3.0×10^{-6}	
	50% Meteorology		95% Meteorology		
Population within 50-Mile Radius of Site	Collective Dose (person-rem)	Latent Cancer Fatalities	Collective Dose (person-rem)	Latent Cancer Fatalities	Annual Risk
120,003	21	1.1×10^{-2}	41	2.1×10^{-2}	1.3 x 10^{-8}

[a] Notation: MEI = individual at nearest site boundary; NPA = nearest public access.

HEPA Filter Fire. In the hypothetical HEPA filter fire scenario, a fire in the bank of HEPA filters is postulated. This accident could be initiated by the ignition of a flammable mixture released upstream of the system or by an external, unrelated fire that spreads to this system. Although the risks associated with this accident are relatively minor, it was analyzed to bound the higher probability, lower consequence type accident category. The airborne release fractions associated with this accident were conservatively chosen so that a HEPA filter failure by crushing or impact was also bounded.

Conditions used in developing the source term for the HEPA filter fire accident are as follows:

- The original inventory of fission products in the filters is based on the total estimated unabated Expended Core Facility releases over a 5-year period.

- One percent of the radionuclide inventory present on the filters becomes airborne during the fire. Release fractions for HEPA filters are small because the filters are constructed of material containing glass fibers which would melt during a fire and trap particles in the medium. Measurements from experiments show that one one-hundredth of 1% of the material in HEPA filters could be released during a fire (DOE 1993b), but 1% has been used in these analyses to allow for uncertainties in the final results of an individual fire.

- The release to the environment occurs at a constant rate over a 15-minute period.

- There is no increase in direct radiation due to this accident.

- No filtration by HEPA filters is assumed.

- The following amounts of radionuclides could be released to the environment. This listing includes nuclides that result in at least 99% of the possible exposure.

Nuclide	Curies	Nuclide	Curies
Cesium-137	1.5×10^{-3}	Cobalt-60	2.1×10^{-3}
Cesium-134	2.0×10^{-4}	Strontium-90	8.9×10^{-4}
Barium-137m	6.3×10^{-6}	Yttrium-90	8.9×10^{-4}
Iron-55	2.3×10^{-3}	Europium-154	9.8×10^{-5}
Nickel-63	3.0×10^{-3}		

The estimated health risks to the general population that might result from the hypothetical HEPA filter fire accident at each location are presented in Table A.18. The number of fatal cancers would be expected to occur over a 50-year period. The probability of a fire in a HEPA filter is estimated based on the probability of other fires spreading to the HEPA filter system. As discussed in the Programmatic SNF and INEL EIS (DOE 1995; Volume 1, Appendix D, Section F.2.4.2), a probability of 5×10^{-3} is assigned to chemical fires. The probability of HEPA fires is considered less than a chemical fire since chemicals would not be stored in the immediate vicinity of the HEPA filter system. Additionally, HEPA filters are not inherently volatile or explosive. It is estimated that the probability for an existing chemical fire to spread to the HEPA filters is less than 0.1. This results in a probability of less than 5×10^{-4} for a HEPA filter fire. A value of 5×10^{-4} was used to develop the risk results in the table.

For the hypothetical HEPA filter fire accident scenario, the radioactive plume might cause contamination of the ground to a downwind distance of less than 0.06 mi (approximately 0.1 km) at the Naval Reactors Facility and the Idaho Chemical Processing Plant. This would yield a total area impacted by the accident of less than 0.5 acre (approximately 0.2 ha). The calculated downwind distance would be contained within the boundaries of INEL.

TABLE A.18 Estimated Health Risks from a HEPA Filter Fire at the Naval Reactors Facility or Idaho Chemical Processing Plant[a]

	50% Meteorology		95% Meteorology	
Site/ Individual	Dose (rem)	Latent Cancer Fatalities	Dose (rem)	Latent Cancer Fatalities
NRF				
Worker	8.7×10^{-4}	3.5×10^{-7}	2.4×10^{-3}	9.6×10^{-7}
NPA	4.5×10^{-7}	2.2×10^{-10}	2.7×10^{-6}	1.4×10^{-9}
MEI	9.9×10^{-6}	5.0×10^{-9}	2.5×10^{-5}	1.3×10^{-8}
ICPP				
Worker	8.7×10^{-4}	3.5×10^{-7}	2.4×10^{-3}	9.6×10^{-7}
NPA	6.3×10^{-7}	3.2×10^{-10}	8.8×10^{-6}	4.4×10^{-9}
MEI	4.3×10^{-6}	2.1×10^{-9}	1.5×10^{-5}	7.4×10^{-9}

	50% Meteorology		95% Meteorology		
Population within 50-Mile Radius of Site	Collective Dose (person-rem)	Latent Cancer Fatalities	Collective Dose (person-rem)	Latent Cancer Fatalities	Annual Risk
NRF					
115,690	7.6×10^{-2}	3.8×10^{-5}	1.1×10^{-1}	5.3×10^{-5}	2.7 x 10^{-8}
ICPP					
120,003	7.7×10^{-2}	3.9×10^{-5}	1.1×10^{-1}	5.3×10^{-5}	2.7 x 10^{-8}

[a] Notation: ICPP = Idaho Chemical Processing Plant; MEI = individual at nearest site boundary; NPA = nearest public access individual; NRF = Naval Reactors Facility.

Minor Water Pool Leakage. In the hypothetical minor water pool leakage scenario, a minor leak develops in the water pool resulting in a gradual discharge to the environment. There is no danger of uncovering any spent nuclear fuel in the water pool, since the leak is so small that it is undetected and water level is maintained in the water pool. Since a strict accounting of water added to and removed from the water pool is maintained, the magnitude of this leak would be less than 4,400 gal/yr (approximately 16,600 L/yr). The 4,400 gal/yr (approximately 16,600 L/yr) value is the maximum amount of water which might leak out of the water pool before periodic review of the water balance would detect a leak. This leak rate is specifically evaluated for the Naval Reactors Facility and conservatively represents the leak rate at the Idaho Chemical Processing Plant.

There is no airborne release above normal levels in the hypothetical water pool leakage scenario. The radionuclide inventory in the leaking water is based on radioactivity analysis of the Expended Core Facility water pool water. The isotopes that were analyzed for but not detected could exist at the minimum detection limit.

TABLE A.19 Radionuclide Releases from a Water Pool Leakage Accident

Nuclide	Sample Results (µCi/mL)	10 CFR Part 20 Effluent Limit (µCi/mL)	Annual Releases (Ci/yr)
Tritium (H-3)	2.0×10^{-4}	1.0×10^{-3}	3.3×10^{-3}
Manganese-54	2.5×10^{-8}	3.0×10^{-5}	4.1×10^{-7}
Iron-55[a]	1.0×10^{-8}	1.0×10^{-4}	1.6×10^{-7}
Cobalt-58	7.0×10^{-8}	2.0×10^{-5}	1.1×10^{-6}
Cobalt-60	1.6×10^{-5}	3.0×10^{-6}	2.6×10^{-5}
Nickel-63	2.3×10^{-7}	1.0×10^{-4}	3.8×10^{-6}
Strontium-90	4.0×10^{-9}	5.0×10^{-7}	6.5×10^{-8}
Yttrium-90	4.0×10^{-9}	7.0×10^{-6}	6.5×10^{-8}
Iodine-129[a]	4.0×10^{-7}	2.0×10^{-7}	6.5×10^{-6}
Cesium-137	4.2×10^{-8}	1.0×10^{-6}	6.9×10^{-7}

[a] Iron-55 and iodine-129 were not detected in the Expended Core Facility water. The numbers quoted reflect the detection limit of the analysis.

It should be noted that the sample results for the water pool indicate that the nuclide levels are all below the Code of Federal Regulations limits for liquid effluent in 10 CFR Part 20 with the exception of cobalt-60. The level of iodine-129 used in the calculations was based on the minimum detection limit of the sample. This level exceeds the effluent limit; however, iodine-129 was not actually detected in the water sample. Since strontium-90 has comparable water solubility to iodine-129 and exists in spent nuclear fuel at about a factor of 1.0×10^6 higher than iodine-129, it is inferred from the detected level of strontium-90 that the actual level of iodine-129 is well below the 10 CFR Part 20 effluent limit.

The estimated health risks to the general population that might result from the hypothetical minor water pool leak at each location are presented summarized in Table A.20. The number of fatal cancers would be expected to occur over a 50-year period. The probability of a leak developing is 10^{-1} per year (DOE 1995; Volume 1, Appendix D, Part B, Section F.1.4.2.1.6.3).

TABLE A.20 Estimated Health Effects from Minor Water Pool Leakage at the Naval Reactors Facility or Idaho Chemical Processing Plant[a]

Location	Dose (rem)	Latent Cancer Fatalities
NRF		
Worker	N/A	N/A
NPA	1.6×10^{-13}	8.0×10^{-17}
MEI	2.5×10^{-9}	1.3×10^{-12}
ICPP		
Worker	N/A	N/A
NPA	1.6×10^{-13}	8.0×10^{-17}
MEI	2.5×10^{-9}	1.3×10^{-12}

Population within 50-Mile Radius of Site	Collective Dose (person-rem)	Latent Cancer Fatalities	Annual Risk
NRF			
115,690	2.6×10^{-5}	1.3×10^{-8}	$1.3 \text{ x } 10^{-9}$
ICPP			
120,003	2.7×10^{-5}	1.3×10^{-8}	$1.3 \text{ x } 10^{-9}$

[a] Notation: ICPP = Idaho Chemical Processing Plant; MEI = individual at nearest site boundary; NPA = nearest public access; NRF = Naval Reactors Facility.

Dropped Fuel Unit. Loading of fuel into containers for storage or shipment to a repository would be done in the proposed Dry Cell Facility at the Expended Core Facility or at the Idaho Chemical Processing Plant. The conceptual method of such an operation involves bringing a container or cask in below the shielded cell and loading it remotely through a hole in the bottom of the cell. No heavy containers are brought into the shielded dry cell. An accident during loading of any container type that could result in a radiological release to the environment would be dropping of an unshielded fuel assembly during handling. This accident would be the same for loading operations for all container alternatives. No rupture of the fuel would occur due to the limited drop height and the robust nature of the Navy fuel designs. Some of the adherent activated corrosion products would be loosened from the surface of the fuel unit by the impact.

The development of the radioactive source term for the dropped fuel unit scenario is based on the following:

- The source term is based on best estimate spent nuclear fuel corrosion products.

- Ten percent of the original corrosion products associated with the single fuel unit with the largest inventory could be released into the dry cell atmosphere.

- The corrosion product inventory route to the environment would be through the dry cell HEPA filters over a 15 minute period.

- All products released to the environment, except carbon-14, would be reduced by a factor of 0.001 by the HEPA filters. The carbon-14 inventory is assumed to all be in the form of CO_2 and, therefore, would not be reduced by the filters.

- There would be no increase in direct radiation due to this accident.

- The following amounts of radionuclides could be released to the environment. This listing includes nuclides that result in at least 99% of the possible exposure.

Nuclide	Curies
Manganese-54	7.5×10^{-6}
Iron-55	2.2×10^{-4}
Iron-59	6.4×10^{-7}
Cobalt-58	4.2×10^{-8}
Cobalt-60	1.2×10^{-4}
Carbon-14	1.3×10^{-3}

The estimated health risks to the general population that might result from the hypothetical dropped fuel unit are presented in Table A.21. The number of latent cancer fatalities would be expected to occur over a 50-year period. The probability of a fuel unit drop accident with the release of radioactive corrosion products is based on the probability of a severe uncontrolled crane failure of 10^{-8} per lift. This is combined with a conservative estimate of 1,000 fuel unit lifts per year resulting in an annual accident probability of 10^{-5} per year. A value of 1×10^{-5} was used to develop the risk results in the table.

For the hypothetical dropped fuel unit accident scenario, the radioactive plume might cause contamination of the ground to a downwind distance of less than 0.06 mi (approximately 0.1 km). This would yield a total area impacted by the accident of less than 0.5 acre (approximately 0.2 ha). The calculated downwind distance would be contained within the boundaries of the INEL site.

TABLE A.21 Estimated Health Effects from a Dropped Fuel Unit in a Dry Cell Facility[a]

	50% Meteorology		95% Meteorology	
Individual	Dose (rem)	Latent Cancer Fatalities	Dose (rem)	Latent Cancer Fatalities
NRF				
Worker	2.9×10^{-5}	1.2×10^{-8}	8.0×10^{-5}	3.2×10^{-8}
NPA	5.3×10^{-9}	2.6×10^{-12}	9.0×10^{-8}	4.5×10^{-11}
MEI	3.0×10^{-7}	1.5×10^{-10}	7.9×10^{-7}	4.0×10^{-10}
ICPP				
Worker	2.9×10^{-5}	1.2×10^{-8}	8.0×10^{-5}	3.2×10^{-8}
NPA	7.4×10^{-9}	3.7×10^{-12}	2.9×10^{-7}	1.5×10^{-10}
MEI	1.3×10^{-7}	6.5×10^{-11}	4.7×10^{-7}	2.3×10^{-10}

	50% Meteorology		95% Meteorology		
Population within 50-Mile Radius of Site	Collective Dose (person-rem)	Latent Cancer Fatalities	Collective Dose (person-rem)	Latent Cancer Fatalities	Annual Risk
NRF					
115,690	6.8×10^{-4}	3.4×10^{-7}	1.6×10^{-3}	8.1×10^{-7}	8.1×10^{-12}
ICPP					
120,003	6.9×10^{-4}	3.4×10^{-7}	1.6×10^{-3}	8.1×10^{-7}	8.1×10^{-12}

[a] Notation: MEI = individual at nearest site boundary; NPA = nearest public access individual; NRF = Naval Reactors Facility; ICPP = Idaho Chemical Processing Plant.

Dry Storage. Accidents during dry storage of naval spent nuclear fuel are considered for the Naval Reactors Facility, the Idaho Chemical Processing Plant and the Birch Creek Area storage site at INEL. The two hypothetical accident scenarios evaluated are the same as those evaluated in the Programmatic SNF and INEL EIS (DOE 1995; Volume 1, Appendix D, Section F.1.4.2.2).

Wind-Driven Projectile Impact into Storage Casks with Mechanical Damage. In the hypothetical projectile impact accident, it is assumed that no fuel damage would result from the impact. Dry storage containers could experience a major wind storm or tornado which could propel a large object into a storage container causing the container seal to be breached. Analysis of the M-140 container shows that it is strong enough to prevent crushing of the naval spent nuclear fuel and release of fission products. For other container types similar analyses have not been performed; however, the consequences due to damage from a wind-driven projectile are expected to be less than those presented for the Idaho Chemical Processing Plant hypothetical airplane crash accident scenario in the next section. If a canister or cask were dropped during handling operations during movement into or out of storage, it is expected that the consequences of such a scenario would be less than those presented for this hypothetical accident scenario.

Conditions used in developing the source term for the projectile impact scenario are as follows:

- The source term is based on best estimate spent nuclear fuel corrosion products.
- One percent of the original corrosion products associated with the fuel could be released from the cask to the atmosphere. This is based on experimental measurements of the fraction of corrosion products loosened from naval spent nuclear fuel by shock and vibration. It was assumed the container seal would be breached enough to allow some leakage even though analysis has shown that a wind-driven missile would not penetrate the container or damage the fuel inside. Only loose corrosion products would be available for release from the container, and any release from the container would have to occur via a convoluted path through the damaged seal.
- The release to the environment occurs at a constant rate over a 15-minute period.
- There is no increase in direct radiation due to this accident.
- The following amounts of radionuclides could be released to the environment. This listing includes nuclides that result in at least 99% of the possible exposure.

	Alternative/Curies		
Radionuclide	MPC	Small MPC and M-140	All Others
Cobalt-60	2.0×10^{-1}	1.3×10^{-1}	2.4×10^{-1}
Iron-55	3.7×10^{-1}	2.5×10^{-1}	4.4×10^{-1}
Cobalt-58	7.4×10^{-2}	5.0×10^{-2}	8.9×10^{-2}
Manganese-54	1.3×10^{-2}	8.4×10^{-3}	1.5×10^{-2}
Iron-59	1.1×10^{-3}	7.2×10^{-4}	1.3×10^{-3}

The estimated health risks to the general population that might result from the hypothetical wind-driven missile accident at each location are summarized in Tables A.20 through A.24. The number of fatal cancers would be expected to occur over a 50-year period. The probability of a wind-driven missile damaging a container is less than 10^{-5}, and a probability of 10^{-5} per year was used in the risk assessment (DOE 1995; Volume 1, Appendix D, Part B, Section F.1.4.2.2.1.3).

For the hypothetical wind-driven missile accident scenario, the radioactive plume might cause contamination of the ground to a downwind distance of less than 0.11 mi (approximately 0.18 km). This would yield a total area impacted by the accident of less than 1.4 acres (approximately 0.57 ha). The calculated downwind distance would be contained within the boundaries of INEL.

TABLE A.22 Estimated Health Risks from Dry Storage Mechanical Damage at INEL: Multi-Purpose Canister [a]

Site/ Individual	50% Meteorology Dose (rem)	50% Meteorology Latent Cancer Fatalities	95% Meteorology Dose (rem)	95% Meteorology Latent Cancer Fatalities
NRF				
Worker	4.3×10^{-2}	1.7×10^{-5}	1.2×10^{-1}	4.8×10^{-5}
NPA	2.1×10^{-5}	1.1×10^{-8}	1.4×10^{-4}	7.0×10^{-8}
MEI	1.7×10^{-4}	8.5×10^{-8}	9.9×10^{-4}	5.0×10^{-7}
ICPP				
Worker	4.3×10^{-2}	1.7×10^{-5}	1.2×10^{-1}	4.8×10^{-5}
NPA	3.0×10^{-5}	1.5×10^{-8}	4.4×10^{-4}	2.2×10^{-7}
MEI	7.4×10^{-5}	3.7×10^{-8}	5.8×10^{-4}	2.9×10^{-7}
Birch Creek Area				
Worker	4.3×10^{-2}	1.7×10^{-5}	1.2×10^{-1}	1.8×10^{-5}
NPA	1.6×10^{-4}	7.8×10^{-8}	5.5×10^{-3}	2.8×10^{-6}
MEI	3.7×10^{-4}	1.8×10^{-7}	1.3×10^{-2}	6.5×10^{-6}

Population within 50-Mile Radius of Site	50% Meteorology Collective Dose (person-rem)	50% Meteorology Latent Cancer Fatalities	95% Meteorology Collective Dose (person-rem)	95% Meteorology Latent Cancer Fatalities	95% Meteorology Annual Risk
NRF					
115,690	4.9×10^{-1}	2.5×10^{-4}	2.1	1.1×10^{-3}	1.1×10^{-8}
ICPP					
120,003	5.0×10^{-1}	2.5×10^{-4}	2.0	1.0×10^{-3}	1.0×10^{-8}
Birch Creek Area					
138,026[b]	3.5×10^{-1}	1.8×10^{-4}	1.8	8.8×10^{-4}	8.8×10^{-9}

[a] Notation: ICPP = Idaho Chemical Processing Plant; MEI = individual at nearest site boundary; NPA = nearest public access individual; NRF = Naval Reactors Facility.

[b] Test Area North population used for this hypothetical location.

TABLE A.23 Estimated Health Risks from Dry Storage Mechanical Damage at INEL: Small Multi-Purpose Canister and M-140 Cask[a]

Site/ Individual	50% Meteorology Dose (rem)	50% Meteorology Latent Cancer Fatalities	95% Meteorology Dose (rem)	95% Meteorology Latent Cancer Fatalities
NRF				
Worker	2.9×10^{-2}	1.2×10^{-5}	8.0×10^{-2}	3.2×10^{-5}
NPA	1.4×10^{-5}	7.0×10^{-9}	9.0×10^{-5}	4.5×10^{-8}
MEI	1.1×10^{-4}	5.5×10^{-8}	6.6×10^{-4}	3.3×10^{-7}
ICPP				
Worker	2.9×10^{-2}	1.2×10^{-5}	8.0×10^{-2}	3.2×10^{-5}
NPA	2.0×10^{-5}	1.0×10^{-8}	2.9×10^{-4}	1.5×10^{-7}
MEI	4.9×10^{-5}	2.4×10^{-8}	3.9×10^{-4}	1.9×10^{-7}
Birch Creek Area				
Worker	2.9×10^{-2}	1.2×10^{-5}	8.0×10^{-2}	3.2×10^{-5}
NPA	1.0×10^{-4}	5.1×10^{-8}	3.6×10^{-3}	1.8×10^{-6}
MEI	2.4×10^{-4}	1.2×10^{-7}	8.4×10^{-3}	4.2×10^{-6}

Population within 50-Mile Radius of Site	50% Meteorology Collective Dose (person-rem)	50% Meteorology Latent Cancer Fatalities	95% Meteorology Collective Dose (person-rem)	95% Meteorology Latent Cancer Fatalities	95% Meteorology Annual Risk
NRF					
115,690	3.3×10^{-1}	1.7×10^{-4}	1.4	7.0×10^{-4}	7.0 x 10^{-9}
ICPP					
120,003	3.3×10^{-1}	1.7×10^{-4}	1.4	7.0×10^{-4}	7.0 x 10^{-9}
Birch Creek Area					
138,026[b]	2.3×10^{-1}	1.2×10^{-4}	1.2	5.8×10^{-4}	5.8 x 10^{-9}

[a] Notation: ICPP = Idaho Chemical Processing Plant; MEI = individual at nearest site boundary; NPA = nearest public access individual; NRF = Naval Reactors Facility.

[b] Test Area North population used for this hypothetical location.

TABLE A.24 Estimated Health Risks from Dry Storage Mechanical Damage at INEL: High-Capacity M-140 Cask, Transportable Storage Cask, and Dual-Purpose Canister [a]

Site/ Individual	50% Meteorology Dose (rem)	50% Meteorology Latent Cancer Fatalities	95% Meteorology Dose (rem)	95% Meteorology Latent Cancer Fatalities
NRF				
Worker	5.0×10^{-2}	2.0×10^{-5}	1.4×10^{-1}	5.6×10^{-5}
NPA	2.5×10^{-5}	1.3×10^{-8}	1.6×10^{-4}	8.0×10^{-8}
MEI	2.0×10^{-4}	1.0×10^{-7}	1.2×10^{-3}	6.0×10^{-7}
ICPP				
Worker	5.0×10^{-2}	2.0×10^{-5}	1.4×10^{-1}	5.6×10^{-5}
NPA	3.5×10^{-5}	1.7×10^{-8}	5.1×10^{-4}	2.6×10^{-7}
MEI	8.6×10^{-5}	4.3×10^{-8}	6.8×10^{-4}	3.4×10^{-7}
Birch Creek Area				
Worker	5.0×10^{-2}	2.0×10^{-5}	1.4×10^{-1}	5.6×10^{-5}
NPA	1.9×10^{-4}	9.3×10^{-8}	6.6×10^{-3}	3.3×10^{-6}
MEI	4.4×10^{-4}	2.2×10^{-7}	1.5×10^{-2}	7.7×10^{-6}

Population within 50-Mile Radius of Site	50% Meteorology Collective Dose (person-rem)	50% Meteorology Latent Cancer Fatalities	95% Meteorology Collective Dose (person-rem)	95% Meteorology Latent Cancer Fatalities	95% Meteorology Annual Risk
NRF					
115,690	5.7×10^{-1}	2.9×10^{-4}	2.4	1.2×10^{-3}	1.2×10^{-8}
ICPP					
120,003	5.8×10^{-1}	2.9×10^{-4}	2.4	1.2×10^{-3}	1.2×10^{-8}
Birch Creek Area					
138,026[b]	4.2×10^{-1}	2.1×10^{-4}	2.1	1.1×10^{-3}	1.1×10^{-8}

[a] Notation: ICPP = Idaho Chemical Processing Plant; MEI = individual at nearest site boundary; NPA = nearest public access individual; NRF = Naval Reactors Facility.

[b] Test Area North population used for this hypothetical location.

Airplane Crash. A hypothetical aircraft accident scenario was developed. Based on the probability of occurrence, specific analyses were only performed for the Idaho Chemical Processing Plant. The accident is postulated to cause damage to a single container. This is based on the fact that containers currently used to ship naval spent nuclear fuel are very rugged. Due to the severity of the shock, the cask might be breached resulting in damage to the fuel. The severe mechanical shock results in the release of corrosion products to the environment. The release of fission products also occurs due to the impact and resultant fire. The fission product release factors are based on overheating testing performed on the naval fuel systems.

Conditions used in developing the source term for the airplane crash scenario are as follows:

- One percent of all of the fuel units stored inside the cask are damaged either by the impact or the resultant fire and those fission products are available for release.
- Of the available fission products, 100% of the noble gases, 3% of the halogens, 1.1% of the cesium, and 0.1% of the remaining solids are released to the environment.
- The release to the environment occurs at a constant rate over a 15-minute period.
- Ten percent of the original corrosion products from the fuel units are released from the cask to the atmosphere.
- The amounts of radionuclides that could be released to the environment are listed in Table A.25. This listing includes nuclides that result in at least 99% of the possible exposure.

TABLE A.25 Radionuclide Releases from a Dry Storage Airplane Crash Accident[a]

	Radionuclide Releases (Ci)			
Nuclide	MPC	Small MPC	M-140 Cask	High Capacity M-140 TSC and DPC
Strontium-90	7.9	4.1	4.9	7.3
Plutonium-241	8.4×10^{-2}	4.3×10^{-2}	5.9×10^{-2}	7.8×10^{-2}
Plutonium-238	2.4×10^{-1}	1.2×10^{-1}	1.5×10^{-1}	2.2×10^{-1}
Cesium-137	91	47	57	84
Cesium-134	71	37	37	66
Cerium-144	18	9.2	7.5	17
Barium-137m	86	44	54	79
Ruthenium-106	1.8	9.0×10^{-1}	7.4×10^{-1}	1.6

[a] Notation: DPC = dual-purpose canister; MPC = multi-purpose canister; TSC = transportable storage cask.

The estimated health risks to the general population that might result from the hypothetical airplane crash accident at each location are summarized in Table A.26. The number of fatal cancers would be expected to occur over a 50-year period. At NRF, the likelihood of occurrence is 5×10^{-8} per year based on a large storage array and the probability at the Idaho Chemical Processing Plant is 4 to 8 times larger (DOE 1995; Volume 1, Appendix D, Part B, Section F.3). The airplane crash probability is higher at the Idaho Chemical Processing Plant since low altitude testing of commercial jet airliners has been conducted near the National Oceanic and Atmospheric Administration tower, which is located about 1.5 miles from ICPP. A probability of 4×10^{-7} is used for the Idaho Chemical Processing Plant.

For the hypothetical airplane crash into a dry storage cask accident scenario, the radioactive plume might cause contamination of the ground to a downwind distance of approximately 2.2 mi (approximately 3.5 km). This would yield a total area impacted by the accident of about 629 acres (approximately 255 ha). The calculated downwind distance would be contained within the boundaries of INEL.

Unloading Operations. Accidents during unloading operations of naval spent nuclear fuel are considered at the hypothetical geologic repository site.

Mechanical Damage. The hypothetical mechanical damage accident at a geologic repository is the same as that discussed for dry storage, namely a wind-driven projectile.

The estimated health risks to the general population that might result from the hypothetical wind-driven projectile accident at the hypothetical geologic repository site are presented in Table A.27. The number of fatal cancers would be expected to occur over a 50-year period. Like the dry storage analysis, a probability of 10^{-5} per year was used in the risk assessment.

For the hypothetical mechanical damage accident scenario, the radioactive plume might result in contamination of the ground to a downwind distance of less than 0.11 mi (approximately 0.18 km). This would yield a total area impacted by the accident of less than 1.4 acres (approximately 0.57 ha). The calculated downwind distance would be contained within the boundaries of a geologic repository site.

Dropped Transfer Container. For the M-140 container alternatives, the naval spent nuclear fuel must be removed from the M-140 transportation casks and placed in an interim container at a repository surface facility. This interim container can then be accepted into the surface facility for subsequent transfer of the fuel to a disposal container. During this fuel movement sequence, it is postulated that the crane or rigging fails resulting in a dropped transfer container which contains a single naval spent nuclear fuel assembly. For all other alternatives, the surface facility will be designed to handle the shipping container, resulting in all fuel handling being conducted in a shielded, filtered facility. Therefore, this postulated accident applies to the M-140 alternatives only.

TABLE A.26 Estimated Health Risks from a Dry Storage Airplane Crash Accident at the Idaho Chemical Processing Plant [a]

Container Type/ Individual	50% Meteorology Dose (rem)	50% Meteorology Latent Cancer Fatalities	95% Meteorology Dose (rem)	95% Meteorology Latent Cancer Fatalities
MPC				
Worker	120	9.5×10^{-2}	330	2.6×10^{-1}
NPA	8.2×10^{-2}	4.1×10^{-5}	1.6	7.9×10^{-4}
MEI	4.1×10^{-1}	2.1×10^{-4}	1.0	5.0×10^{-4}
Small MPC				
Worker	61	4.9×10^{-2}	170	1.4×10^{-1}
NPA	4.2×10^{-2}	2.1×10^{-5}	8.1×10^{-1}	4.0×10^{-4}
MEI	2.1×10^{-1}	1.1×10^{-4}	5.1×10^{-1}	2.6×10^{-4}
M-140 cask				
Worker	73	5.8×10^{-2}	200	$1.6 x 10^{-1}$
NPA	5.0×10^{-2}	2.5×10^{-5}	9.6×10^{-1}	4.8×10^{-4}
MEI	2.5×10^{-1}	1.3×10^{-4}	6.0×10^{-1}	3.0×10^{-4}
TSC, DPC, and High-Capacity M-140				
Worker	110	8.8×10^{-2}	300	2.4×10^{-1}
NPA	7.6×10^{-2}	3.8×10^{-5}	1.5	7.3×10^{-4}
MEI	3.8×10^{-1}	1.9×10^{-4}	9.2×10^{-1}	4.6×10^{-4}

Container Type	50% Meteorology Collective Dose[b] (person-rem)	50% Meteorology Latent Cancer Fatalities	95% Meteorology Collective Dose[b] (person-rem)	95% Meteorology Latent Cancer Fatalities	Annual Risk
125-ton MPC	3.4×10^{3}	1.7	5.2×10^{3}	2.6	1.0×10^{-6}
75-ton MPC	1.7×10^{3}	8.6×10^{-1}	2.7×10^{3}	1.3	5.2×10^{-7}
M-140 cask	2.1×10^{3}	1.0	3.2×10^{3}	1.6	6.4×10^{-7}
TSC, DPC, and High-Capacity M-140	3.1×10^{3}	1.6	4.8×10^{3}	2.4	9.6×10^{-7}

[a] Notation: DPC = dual-purpose canisters; MPC = multi-purpose canister; MEI = individual at nearest site boundary; NPA = nearest public access individual; TSC = transportable storage cask.

[b] Population within a 50-mi (approximately 80-km) radius of the site = 120,003.

TABLE A.27 Estimated Health Effects from a Mechanical Damage (Wind-Driven Projectile) Accident during Unloading Operations at a Geologic Repository Site[a]

Container Type/ Individual	50% Meteorology Dose (rem)	50% Meteorology Latent Cancer Fatalities	95% Meteorology Dose (rem)	95% Meteorology Latent Cancer Fatalities
MPC				
Worker	1.8×10^{-2}	7.2×10^{-6}	2.9×10^{-1}	1.2×10^{-4}
MEI	5.2×10^{-5}	2.6×10^{-8}	1.7×10^{-3}	8.7×10^{-7}
Small MPC and M-140				
Worker	1.2×10^{-2}	4.8×10^{-6}	2.0×10^{-1}	7.8×10^{-5}
MEI	3.5×10^{-5}	1.7×10^{-8}	1.2×10^{-3}	5.8×10^{-7}
High-capacity M-140, TSC, and DPC				
Worker	2.2×10^{-2}	8.6×10^{-6}	3.5×10^{-1}	1.4×10^{-4}
MEI	6.2×10^{-5}	3.1×10^{-8}	2.1×10^{-3}	1.0×10^{-6}

Container Type	50% Meteorology Collective Dose[b] (person-rem)	50% Meteorology Latent Cancer Fatalities	95% Meteorology Collective Dose[b] (person-rem)	95% Meteorology Latent Cancer Fatalities	95% Meteorology Annual Risk
MPC	6.3×10^{-2}	3.1×10^{-5}	3.0	1.5×10^{-3}	1.5×10^{-8}
Small MPC and M-140	4.2×10^{-2}	2.1×10^{-5}	2.0	1.0×10^{-3}	1.0×10^{-8}
High-capacity M-140, TSC, and DPC	7.5×10^{-2}	3.7×10^{-5}	3.6	1.8×10^{-3}	1.8×10^{-8}

[a] Notation: DPC = dual-purpose canister; MEI = individual at nearest site boundary; MPC = multi-purpose canister; TSC = transportable storage cask.
[b] Population within 50-mi (approximately 80-km) radius of the site = 352,157.

The development of the radioactive source term for the dropped transfer container scenario is based on the following:

- The source term is based on best estimate spent nuclear fuel corrosion products.

- One percent of the original corrosion products associated with the one fuel assembly could be released from the transfer container to the atmosphere. This is based on experimental measurements of the fraction of corrosion products loosened from naval spent nuclear fuel by shock and vibration. It is also postulated that the container door seal fails and leakage can occur.

- The transfer of fuel from the M-140 is postulated to occur in a unfiltered area and no reduction is taken for filtering.

- The release to the environment occurs at a constant rate over a 1 hour period which is the accident default time in GENII.

- There is no increase in direct radiation due to this accident.

- The following amounts of radionuclides could be released to the environment. This listing includes nuclides that result in at least 99% of the possible exposure.

Nuclide	Curies
Manganese-54	7.51×10^{-4}
Iron-55	2.21×10^{-2}
Iron-59	6.38×10^{-5}
Cobalt-58	4.43×10^{-3}
Cobalt-60	1.20×10^{-2}

The estimated health risks to the general population that might result from the hypothetical dropped transfer container at a geologic repository are presented in Table A.28. The number of latent cancer fatalities would be expected to occur over a 50-year period. This accident would not be applicable to the alternatives making use of multi-purpose canisters because the containers would not be opened during the unloading operations. The probability of a transfer container drop accident with the release of radioactive corrosion products is based on the probability of a severe uncontrolled crane failure of 10^{-8} per lift. This is combined with a conservative estimate of 1,000 lifts per year unloading M-140 or modified M-140 containers at a repository surface facility to obtain an annual accident probability of 10^{-5} per year. An annual probability of occurrence of 1×10^{5} was used to develop the risk results in the table.

For the hypothetical dropped transfer container accident scenario, the radioactive plume might cause contamination of the ground to a downwind distance of less than 0.06 mi (approximately 0.1 km). This would yield a total area impacted by the accident of less than 0.5 acre (approximately 0.2 ha). The calculated downwind distance would be contained within the boundaries of a geologic repository site.

TABLE A.28 Estimated Health Effects from a Dropped Transfer Container during Unloading Operations at a Geologic Repository Site[a]

Site/ Individual	50% Meteorology: Dose (rem)	50% Meteorology: Latent Cancer Fatalities	95% Meteorology: Dose (rem)	95% Meteorology: Latent Cancer Fatalities
Worker	1.1×10^{-3}	4.3×10^{-7}	1.7×10^{-2}	7.0×10^{-6}
MEI	3.1×10^{-6}	1.6×10^{-9}	1.0×10^{-4}	5.2×10^{-8}

Population within 50-Mile Radius of Site	50% Meteorology: Collective Dose (person-rem)	50% Meteorology: Latent Cancer Fatalities	95% Meteorology: Collective Dose (person-rem)	95% Meteorology: Latent Cancer Fatalities	Annual Risk
352,157	3.7×10^{-3}	1.9×10^{-6}	1.8×10^{-1}	9.0×10^{-5}	9.0×10^{-10}

[a] Notation: MEI = individual at nearest site boundary.

A.2.6 Impact of Accidents on Close-In Workers

An evaluation has been made of the impact to close-in workers involved in naval spent nuclear fuel operations that might occur due to the various radiological accidents postulated. This evaluation focused on the radiological consequences of the accident. Clearly, a limited number of fatalities may occur which are related to spent nuclear fuel handling only in a secondary manner; i.e., the worker who happened to be in the facility may be killed due to a plane crash, seismic event, crane failure, etc. These secondary effects are not discussed in the following. Rather, only radiological consequences are considered.

Drained Water Pool Due to Seismic Event. No fatalities to workers close to the scene of the accident would be expected due to radiological consequences. This is because drainage of the large amount of water in a water pool is expected to take several days which provides ample time for workers to leave the facility.

Accidental Criticality in a Water Pool Due to Human Error. It is likely no fatalities would occur. At most, two or three workers may receive some appreciable radiation exposure. This is because the criticality would occur under approximately 20 ft (approximately 6.1 m) of water. Shielding by the water would be sufficient to prevent exposure of nearby workers. Expulsion of a cone of water above the criticality might lead to significant exposure to any workers who were directly above the location of the criticality.

Mechanical Damage to Fuel in a Water Pool Due to Operator Error or Crane Failure. No fatalities to workers would be expected from radiological consequences. This is because the release of the source term is under water. Attenuation by the water would occur for most products, but release of noble gases would cause a direct radiation exposure to workers in the area. Upon releases from the surface of the water pool, radiation alarms would sound requiring evacuation of nearby workers. Timely evacuation would prevent substantial radiation exposure.

Airplane Crash into Water Pool. No fatalities to workers would be expected from radiological consequences. This is because any release of radioactive products would be underwater and radiation alarms would sound requiring evacuation of nearby workers. Timely evacuation would prevent substantial radiation exposure.

HEPA Filter Fire. No fatalities would be expected among nearby workers from the radiological consequences of a fire in a HEPA filter. This is because HEPA filters are not located in an area where workers are likely to be working. In addition, the release of radioactivity involved in a HEPA filter fire is not large.

Small Leaks from Water Pools. No fatalities are expected among nearby workers from the radiological consequences of a small leak from a water pool. The leak would be expected to be into the ground through the water pathway. Drinking water supplies would not be immediately impacted. In addition, the typical concentration of radioactivity in the water is low.

Dropped Fuel Unit. No fatalities would be expected among nearby workers from the radiological consequences of a dropped fuel unit in the Dry Cell Facility. The drop would occur in a shielded, filtered cell which provides protection to the nearby workers.

Wind-Driven Projectile Impact on Storage Casks. It is likely there would be no fatalities to workers from radiological consequences. This is because there usually would be no nearby workers except for brief periods when a container is being placed in the dry storage array. Since a wind-driven missile is not expected to penetrate a dry storage container, direct radiation exposures even to nearby workers would not be expected. The container seal could be breached and some airborne products released. At most, two or three nearby workers may receive some radiation exposure from inhalation of airborne radioactivity. These same consequences also apply to this hypothetical accident should it occur during unloading operations.

Airplane Crash into Dry Storage. It is not likely that any fatalities would occur to nearby workers due to the radiological consequences of this accident. Workers are usually not in the dry storage array except when a container is being placed into the array. At most, two or three nearby workers might receive significant radiation exposure from inhalation of airborne radioactivity since the container seal may be breached. The low probability of the airplane crash itself, coupled with the probability that workers would be close enough to be affected, coupled with the probability that the wind would be blowing in the direction of the workers, makes it very unlikely that any worker would receive substantial radiation exposure.

Dropped Transfer Container. It is likely there would be no fatalities to workers from radiological consequences. At most, two or three nearby workers may receive some radiation exposure from inhalation of airborne radioactivity.

A.2.7 Analysis of Uncertainties

An extensive discussion of uncertainty analysis related to this Environmental Impact Statement can be found in the Programmatic SNF and INEL EIS (DOE 1995; Volume 1, Appendix D, Attachment F, Section F.1.5). In summary, the calculations in this EIS have been performed in such a way that the estimates of risk provided are unlikely to be exceeded during either normal operations or in the event of an accident. For routine operations, the results of monitoring of actual operations provide clearly realistic source terms, which, when combined with conservative estimates of the effects of radiation, produce estimates of risk which are very unlikely to be exceeded. The effects for all alternatives have been calculated using the same source terms and other factors, so this EIS provides an appropriate means of comparing potential impacts on human health and the environment.

The analyses of hypothetical accidents provide more opportunities for uncertainty, primarily because the calculations must be based on sequences of events and models of effects which have not occurred. In this appendix, the goal in selecting the hypothetical accidents analyzed has been to evaluate events which would produce effects which would be as severe or more severe than any other accidents which might reasonably be postulated. The models have attempted to provide estimates of the probabilities, source terms, pathways for dispersion and exposure, and the effects on human health and the environment which are as realistic as possible. However, in many cases, the very low probability of the accidents postulated has required the use of models or values for input which produce estimates of consequences and risks which are higher than would actually occur because of the desire to provide results which will not be exceeded. In summary, the risks presented in this appendix are believed to be at least 10 to 100 times larger than what would actually occur.

The use of conservative analyses is not an important problem or disadvantage in this EIS since all of the alternatives have been evaluated using the same methods and data, allowing a fair comparison of all of the alternatives on the same basis. Furthermore, even using these conservative analytical methods, the risks for all of the alternatives are small, which greatly reduces the significance of any uncertainty analysis parameters.

A.3 Toxic Chemical Issues Associated with Naval Spent Nuclear Fuel Loading, Storage, and Unloading

An evaluation of the Expended Core Facility normal operations and hypothetical accident scenarios which could result in toxic chemical releases was performed (DOE 1995; Volume 1, Appendix D, Part B, Section F.2). The results for normal operations showed that no ambient air quality standards would be exceeded. For hypothetical accident scenarios, the evaluations showed that no member of the general public near INEL or a geologic repository would exceed Emergency Response Planning Guide-1 (ERPG-1) levels except for a sulfuric acid spill and fire scenario at a geologic repository, where the potential exposure to the maximally exposed offsite individual is greater than ERPG-1 levels but less than ERPG-2 levels under 95% meteorological conditions.

A.4 Aircraft Crash Probabilities

The probability of an airplane crashing into a fuel storage area or a fuel loading or unloading facility was evaluated (DOE 1995; Volume 1, Appendix D, Part B, Section F.3). An airplane crash into these facilities is of concern since it might result in the release of corrosion products from the stored fuel or the release of radioactive fission products from the fuel. The method outlined in "A Methodology for Calculation of the Probability of Crash of an Aircraft into Structures in Weapon Storage Areas" (Sandia 1983) was used to predict the crash probabilities. This calculation methodology takes into consideration the crash probabilities associated with landing and takeoff operations at nearby airports and crashes during in-flight operations.

The aircraft crash probability analysis is based on the examination of large civilian aircraft and military aircraft crossing the space within a 10-mi (approximately 16-km) radius of each site. The crash probability of general aviation aircraft is not included in this assessment since aircraft of this type generally do not possess sufficient mass or attain sufficiently high velocities to produce a serious radiological threat in the event that they crash into a fuel storage area or a fuel examination facility. Further, the crash probability contribution due to air travel beyond 10 mi (approximately 16 km) was determined to be very small based on the models and conditions used in this analysis, and therefore has been omitted.

A.5 Fugitive Dust

An evaluation of fugitive dust emissions that could be generated during the construction of a large laboratory facility like the Expended Core Facility was performed (DOE 1995; Volume 1, Appendix D, Part B, Section F.4). Since it was determined that the release of fugitive dust would not result in any adverse effects for this large spent nuclear fuel handling, examination, and shipping facility, it can be concluded that the construction of a minor addition to an Expended Core Facility type of facility would also result in no adverse impacts.

A.6 Occupational Accidents

Occupational accidents can occur in the workplace during the construction or operation of any industrial facility. In order to assess the possible extent of occupational accidents during construction and nonconstruction operations at naval spent nuclear fuel facilities, projections of the number of fatalities and injuries or illnesses were made (DOE 1995; Volume 1, Appendix D, Part B, Section F.5). The projections are based on average occupational fatality and injury incidence rate data for U.S. Department of Energy operations and their contractors (DOE 1993a). The results of all calculations show that the number of fatalities and injuries or illnesses for construction activities and storage and examination operations would be low.