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1	1	Cog. Eng. TA Tomaszewski	Tom Tomaszewski	5-2-96	G1-11	DR Precechtel	[signature]	5/3/96	R3-48	1	1
1	1	Cog. Mgr. JG Field	[signature]	5/2/96	G1-11	JE Geary	VCB [signature]	5/8/96	S5-07	1	1
1	1	QA CR Hoover	[signature]	5-2-96	G1-11	SS Shiraga	[signature]	5/2/96	G1-11	1	1
1	1	Safety DW McNally	DW McNally	5-2-96	G1-11	RJ Smith	[signature]	5/2/96	G1-11	1	1
1	1	SA Brisbin	SA Brisbin	5-2-96	R3-48	CA Thompson	[signature]	5/6/96	R3-85	1	1
1	1	JR Green	JR Green	5-2-96	G1-11	SEAC WJ Schlauder	WJ Schlauder	5/7/96	S7-84	1	1
1	1	FW Moore	FW Moore	5-2-96	X3-85						

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Packaging Design Criteria for the K East Basin Sludge Transportation System

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Abstract: This packaging design criteria (PDC) establishes the onsite transportation safety criteria for a reusable packaging and transport system to transport K East Basin sludge and water. This PDC provides the basis for the development of a safety analysis report for packaging; establishes the packaging contents and safety class of the package; and provides design criteria for the package, packaging, and transport systems.

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LIST OF TERMS

AISC	American Institute of Steel Construction
ALARA	as low as reasonably achievable
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
BTU/h	British thermal units per hour
CEDE	committed effective dose equivalent
Ci/gal	curies per gallon
cm	centimeter
container	The vessel holding the sludge and water. Part of the packaging.
DOT	U.S. Department of Transportation
dpm/cm^2	disintegrations per minute per cubic centimeter
DST	double-shell tank
FMVSS	Federal Motor Vehicle Safety Standards
ft	foot
ft^3	cubic foot
g	gram
gal	gallon
g/L	grams per liter
g/mL	grams per milliliter
HEPA	high-efficiency particulate air (filter)
HRCQ	highway route controlled quantity
in.	inch
kg	kilogram
kg/m^3	kilograms per cubic meter
km	kilometer
km/h	kilometers per hour
kPa	kilopascal
lb	pound
lb/ft^3	pounds per cubic foot
m	meter
m^3	cubic meter
$\mu g/L$	micrograms per liter
μm	micrometer (micron)
mi	mile
mi/h	miles per hour
mm	millimeter
mrem/h	millirem per hour
OSHA	Occupational Safety and Health Administration
package	The combination of packaging and payload.
packaging	The hardware that contains and protects the payload. Packaging includes the container.
payload	The packaging contents. Sludge and water.
psi	pounds per square inch
NDA	nondestructive assay
NRC	U.S. Nuclear Regulatory Commission
PDC	packaging design criteria
PUREX	Plutonium Uranium Reduction Extraction Facility
SAE	Society of Automotive Engineers
SARP	safety analysis report for packaging

LIST OF TERMS (cont)

SNF	spent nuclear fuel
TWRS	Tank Waste Remediation System
W	watt
wt%	weight percent

PACKAGING DESIGN CRITERIA FOR THE K EAST BASIN SLUDGE TRANSPORTATION SYSTEM

1.0 INTRODUCTION

1.1 BACKGROUND

The K Basins, built in the early 1950s, provide underwater storage of N Reactor fuel irradiated from 1978 through 1987. In 1992, the decision to deactivate the Plutonium Uranium Reduction Extraction (PUREX) Facility precluded processing the approximately 2,100 metric tons (2,315 tons) of N Reactor spent nuclear fuel (SNF) left in the K Basins, where it has remained. A significant fraction of the SNF has become degraded due to cladding breaches during reactor discharge and corrosion has continued during storage.

The spent fuel is stored in open-top canisters, some of which have closed bottoms and others of which have screened bottoms. The open canisters release fission products into the basin water that, combined with environmental particulate matter, have settled to the bottom as sludge. Depths exceeding 0.9 m (3 ft) have been measured in some locations. Using sludge depth measurements, the total sludge volume in the K East Basin is estimated to be as high as 67.5 m^3 (17,832 gal [Short 1995]).

The basin water and sludge have the potential to leak to the environment due to the age and condition of the Basin. Current planning is to remove the sludge, transport it to and place it into a selected Tank Waste Remediation System (TWRS) double-shell tank (DST) located in the 200 East Area. The particular tank has not yet been identified. This preferred sludge path forward alternative is identified in Alderman (1995).

1.2 PURPOSE AND SCOPE

This packaging design criteria (PDC) establishes the onsite transportation safety criteria for a reusable packaging and transport system to transport K East Basin sludge and water. This PDC provides the basis for the development of a Safety Analysis Report for Packaging (SARP), establishes the packaging contents and safety class of the package, and provides design criteria for the package, packaging, and transport systems.

The SARP will approve the transport system for use on the Hanford Site and will demonstrate that the packaging meets the transportation safety requirements of WHC-CM-2-14, *Hazardous Material Packaging and Shipping.*

1.3 JUSTIFICATION

Various transport and packaging options were evaluated for transferring K Basin sludge to the TWRS. The basis to use a trailer-mounted American Society of Mechanical Engineers (ASME) pressure vessel, approximately 3 m^3 to

6 m^3 (793 gal to 1,585 gal) in volume, is documented in Brisbin (1995b). An option from Brisbin (1995b) to use a high-integrity container was eliminated due to the activity level of the source term.

2.0 PACKAGE CONTENTS

The payload is expected to vary in size from a minimum of 3 m^3 (793 gal) to a maximum of 6 m^3 (1,585 gal), consisting of 20% to 30% sludge by volume, the rest being interstitial basin and process water. The sludge itself, in turn, consists of 17 wt% to 52 wt% of dry solids. It is the solids fraction that contributes the bulk of the radioactivity.

Sludge physical data are presented in Table 1; uranium isotopic fractions are shown in Table 2; mass and activity levels for the total sludge inventory, the water, the worst-case sludge, the total sludge and water, and the single-shipment worst case are presented in Tables 3 through 7.

Table data originate from *Spent Nuclear Fuel Project Technical Databook* (Short 1995) and represent best available data. Chemical and radionuclide data for the sludge and the radionuclide data for water are taken from Brisbin (1995a). The physical and radionuclide composition of the sludge is not distributed homogeneously throughout the basin; however, the inventory was averaged to more closely represent the expected removal process. All data were then adjusted to account for total volume, uranium isotopes, and other actinides, as discussed in Section 2.2.

2.1 PAYLOAD DESCRIPTION

The payload is a mixture of basin water, process water, and sludge. The sludge is a radioactive mixture of solids and interstitial basin water (with dissolved solids). The sludge has a thin crust with underlying layers of solid and flocculent materials. The solids consist of fuel corrosion products; fuel pieces; uranium oxide and fission products; activated metals; concrete; grit; aluminum and iron oxides; paint; dirt, dust; and plant, insect, and previously airborne environmental debris. The basin water is radioactive and provides the covering to the sludge. The process water comes from the loading and flushing operations.

The wet sludge density, averaged over the entire K East Basin inventory, is 1,325 kg/m^3, with a range of 1,130 to 1,535 kg/m^3. The solid portion of the sludge varies from 17 wt% to 52 wt%, the rest being interstitial basin water. After incorporating measurement uncertainties, the maximum total sludge volume is estimated to be 67.5 m^3, with 50.51 m^3 being the expected value.

Table 1 provides the physical characteristics of the K East Basin sludge.

Table 1. Physical Characteristics of K East Basin Sludge.

Property	Range
Density[1]	1.13-1.535 g/mL
Mean particle size[2]	1.53-1.68 μm
Solids (wt%)[3]	17.52% - 51.29%
Sludge volume	67.5 m^3 maximum 50.51 m^3 average

[1]Density is of wet sludge after settling.

[2]Particle size is average size of all particles in sample. Most particles are < 2μm diameter; over half the volume is in particles > 20-40 μm; however, some fuel pieces may be up to 0.64 cm (0.25 in.) in diameter.

[3]Weight percent of solids is the fractions of solids in the sludge (the remainder is water).

2.2 RADIONUCLIDE COMPOSITION

The K East Basin contains irradiated fuel that is stored underwater. Along with this irradiated fuel is a buildup of sludge that has settled to the bottom of the basin. When the sludge is removed from the basin, it will be mixed in with the water from the basin, which is contaminated at a negligible level. It is assumed the waste will consist of 30% sludge and 70% water by volume (from a maximum expected "sludge pumping efficiency" of 30%).

This section characterizes two source terms. The first source represents the total source inventory to be shipped. This source consists of 67.5 m^3 of sludge and 157.4 m^3 of water for a total volume of 224.9 m^3. The second source represents the worst-case source expected for a single shipment and consists of 1.8 m^3 of sludge and 4.2 m^3 of water for a total volume of 6.0 m^3.

The curie inventories for the K East Basin were decayed to May 1993 (Short 1995). The radionuclide inventories from Short (1995) did not include an isotopic breakdown of the uranium isotopes, but did include the total amount of uranium present. To determine the isotopic breakdown of the uranium, it was assumed the concentrations would be similar to that for Mark 1A fuel with an approximate burnup resulting in 12% ^{240}Pu (Schwarz 1992). Mark 1A fuel was used, because it contains more highly enriched uranium than Mark IV fuel; 12% ^{240}Pu was used, because it is similar to the plutonium mixture specified for the sludge.

Table 2 lists the estimated isotopic uranium concentrations for the total source, the water, and the worst-case sludge source terms. The uranium mass present in the sludge for the total sludge source and the worst-case sludge source is provided in Short (1995). The isotopic breakdown of this total mass was calculated by taking the total mass and multiplying by the mass fractions for each isotope. The water does not include a uranium mass. To estimate the amount of uranium in the water, the sludge uranium mass was multiplied by the amount of plutonium in the water divided by the amount of plutonium in the sludge.

Table 2. Uranium Isotopic Fractions.

Isotope	Fraction[1]	Sludge mass for 50.51 m^3 (g)	Water (μg/L)	Worst sludge mass for 1.37 m^3 (g)
^{234}U	7.16E-05	1.05E+02	1.98E-02	5.79E+00
^{235}U	8.45E-03	1.23E+04	2.34E+00	6.83E+02
^{236}U	1.02E-03	1.49E+03	2.83E-01	8.27E+01
^{238}U	9.90E-01	1.45E+06	2.74E+02	8.00E+04
Total	1.00E+00	1.46E+06[2]	2.76E+02[3]	8.08E+04[2]

[1]Source: Schwarz, R. A., 1992, New Origen2 Runs for N-Reactor Fuel (internal memo to K. H. Bergsman, February 25), Westinghouse Hanford Company, Richland, Washington (obtained from compositions for Mark 1A 12% ^{240}Pu fuel).

[2]Source: Short, S. M., 1995, Spent Nuclear Fuel Project Technical Databook, WHC-SD-SNF-TI-015, Rev. 0, Westinghouse Hanford Company, Richland, Washington (from Table 3.9).

[3](Sludge U mass)*(Water Pu mass/Sludge Pu mass).

Table 3 lists the mass and activity for all of the sludge to be shipped, decayed to May 1993. For the SARP, these values should be decayed to the latest expected shipping date to account for the buildup of ^{241}Am. The values for a volume of 50.51 m^3 were obtained from Short (1995). Uncertainties in the sludge mass could result in a total sludge volume of 67.5 m^3 being shipped. To be conservative, the values in Table 3 were then multiplied by a factor of 67.5/50.51 = 1.336 to determine an upper limit mass and activity for 67.5 m^3, which is also listed in Table 3.

Notice that according to Table 3, that 12.9% (628/4,880) of the plutonium is ^{240}Pu. Also notice that the uranium masses calculated in Table 2 for a volume of 50.51 m^3 are included in this table.

By comparing measurement values with calculated values, a number of radionuclides are calculated to exist, but have not been accounted for in the measurement data. Some of the more important isotopes are ^{244}Cm, which dominates the neutron source; ^{208}Tl and ^{212}Bi, which are decay products of ^{236}Pu and contribute to the high-energy gamma-ray source; and ^{144}Pr, ^{106}Rh, ^{125}Sb, and ^{134}Cs, which also make major contributions to the gamma-ray source term. These isotopes are not accounted for in this analysis and further work should be done for the SARP to determine if any of these isotopes are present in the sludge.

Table 4 lists the mass and activity of the water provided in Brisbin (1995a) from measurements made in 1994 and 1995. The numbers are in units of μCi/L. These numbers were used to determine the mass and activity in 157.4 m^3 of water and 4.2 m^3 of water. Given that there is a total of 67.5 m^3 of sludge, which will make up 30% of the source, then there must be 157.4 m^3 of water included with the sludge to make up the other 70% of the source. Similarly, each shipment will contain 6 m^3 of waste, which corresponds to 1.8 m^3 of sludge and 4.2 m^3 of water.

Table 3. Mass and Activity, Total Sludge (May 1993).

Isotope	Volume (50.51 m^3)[1]		Volume (67.5 m^3)[2]	
	Ci[3]	Grams	Ci	Grams
^{60}Co	2.86E+01	2.53E-02	3.82E+01	3.38E-02
^{90}Sr	1.33E+03	9.75E+00	1.78E+03	1.30E+01
^{90}Y	1.33E+03	2.44E-03	1.78E+03	3.26E-03
^{137}Cs	1.01E+03	1.16E+01	1.35E+03	1.55E+01
^{137m}Ba	9.55E+02	1.78E-06	1.28E+03	2.37E-06
^{154}Eu	2.98E+01	1.10E-01	3.98E+01	1.47E-01
^{155}Eu	1.70E+01	3.66E-02	2.27E+01	4.88E-02
^{238}Pu	6.60E+01	3.86E+00	8.81E+01	5.15E+00
^{239}Pu	2.60E+02	4.18E+03	3.47E+02	5.59E+03
^{240}Pu	1.43E+02	6.28E+02	1.91E+02	8.38E+02
^{241}Pu	5.66E+03	5.49E+01	7.56E+03	7.34E+01
^{242}Pu	4.36E-02	1.14E+01	5.82E-02	1.52E+01
^{241}Am	7.69E+02	2.24E+02	1.03E+03	2.99E+02
^{234}U	6.53E-01	1.05E+02[4]	8.72E-01	1.40E+02
^{235}U	2.67E-02	1.23E+04[4]	3.56E-02	1.65E+04
^{236}U	9.67E-02	1.49E+03[4]	1.29E-01	2.00E+03
^{238}U	4.86E-01	1.45E+06[4]	6.49E-01	1.93E+06
Total	1.16E+04	1.47E+06	1.55E+04	1.96E+06

[1]Source: Short, S. M., 1995, Spent Nuclear Fuel Project Technical Databook, WHC-SD-SNF-TI-015, Rev. 0, Westinghouse Hanford Company, Richland, Washington (Table 2.4).

[2]Table 2.1 from Short (1995).

[3]Table 3.11 from Short (1995).

[4]Values from Table 2.

Table 4. Mass and Activity, Water (1994, 1995).

Isotope	μCi/L[1]	μg/L	Total inventory for 157.4 m^3		Inventory for 4.2 m^3	
			Ci	Grams	Ci	Grams
^{3}H	1.52E-03	1.58E-07	2.39E-04	2.48E-08	6.38E-06	6.62E-10
^{90}Sr	8.30E+00	6.09E-02	1.31E+00	9.58E-03	3.49E-02	2.56E-04
^{90}Y[2]	8.30E+00	1.53E-05	1.31E+00	2.40E-06	3.49E-02	6.41E-08
^{137}Cs	1.30E+01	1.49E-01	2.05E+00	2.35E-02	5.46E-02	6.28E-04
^{137m}Ba[3]	1.30E+01	2.42E-08	2.05E+00	3.80E-09	5.46E-02	1.02E-10
^{238}Pu	9.95E-03	5.81E-04	1.57E-03	9.15E-05	4.18E-05	2.44E-06
^{239}Pu[4]	4.51E-02	7.26E-01	7.10E-03	1.14E-01	1.89E-04	3.05E-03
^{240}Pu[4]	4.51E-02	1.98E-01	7.10E-03	3.12E-02	1.89E-04	8.31E-04
^{241}Am	2.07E-01	6.03E-02	3.26E-02	9.49E-03	8.69E-04	2.53E-04
^{234}U	1.24E-04	1.98E-02[5]	1.95E-05	3.12E-03	5.19E-07	8.31E-05
^{235}U	5.05E-06	2.34E+00[5]	7.95E-07	3.68E-01	2.12E-08	9.81E-03
^{236}U	1.83E-05	2.83E-01[5]	2.88E-06	4.45E-02	7.69E-08	1.19E-03
^{238}U	9.20E-05	2.74E+02[5]	1.45E-05	4.31E+01	3.87E-07	1.15E+00
Total	4.29E+01	2.78E+02	6.75E+00	4.37E+01	1.80E-01	1.17E+00

[1]Source: Brisbin, S. A., 1995, Data for Preparation of the K Basin Sludge Packaging Design Criteria (internal memo SAB-95-007 to T. A. Tomaszewski, December 8), Westinghouse Hanford Company, Richland, Washington.

[2]Assumed equal to ^{90}Y.

[3]Content assumed equal to ^{137}Cs.

[4] ^{239}Pu and ^{240}Pu assumed equal to total because breakdown not provided.

[5]Values obtained from Table 2.

Table 5 lists the mass and activity of the area in the K East Basin with the highest radioactivity per volume. The worst case exists for the wash pit, which has a volume of 1.37 m^3. Values from Short (1995) were scaled to determine the mass and activity for a 1.8-m^3 sludge source. (In actuality, the wash pit data were derived from the weasel pit data; therefore, in effect, they are equally worst-case.)

Table 6 combines the sludge information from Table 3 and the water information from Table 4 to show the total mass and activity of the waste to be shipped.

Table 7 combines the water information from Table 4 and the worst-case sludge information from Table 5 to show the worst-case source in a single 6-m^3 payload.

For the values in Tables 6 and 7, an Origen2 run was made to determine if all of the major isotopes had been included. Some minor actinides were added to the list, because they contribute to the actinide photon source. These actinides were decayed ten years to approximate the minimum decay time since the reactor was shut down.

Appendix A contains the Origen2 input files used to calculate the additional actinides included in Tables 6 and 7. In addition, it contains the peer review checklist used during development of the K East Basin sludge container source term.

2.3 FISSILE CLASSIFICATION

The payload is classified as "fissile material" per WHC-CM-2-14.

Known fissile isotopes present in the sludge are ^{235}U, ^{238}Pu, ^{239}Pu, and ^{241}Pu (see Tables). The fissile content of the water (Table 4) is negligible.

A 1.8 m^3 payload of "average sludge" (Tables 3, 4, and 6) contains 591 g of fissile material. (The total sludge fissile inventory (22.17kg) from Table 6, multiplied by the maximum anticipated sludge shipment size (1.8 m^3), ratioed by the total sludge inventory (67.5 m^3), equals an "average sludge" shipment fissile content of 591 g (22,168 g x 1.8 m^3 / 67.5 = 591 g).

A 1.8 m^3 payload of "worst case sludge" (Tables 5 and 7) contains 1,218 g of fissile material. (The "worst case" single-shipment sludge fissile inventory [1,218 g] is summed directly from Table 7.)

The transportation index will be determined in the SARP based on a criticality analysis using the criteria of Section 5.1.5. Sludge transfers shall be controlled within the limits specified by the SARP.

Table 5. Mass and Activity, Worst-Case Sludge (May 1993).

Isotope	Inventory for 1.37 m^3		Inventory for 1.8 m^3	
	Ci[1]	Grams	Ci	Grams
^{60}Co	1.28E+00	1.13E-03	1.68E+00	1.49E-03
^{90}Sr	6.39E+01	4.68E-01	8.40E+01	6.16E-01
^{90}Y	6.39E+01	1.17E-04	8.40E+01	1.54E-04
^{137}Cs	4.89E+01	5.62E-01	6.42E+01	7.39E-01
^{137m}Ba	4.62E+01	8.59E-08	6.07E+01	1.13E-07
^{154}Eu	1.35E+00	5.00E-03	1.77E+00	6.57E-03
^{155}Eu	7.62E-01	1.64E-03	1.00E+00	2.15E-03
^{238}Pu	3.81E+00	2.23E-01	5.01E+00	2.92E-01
^{239}Pu	1.50E+01	2.41E+02	1.97E+01	3.17E+02
^{240}Pu	8.23E+00	3.61E+01	1.08E+01	4.75E+01
^{241}Pu	3.26E+02	3.16E+00	4.28E+02	4.16E+00
^{242}Pu	2.51E-03	6.57E-01	3.30E-03	8.64E-01
^{241}Am	2.90E+01	8.45E+00	3.81E+01	1.11E+01
^{234}U	3.61E-02	5.79E+00[2]	4.75E-02	7.60E+00
^{235}U	1.48E-03	6.83E+02[2]	1.94E-03	8.97E+02
^{236}U	5.35E-03	8.27E+01[2]	7.03E-03	1.09E+02
^{238}U	2.69E-02	8.00E+04[2]	3.53E-02	1.05E+05
Total	6.08E+02	8.11E+04	7.99E+02	1.07E+05

[1]Source: Short, S. M., 1995, Spent Nuclear Fuel Project Technical Databook, WHC-SD-SNF-TI-015, Rev. 0, Westinghouse Hanford Company, Richland, Washington (Table 3.10, wash pit column).

[2]Values obtained from Table 2.

Table 6. Mass and Activity, Total Sludge and Water (May 1993).

Isotope	Activity (Ci)			Mass (g)		
	Sludge[1] (67.45 m^3)	Water[2] (157.4 m^3)	Total (224.83 m^3)	Sludge[1] (67.45 m^3)	Water[2] (157.4 m^3)	Total (224.83 m^3)
^{3}H		2.39E-04	2.39E-04		2.48E-08	2.48E-08
^{60}Co	3.82E+01		3.82E+01	3.38E-02		3.38E-02
^{90}Sr	1.78E+03	1.31E+00	1.78E+03	1.30E+01	9.58E-03	1.30E+01
^{90}Y	1.78E+03	1.31E+00	1.78E+03	3.26E-03	2.40E-06	3.27E-03
^{137}Cs	1.35E+03	2.05E+00	1.35E+03	1.55E+01	2.35E-02	1.55E+01
^{137m}Ba	1.28E+03	2.05E+00	1.28E+03	2.37E-06	3.80E-09	2.37E-06
^{154}Eu	3.98E+01		3.98E+01	1.47E-01		1.47E-01
^{155}Eu	2.27E+01		2.27E+01	4.88E-02		4.88E-02
^{238}Pu	8.81E+01	1.57E-03	8.81E+01	5.15E+00	9.15E-05	5.15E+00
^{239}Pu	3.47E+02	7.10E-03	3.47E+02	5.59E+03	1.14E-01	5.59E+03
^{240}Pu	1.91E+02	7.10E-03	1.91E+02	8.38E+02	3.12E-02	8.38E+02
^{241}Pu	7.56E+03		7.56E+03	7.34E+01		7.34E+01
^{242}Pu	5.82E-02		5.82E-02	1.52E+01		1.52E+01
^{241}Am	1.03E+03	3.26E-02	1.03E+03	2.99E+02	9.49E-03	2.99E+02
^{234}U	8.72E-01	1.95E-05	8.72E-01	1.40E+02	3.12E-03	1.40E+02
^{235}U	3.56E-02	7.95E-07	3.56E-02	1.65E+04	3.68E-01	1.65E+04
^{236}U	1.29E-01	2.88E-06	1.29E-01	2.00E+03	4.45E-02	2.00E+03
^{238}U	6.49E-01	1.45E-05	6.49E-01	1.93E+06	4.31E+01	1.93E+06
^{231}Th[3]			3.56E-02			6.70E-08
^{234}Th[3]			6.50E-01			2.80E-05
^{233}Pa[3]			3.47E-03			1.67E-07
^{234}Pa[3]			8.44E-04			4.22E-10
^{234m}Pa[3]			6.50E-01			9.45E-10
Total	1.55E+04	6.75E+00	1.55E+04	1.96E+06	4.37E+01	1.96E+06

[1]Values from Table 3.
[2]Values form Table 4.
[3]Additional Actinides, calculated by Origen2, decayed ten years.

Table 7. Mass and Activity, Single Shipment, Worst Case (May 1993).

Isotope	Activity (Ci)			Mass (g)		
	Sludge[1] (1.8 m^3)	Water[2] (4.2 m^3)	Total (6.0 m^3)	Sludge[1] (1.8 m^3)	Water[2] (4.2 m^3)	Total (6.0 m^3)
^{3}H		6.38E-06	6.38E-06		6.62E-10	6.62E-10
^{60}Co	1.68E+00		1.68E+00	1.49E-03		1.49E-03
^{90}Sr	8.40E+01	3.49E-02	8.40E+01	6.16E-01	2.56E-04	6.16E-01
^{90}Y	8.40E+01	3.49E-02	8.40E+01	1.54E-04	6.41E-08	1.54E-04
^{137}Cs	6.42E+01	5.46E-02	6.43E+01	7.39E-01	6.28E-04	7.39E-01
^{137m}Ba	6.07E+01	5.46E-02	6.08E+01	1.13E-07	1.02E-10	1.13E-07
^{154}Eu	1.77E+00		1.77E+00	6.57E-03		6.57E-03
^{155}Eu	1.00E+00		1.00E+00	2.15E-03		2.15E-03
^{238}Pu	5.01E+00	4.18E-05	5.01E+00	2.92E-01	2.44E-06	2.92E-01
^{239}Pu	1.97E+01	1.89E-04	1.97E+01	3.17E+02	3.05E-03	3.17E+02
^{240}Pu	1.08E+01	1.89E-04	1.08E+01	4.75E+01	8.31E-04	4.75E+01
^{241}Pu	4.28E+02		4.28E+02	4.16E+00		4.16E+00
^{242}Pu	3.30E-03		3.30E-03	8.64E-01		8.64E-01
^{241}Am	3.81E+01	8.69E-04	3.81E+01	1.11E+01	2.53E-04	1.11E+01
^{234}U	4.75E-02	5.19E-07	4.75E-02	7.60E+00	8.31E-05	7.60E+00
^{235}U	1.94E-03	2.12E-08	1.94E-03	8.97E+02	9.81E-03	8.97E+02
^{236}U	7.03E-03	7.69E-08	7.03E-03	1.09E+02	1.19E-03	1.09E+02
^{238}U	3.53E-02	3.87E-07	3.53E-02	1.05E+05	1.15E+00	1.05E+05
^{231}Th[3]			1.94E-03			3.65E-09
^{234}Th[3]			3.54E-02			1.53E-06
^{233}Pa[3]			1.32E-04			6.36E-09
^{234}Pa[3]			4.60E-05			2.30E-11
^{234m}Pa[3]			3.54E-02			5.15E-11
Total	7.99E+02	1.80E-01	8.00E+02	1.07E+05	1.17E+00	1.07E+05

[1]Values from Table 5.
[2]Values form Table 4.
[3]Additional actinides, calculated by Origen2, decayed ten years.

2.4 CHEMICAL COMPOSITION

Chemical inventory of the sludge is provided in Table 8 (Short 1995), plus the following elements (as isotopes): ^{241}Am, ^{137}Cs, ^{154}Eu and ^{155}Eu, ^{90}Sr and ^{90}Y (from Table 3).

Table 8. Chemical Constituents in K East Basin Sludge.*

Chemical	Total (kg)	Chemical	Total (kg)	Chemical	Total (kg)	Chemical	Total (kg)
Al	5.82E+02	Cu	9.14E+00	Nd	3.45E+00	Sr	8.42E-01
As	1.11E+00	Fe	6.20E+03	Ni	2.42E+00	Ti	3.57E+00
Ba	2.93E+00	K	4.05E+00	P	1.08E+01	Tl	3.93E+00
Be	2.18E-01	Li	1.97E+00	Pb	1.29E+01	V	9.60E+00
Ca	1.11E+02	Mg	2.49E+01	S	8.79E+00	Zn	2.64E+01
Cd	2.39E+00	Mn	9.43E+00	Sb	5.57E+00	Zr	4.38E+00
Co	5.66E-01	Mo	9.52E-01	Si	4.86E+01	U	2.00E+03
Cr	2.34E+01	Na	4.94E+00	Sm	1.23E+01	Pu	6.73E+00
Other	2.31E+04					Total	3.22E+04

*Source: Short, S. M., 1995, Spent Nuclear Fuel Project Technical Databook, WHC-SD-SNF-TI-015, Rev. 0, Westinghouse Hanford Company, Richland, Washington. See also, Section 2.4 for additional elements.

The sludge has an in situ pH range of 5 to 9. After it is loaded into the transport container, the chemistry will be adjusted to meet TWRS storage tank chemical acceptance criteria shown in Table 9.

Table 9. OSD-T-151-00007 Limits.

Constituent	Limit (M)
$[NO_3] \leq 1.0$ M	
Hydroxide	$0.01 \text{ M} \leq [OH] \leq 5.0$
Nitrite	$0.011 \leq [NO_2] \leq 5.5$
$1.0 \text{ M} \leq [NO_3] \leq 3.0$ M	
Hydroxide	$0.1 \times [NO_3] \leq [OH] < 10$
Nitrite	$[OH] + [NO_2] \geq 0.4 \times [NO_3]$
$[NO_3] > 3.0$ M	
Hydroxide	$0.3 \leq [OH] < 10$
Nitrite	$[OH] + [NO_2] \geq 1.2$
Nitrate	$[NO_3] < 5.5$ M

2.5 TRANSPORTATION CLASS

The worst-case payload contains 15,200 A_2s, a Type B, highway route controlled quantity (HRCQ), fissile material. The A_2s are taken from the revised Table A-1 of 10 CFR 71, effective date April 1996.

2.6 THERMAL DESCRIPTION

The sludge heat generation rate averaged over the entire K East Basin sludge inventory is 187 BTU/h (54.8 W). The decay heat for the worst-case single shipment using the inventory of Table 7 is 11.16 BTU/h (3.27 W).

The temperature of the sludge is expected to be approximately the same as the basin water temperature: 6 °C to 32 °C (42 °F to 90°F). Basin water temperature is usually maintained at approximately 10 °C (50 °F).

2.7 GAS GENERATION

Sludge and water mixtures may produce gases from fission gas release, radiolysis, and uranium reaction with water. Radiolysis and uranium/water reactions produce hydrogen gas. Refer to Section 5.1.7 for the gas generation analysis requirements and operating pressure limits.

3.0 FACILITY OPERATIONS AND INTERFACES

The packaging and transport system shall be compatible with the sludge offload equipment and system operations at the K Basins and the AW Tank Farm.

It is anticipated that the entire sludge removal campaign will involve 70-100 shipments over a three-year period. The shipment route will be southeast from the K Basins; east on Route 1; south on Route 4S to 200 East Area; east on 4th Street; around AP Tank Farm to the east gate of AW Tank Farm; through the east gate to a DST staging area, for a one-way total distance of 18 km (11 mi). The route is located entirely within the Hanford Site boundary. Because a radioactive heel of unknown size will reside within the container during its return trip, the accident risk analysis, Section 5.1.2, shall take into account return mileage.

3.1 ORIGINATING FACILITY

The loading of the sludge container will take place within a covered loadout area, yet to be defined, adjacent to the K East Basin. The packaging and transport trailer will arrive as a single-unit, fixed system; the container will not be removed from the trailer during loading operations.

The sludge chemistry will be adjusted at the K East Basin to meet AW Farm waste acceptance criteria prior to transport. The container shall include a means to mix the contents following chemical addition.

The payload in the container shall be monitored and controlled to ensure that the maximum gross weights (Section 4.2.7) and radiation levels (Section 4.2.8) are not exceeded.

A sample may be obtained and sent to the 222-S Laboratory for analysis to verify container contents. A nondestructive assay (NDA) will be performed to determine curie content of certain radionuclides residing in the filled container.

3.2 RECEIVING FACILITY

The receiving facility is currently planned to be a DST located in the 200 East Area. The packaging and transport trailer will arrive as a single-unit, fixed system; the container will not be removed from the trailer during unloading operations. The tank farm will be modified to provide a spill retention basin and a 7.6-cm (3-in.) double-encased pipe with valving, leak detection, and a mating connector to connect to the container's sludge removal system. Leak detectors will be interlocked to the sludge removal pump. Flush water and electrical power will be provided by the receiving facility. However, the transport system shall provide the equipment necessary to interface with tank farm utilities. If process air is required, it shall be provided with the transport system. Once the majority of sludge is pumped from the container, the residual heel will be sluiced from the container. Following sluicing, the transfer lines will be flushed, and the transport system will be disconnected from the receiving facility.

Current TWRS DST receiving constraints are that the plutonium concentration be limited to 0.5 g/L maximum and that the solids-to-plutonium weight ratio be greater than 1,000. A preliminary study (Precechtel 1995) shows that sludge concentrations of less than 80% by weight meet the TWRS DST receiving criteria. A transfer limit of 6 Ci/3.79 L (6 Ci/gal) applies to DSTs in the AW Tank Farm. Additional chemistry constraints are given in Section 2.4.

Communication between the transport system and Tank Farm Operations will be maintained at all times during transfers.

4.0 PACKAGING/TRANSPORT SYSTEM DESIGN CRITERIA

4.1 GENERAL

The packaging and trailer shall be designed and delivered as a system, with all support hardware (Section 4.4) furnished and attached. Where deemed necessary for operational/as low as reasonably achievable (ALARA) considerations, the purchaser shall consider the need for a catch-basin/liquid retention system be in place on board the trailer to mitigate the effects of an unexpected spill or liquid loss.

The functional requirements for the packaging and transport system are as follows:

- Interface with and fit within the K Basin loadout facility
- Receive and contain K Basin sludge and water
- Travel to a TWRS DST in the 200 Area while loaded with sludge and water
- Interface with and fit within the TWRS offload facility
- Return travel to the K Basin after bulk sludge is offloaded
- Be operable under the ambient conditions given in Tables 13 and 14
- Provide for safe shutdown of equipment during sludge removal activities in the event of equipment failure; i.e., leakage
- Include features to accept sludge from the loadout system and remove the sludge from the container while minimizing the spread of contamination during coupling/uncoupling operations
- Facilitate decontamination. The interior and exterior surfaces of the container shall be smooth and essentially impermeable to radioactive contamination and buildup
- Meet ALARA radiation objectives per Bergsman (1996); the Hanford Site "Master Safety Rules" referenced in WHC-CM-1-10, *Safety Manual*; and Occupational Safety and Health Administration (OSHA) standards per 29 CFR 1910.

4.2 PACKAGING AND CONTAINER

The packaging shall meet onsite Type B HRCQ performance criteria. The container shall be an ASME pressure vessel, designed, fabricated and certified to ASME (1992), Section VIII. Analysis of the container may be performed in lieu of actual testing.

4.2.1 General Requirements

The container shall meet the transportation safety requirements of Section 5.1 and the following performance requirements:

- Fit within the dimensional confines given in Section 4.2.5 and weigh no more than specified in Table 12 (fully loaded container and all support hardware)
- Be compatible with the pH range and mixture of chemical constituents identified in Sections 2.2 and 2.4

- Be "leak-testable" (able to accommodate leak testing) per ANSI N14.5 (ANSI 1987), Sections 6.3.1 and 6.5.
- Include features to localize and minimize the size of the sludge heel (such as would be provided by a sloped bottom)
- Include features, such as damping, to mitigate the effects of water sloshing
- Include a means for chemical-addition to adjust contents to meet the chemical acceptance criteria (Section 2.4)
- Include features to obtain sludge samples for laboratory analyses
- Include features to install NDA instrumentation

4.2.2 Loading and Unloading

The transport system shall be compatible with the sludge loadout system located at the K Basin and the sludge offload system at the TWRS AW Tank Farm.

The maximum container fill rate is anticipated to be 100 gal/min (6.3 L/s) through a 5.1-cm (2-in.) fill line. The fill line shall connect to the container fill port using a dry disconnect coupler. Air displaced from the container during filling and discharging operations shall be vented through at least two, passive, HEPA-filtered vents that are capable of being sealed during transport. During loading, the container will be monitored to control sludge volume and fissile content, using level detectors and NDA instrumentation features that will be interlocked with the loadout system.

After the sludge is loaded into the container, it will be chemically adjusted to meet AW Tank Farm waste acceptance criteria.

At the time of removal from the basin, the sludge characteristics shall be compared to the operational safety limits established in the SARP, using NDA or actual laboratory analyses of samples. Safety limits of Sections 5.1.3, 5.1.4, 5.1.5, and 5.1.7, as finalized in the SARP, shall not be exceeded.

Container contents will be unloaded via the sludge offload system, using a pumping system provided as part of the transport system. The transport system shall mate with a 7.6-cm (3-in.) transfer line via a dry disconnect coupler and have its controls interlocked with the sludge offload system leak detection equipment. The transport system shall include equipment to connect to TWRS-supplied utilities; i.e., electrical, flush water.

4.2.3 Material Requirements

Packaging materials shall be American Society for Testing and Materials-certified materials.

Packaging materials shall be compatible with the sludge such that any chemical, galvanic, and corrosive reactions occurring between the packaging and the sludge do not limit the service life stated in Section 4.2.12. Where necessary, sufficient corrosion allowance shall be provided. Materials shall be of suitable surface finish to accommodate decontamination.

4.2.4 Fabrication Methods

The pressure-vessel container shall be fabricated in accordance with ASME (1992), Section VIII, in accordance with the manufacturer's established fabrication, inspection, and testing programs, according to the guidelines of WHC-CM-4-2.

Welding, welder/welding operator qualifications, and weld inspection shall be per ASME (1992), Section VIII.

4.2.5 Dimensions and Volume

The packaging shall be sized such that the maximum gross weights (Section 4.2.7) and radiation levels (Section 4.2.8) are not exceeded and such that the number of shipments is minimized. The minimum container size shall be 3 m^3 and the maximum size shall be 6 m^3. The packaging shall fit within the confines of an 2.44 m (8 ft) wide, single-drop, flatbed trailer and shall rest on the drop deck. The trailer and packaging shall have a maximum combined overall height not to exceed 3.66 m (12 ft). Trailer dimensional requirements are shown in Table 12.

4.2.6 Weight of Contents

For a maximum payload of 6 m^3, the weight of the contents is expected to be approximately 6,985 kg (15,400 lb). The payload will consist of up to 30% sludge by volume, the rest being interstitial basin and process water. Refer to Section 2.1 for a description of the payload.

4.2.7 Maximum Gross Weight

The maximum combined weight of the trailer, packaging, payload, and support equipment shall be per Table 12. The actual individual weights of the trailer, packaging, and support equipment shall be determined and recorded by the supplier for use during the crush analysis of Section 5.1.2.

4.2.8 Shielding Requirements

Shielding thickness shall be based on the highest specific-activity sludge, with the sludge settled to the bottom of the container. Shielding may be integral with the container or may be provided exterior to the package. If lead is used, it shall be isolated from contact with radioactive material. Shielding shall be provided to meet the radiation dose rate limits of

Section 5.1.4, except that the more restrictive operations-control design limit of 100 mrem/h at any point on the external surface of the package shall apply.

4.2.9 Ports, Seals, and Closures

Packaging ports and closures are to be sealed from the atmosphere during transport with positive closure devices. Closure devices shall not be able to be opened unintentionally. Seals and closure devices must remain functional during the normal and accident conditions described in Sections 5.1.1 and 5.1.2. Seals and sealing surfaces shall have a means of being protected during equipment handling processes.

4.2.10 Venting and Filters

The packaging container shall have at least two passive HEPA-filtered vents. The HEPA filters shall be of a standard size and be constructed of materials compatible with water. The size, number, and location shall be determined by the gas generation analysis (Section 5.1.7) and the filling and discharge rates. The filter system (Section 4.4) shall be sealed from the atmosphere while the package is under transport.

4.2.11 Heel Minimization and Removal

The container shall be designed to minimize the size of the sludge heel, consistent with the ALARA goals of Section 5.2. The container interior shall be designed in a manner that allows for removal of the majority of sludge heel, including particles as large as 0.64 cm (0.25 in.).

4.2.12 Service Life

The minimum service life of the packaging shall be 20 years. Service life of routine-maintenance components, interior and exterior to the container, shall be maximized, thereby reducing radiation exposure.

4.2.13 Decontamination

Prior to transport, smearable contamination on the external surfaces of the packaging shall be removed to within the limits of Table 10. The external surfaces of the packaging shall be designed to facilitate contamination removal. Internal surfaces of the container shall be essentially resistant to radioactive buildup and shall facilitate cleanup by water spray. Interior surface contours shall minimize sludge trapping and shall accommodate flushing to a retrieval point.

Table 10. Packaging External Decontamination Limits.

Contaminant	Maximum permissible limits	
	$\mu Ci/cm^2$	dpm/cm^2
Beta-gamma emitting radionuclides; all radionuclides with half-lives less than ten days; natural uranium; natural thorium; uranium-235; uranium-238; thorium-232; thorium-228 and thorium-230 when contained in ores or physical concentrates	10^{-5}	22
All other alpha emitting radionuclides	10^{-6}	2.2

Source: 49 CFR 173.443(a), 1994, "Transportation," Code of Federal Regulations, as amended.

4.2.14 Tiedown and Lifting Attachments

The packaging (Section 4.0) shall be attached to the trailer by tiedowns and/or a blocking and bracing system. Structural parts of the packaging that could be used as a tiedown point(s), but are not designed as such, shall be rendered inoperable during transport. The tiedown and/or blocking and bracing system design shall accommodate the following *g* factors, applied to the weight of a fully loaded package including all attached support hardware.

Any tiedown attachment point on the package shall not cause package failure when the package is subjected to a static force positioned at its center of gravity, having the following loading:

- A vertical component of 2*g*
- A horizontal component along the direction of vehicle travel of 10*g*
- A horizontal component perpendicular to the direction of vehicle travel of 5*g*.

Lifting attachments, to lift the container itself, shall be designed such that their failure will not impair the package integrity and shall have a safety factor of at least three (3) applied to yield. Any structural part of the package not approved for lifting the container shall be rendered inoperable for lifting. In operation, the container will reside permanently on the trailer and will not be removed.

4.2.15 Containment Boundary

The containment boundary is provided by the sludge container.

4.3 TRANSPORT TRAILER

4.3.1 General Requirements

The trailer shall meet the following requirements:

- Be a National Highway Traffic Safety Administration-registered trailer meeting the minimum design requirements of Section 4.3
- Be an open lowboy, single drop, 12.2 m (40 ft) long overall, and 2.4 m (8 ft) wide
- Accommodate the concentrated load of the container full of sludge and water and attached equipment (estimated at 27,216 kg [60,000 lb], minimum)
- Have packaging attachment cross members meeting the securement systems requirements of 49 CFR 393.102(d)
- Have a factor of safety with respect to yield strength of 2:1 for the concentrated load.
- Be operable under the ambient conditions specified in Tables 13 and 14.

Prior to delivery, the trailer shall demonstrate acceptance at the Seller's facility by being subjected to both a static and a rolling road test carrying weight equal to the actual distributed load.

4.3.2 Regulatory Requirements

The trailer shall comply with the federal regulations and standards listed in Table 11 and shall comply with all current applicable federal and Washington state regulations at time of manufacture.

Table 11. Trailer Regulatory Standards. (2 sheets total)

Part	49 CFR--current issue, including revisions
566	Manufacturer identification
567	Certification
393	Parts and accessories necessary for safe operation
172, Appendix C	Dimensional specifications for recommended placard holder

Table 11. Trailer Regulatory Standards. (2 sheets total)

Part	49 CFR--current issue, including revisions	
571	Federal motor vehicle safety standards--vehicle safety standards developed by the U.S. Department of Transportation for commercial vehicle certification with the National Highway Traffic Safety Administration	
	Section	Title
	106	Brake hose
	108	Lamps, reflective devices, and associated equipment
	115	Vehicle identification number
	119	New pneumatic tires for vehicles other than passenger cars
	120	Tire selection and rims for motor vehicles other than passenger cars
	121	Air brake systems

4.3.3 Weight and Dimensional Requirements

The trailer, with a fully loaded package and all support hardware attached, shall not exceed the requirements of Table 12. In addition, if reasonably feasible, the trailer's maximum gross loaded weight (with the maximum sized payload) shall have a design goal weight limit of 36,287 kg (80,000 lb).

Table 12. Trailer Characteristics.

Maximum gross loaded weight without tractor	45,359 kg (100,000 lb)
Maximum length	12.2 m (40 ft)
Maximum overall height including packaging and all attached support equipment	366 cm (12 ft)
Maximum height of drop deck	55.9 cm (22 in.)
Maximum width	2.4 m (8 ft)

4.3.4 Material and Structural Requirements

Trailer materials shall comply with American Society for Testing and Materials (ASTM) or American Institute of Steel Construction (AISC) standards.

All structural components must meet (at least) a 2:1 factor of safety on yield strength.

The main frame shall be an inboard I-beam design or equal. Web stiffeners shall be used at high-load points.

Requirements are as follows.

- Cross bearers shall be heavy-duty "C" channel cross members with a stabilizing return lip on the top flange (or equivalent).
- Front cross member shall be 0.48-cm (0.1875-in.) formed section having smooth top and bottom edges (or equivalent).
- Upper coupler shall be 0.64-cm- (0.25-in.-) thick pickup plate supported by a full-depth cross-member box assembly (or equivalent).
- Pickup plate shall have gusseted turnup lip, or equivalent protection, for the front cross member and glad hands during tractor coupling.
- The wheel area shall have a running gear frame of welded I-beam (or equivalent).

4.3.5 Trailer Tiedown Structures

The trailer tiedown structure shall be of sufficient strength to preclude yielding of material in the trailer tiedown devices, the blocking and bracing devices, the trailer attachment points, and the trailer itself when subjected to the dynamic loading of Section 4.2.14.

Trailer tiedowns shall also not yield under the following load factor requirements of IAEA (1990) Safety Series 37:

- A vertical component of 3*g* down, 2*g* up
- A horizontal component along the direction of vehicle travel of ± 2*g*
- A horizontal component perpendicular to the direction of vehicle travel of ± 1*g*.

4.3.6 Landing Gear

The landing gear shall have a two-speed, manual crank with sand pads capable of accommodating a fully loaded trailer. Sand pads shall be sized so as not to sink into asphalt and the spill-pad geotextile under the ambient conditions of Tables 13 and 14.

4.3.7 Suspension

The trailer suspension shall be capable of handling a concentrated container, fully loaded (estimated at 27,216 kg (60,000 lb)), plus the weight of all support equipment, and shall have readily available replacement parts for maintenance.

Requirements are as follows.

- The suspension shall be an air ride system.
- The number of axles shall be minimized, with a minimum load capacity of 10,206 kg (22,500 lb) each, and shall be furnished with oil seals.
- The wheels shall be disc wheels, 10 hole, painted according to Section 4.3.11.
- The tires shall be 255/70R x 22.5, radial type (or equivalent).

4.3.8 Brake System

The brakes shall be an air brake system, S-cam type, air actuated, with type 30 brake chambers that drive 15.2-cm (6-in.) automatic slack adjusters. Air system hoses shall meet FMVSS-121 and FMVSS-106 standards. Glad hands shall be centered on the front cross member, and dummy glad hands shall be provided.

4.3.9 King Pin

A Society of Automotive Engineers (SAE) king pin shall be welded to the pickup plate and reinforced by 0.95-cm- (0.375-in.-) thick vertical stiffeners (or equivalent). The king pin diameter shall be 6.35 cm (2.5 in.). The king pin height shall be 122-127 cm (48-50 in.). The king pin setting shall be 76.2 cm (30 in.), or industry equivalent, to provide a swing clearance of 178-188 cm (70-74 in.).

4.3.10 Lighting

The lighting system shall conform to FMVSS-108 and shall incorporate light-emitting diode lamps. Connections shall be seven-way standard contact. All wiring shall be sealed in metal or plastic conduit and routed, secured, and protected from abrasion and chafing.

4.3.11 Painting

The trailer and wheels shall be primed and painted with products suitable for disposal as non-hazardous waste at the Hanford site. One product that currently meets this requirement is Amercoat* 450-HS. Both the primer and finish coats shall be applied according to manufacturer's instructions, with a minimum of two finish coats of white color (Amercoat white product code RT-8301). Prior to priming, surfaces shall be clean and free of weld slag and other foreign materials.

*Amercoat is a trademark of American Paint Corporation, Leominster, MA.

4.3.12 Service Life and Additional Requirements

- The trailer shall have a service life of 20 years.
- The bumper (rear-end protection) height and width shall comply with 49 CFR 393.86.
- There shall be two mud flaps and anti-sail spray guards at rear wheel areas.
- There shall be four metal flip-frame type placards designed and placed on the trailer per 49 CFR 172.500, Subpart F, "Placarding."
- The trailer shall be capable of being washed down with high-pressure water.
- The trailer shall have rub rails with stake pocket capability located on each side and each end of the trailer. Rub rails shall be welded on.
- The trailer shall have working decks covered with 0.48-cm (0.1875-in.) stainless steel diamond plate.
- The trailer welding, weld joint preparation, cleaning, welding procedures, welder qualifications, and inspections shall be in accordance with ANSI/AWS D1.1 for steel (ANSI/AWS 1989c), ANSI/AWS D1.2 for aluminum (ANSI/AWS 1989a), and ANSI/AWS D1.3 for sheet metal (ANSI/AWS 1989b). Welding qualifications in accordance with ASME (1989), Section IX, are acceptable. All slag, spatter, and weld discontinuities shall be removed by grinding or by other industry accepted method. All load-bearing welds shall be magnetic particle and/or liquid penetrant weld examined. All weld examinations shall be performed in accordance with ASNT SNT-TC-1A (ASNT 1984).

4.4 SUPPORT EQUIPMENT

Support equipment shall be provided with, and mounted onto, the transport system. Support equipment is defined as that equipment which is essential to the overall mission of sludge removal, transport, and final offloading but is not part of the packaging or transporter. Support equipment includes equipment to pump the sludge from the container, operate and monitor loading and offloading operations, obtain samples for laboratory analyses, perform radioactive NDA, mix container contents, vent displaced air during loading and unloading operations, and flush the container and piping following loading and unloading operations. (Specific equipment and service life requirements will be identified in a purchase specification.) Support equipment may include, but is not limited to, the following:

- Redundant, sealable, passive, high-efficiency particulate air (HEPA) filtered vents capable of being sealed during transport
- Equipment to sluice the container interior

- A console to monitor and control offloading operations
- Equipment to remove container contents
- Equipment to remove residual sludge heel
- Equipment (that does not breach containment) for neutron detection
- Equipment to mix container contents
- Equipment to monitor the liquid/sludge level to prevent overfilling and to monitor the mass balance during pumpout
- Hose reel and hose to connect to flush water supply
- Equipment as necessary to interface with TWRS-supplied utilities, i.e., electrical power, on and offloading piping, flush water, supplied air, etc.

5.0 GENERAL REQUIREMENTS

5.1 TRANSPORTATION SAFETY

The SARP shall document that the packaging and transport system meets Hanford Site, Type B, HRCQ, fissile, transportation safety criteria, or other criteria consistent with its application, per WHC-CM-2-14, for the payload defined in Section 2.0 and the normal and accident conditions defined in Sections 5.1.1 and 5.1.2. Environmental data for normal and accident conditions are specified in Section 5.1.6.

The design of the overall packaging and support equipment systems shall take into account the safety of the workers from the perspective of the Hanford Site "Master Safety Rules" referenced in WHC-CM-1-10 and OSHA standards per 29 CFR 1910.

5.1.1 Normal Conditions

The package shall be demonstrated to withstand normal onsite transfer conditions either through testing or analysis. Normal shock and vibration associated with truck transport shall be evaluated to ensure that the package maintains containment (leaktight), shielding, and nuclear criticality control under the following conditions: (Note: The package will remain on board the transport trailer during all filling and unloading operations.)

- Environmental Conditions. The design temperature limits for the individual components, parts, and materials of the package shall be determined by analyses and/or testing. The analyses and/or tests shall be based upon the conditions listed in Section 5.1.6. Operational temperatures shall be shown to not exceed the design limits.

- Maximum heat generation rate of worst-case source from Section 2.2 plus maximum solar heat load (see Table 14) plus maximum air temperature of 46 °C (115 °F)
- Minimum air temperature of -33 °C (-27 °F) plus maximum heat generation rate from worst case source in Section 2.2
- Minimum air temperature of -33 °C (-27 °F) and zero heat generation rate.

- Reduced External Pressure. An external pressure of 24.0 kPa (3.5 psi) absolute.
- Increased External Pressure. An external pressure of 138 kPa (20 psi) absolute.
- Vibration. The package shall be evaluated per ANSI N14.23 (ANSI 1992) for normal vibration during movement by the selected transport vehicle along the route specified in Section 3.0.
- Water Spray. The package shall be evaluated for a water spray that simulates exposure to rainfall of approximately 5 cm (2 in.) per hour for at least one hour.
- Penetration. Impact of the hemispherical end of a vertical steel cylinder of 3.2-cm (1.25-in.) diameter and 6-kg (13-lb) mass, dropped from a height of 1 m (40 in.) onto the exposed surface of the package that is expected to be most vulnerable to puncture. The long axis of the cylinder shall be perpendicular to the package surface.

5.1.2 Accident Conditions

For Hanford onsite transportation conditions, accident events are defined for impact, puncture, fire, and crush. The package shall be designed to provide containment, shielding, and criticality control for these conditions over the travel route and distance specified in Section 3.0.

The preliminary risk analysis (Green 1996) determined these design criteria based on package failure threshold.

Based on the preliminary risk evaluation (Green 1996), the following provide the accident safety design criteria. For purposes of onsite package evaluation, these events are assumed to occur nonsequentially. For design evaluation, these accidents shall be evaluated at an ambient temperature between -33 °C (-27 °F) and 46 °C (115 °F), whichever is more severe for the individual incident. The packaging system shall be evaluated carrying the worst-case payload, as described in Section 2.0.

- Impact. Impact failure shall not occur below a change in velocity of 56 km/h (35 mi/h) onto a typical Hanford Site surface. The package shall impact in an orientation expected to cause maximum damage.

- Puncture. The worst-case credible puncture incident shall provide the equivalent resistance of 7.6 cm (3 in.) of steel or steel equivalent.

- Fire. The packaging shall survive an 802 °C (1,475 °F) engulfing fire for 15 minutes with no loss of contents in excess of Section 5.1.2.2 criteria. The surface absorptivity of the package shall be the greater of the anticipated absorptivity or 0.8 and shall be assumed to have an emissivity coefficient of 0.9. The package can be assumed to be actively cooled after the 15 minutes. All containment boundary seals shall remain functional. Steam pressure buildup due to water boiling shall be evaluated and accounted for in the design.

- Crush. The packaging shall survive a 7,258-kg (16,000-lb) crush force from the trailer, with the force oriented in the direction expected to induce the most damage to the container. If the actual weight of the trailer after fabrication is greater than 7,258 kg (16,000 lb), the SARP shall adjust the final risk analysis using the actual trailer weight.

5.1.2.1 Accident Frequency Analysis. The SARP shall document the results of an accident frequency analysis to assess the safety of the packaging and to determine the estimated annual accident release frequency during transfers. If mileage or time restrictions apply, these restrictions shall be identified in the SARP.

5.1.2.2 Dose Consequence Analysis. An evaluation of dose consequences will be performed as required to verify the package meets the criteria of Mercado (1994). A preliminary dose consequence study is included as an attachment to Green (1996).

5.1.3 Thermal

Decay heat generation of the sludge shall not preclude the packaging from maintaining its integrity. The SARP shall document the thermal safety analysis and establish a decay heat generation limit. The heat generation is given in Section 2.6.

The maximum accessible surface temperature of the package shall not exceed 185 °F in the shade under the ambient conditions of Table 13.

5.1.4 Shielding

A shielding analysis shall be provided in the SARP to ensure that the packaging will meet the following dose rate limits under the normal and accident conditions of Sections 5.1.1 and 5.1.2.

- Shielding shall ensure that radiation levels under normal transport conditions (Section 5.1.1) do not exceed the following:

  - 200 mrem/h at any point on the external surface of the package (See also Section 4.2.8 for an operations-control design limit.)

  - 10 mrem/h at 2 m (6.6 ft) from the edge of the trailer (exclusive-use limit)

  - 2 mrem/h in any normally occupied position of the transport vehicle.

- Shielding shall ensure that radiation levels under credible accident conditions (Section 5.1.2) do not exceed 1000 mrem/h at 1 m (3.3 ft) from the container if any shielding is dislodged from the accident

5.1.5 Criticality

A criticality analysis shall be performed and documented in the SARP using the worst-case payload (Section 2.2) to demonstrate that the payload will remain subcritical (k_{eff} shall be less than 0.95. k_{eff} is the mean value plus two standard deviations, plus bias) under the following conditions:

- During the normal transport conditions of Section 5.1.1, for three packages, under the most reactive credible configuration consistent with the chemical and physical form of the packaged material with full water reflection

- During and subsequent to the accident conditions of Section 5.1.2, for one package, under the most reactive credible configuration consistent with the chemical form and damaged condition the packaged material, with optimum interspersed aqueous moderation, with full water reflection.

5.1.6 Environmental Data

Environmental conditions under which the packaging and trailer will operate are found in this section and WHC-SD-TP-RPT-004 (Fadeff 1992).

Ambient air temperatures at the Hanford Site for the peak summer month are shown in Table 13. The maximum solar radiation is shown in Table 14.

Table 13. Peak Hanford Air Temperatures

Time	Temperature °C/°F	Time	Temperature °C/°F
12 a.m.	28/82	2 p.m.	44/111
2 a.m.	26/78	4 p.m.	46/115
4 a.m.	24/75	6 p.m.	45/113
6 a.m.	23/74	8 p.m.	38/100
8 a.m.	29/85	10 p.m.	32/89
10 a.m.	36/97	12 a.m.	28/82
12 p.m.	39/103		

Table 14. Maximum Solar Radiation (BTU/h-ft^2).

Time	Vertical surfaces facing								Horizontal surface facing up
	N	NE	E	SE	S	SW	W	NW	
4 a.m.	0	0	0	0	0	0	0	0	0
6 a.m.	57	192	211	105	17	17	17	17	64
8 a.m.	35	173	268	208	42	32	32	32	127
10 a.m.	42	56	177	213	126	45	42	42	281
12 noon	45	45	49	120	167	120	49	45	314
2 p.m.	42	42	42	45	126	213	177	56	281
4 p.m.	35	32	32	32	42	208	268	173	127
6 p.m.	57	17	17	17	17	105	211	192	64
8 p.m.	0	0	0	0	0	0	0	0	0

5.1.7 Gas Generation Analysis

K East Basin sludge and water mixtures shall be evaluated for radiolytic hydrogen gas generation. Shipping time will be specified within the SARP to less than the amount of time that would be required to reach a hydrogen gas concentration of 5% of the free container volume within a sealed container (if sealed within an oxygen bearing atmosphere). As a bounding case, the container can be assumed to be sealed for a period of five days during the transfer route specified in Section 3.0. A maximum <u>design</u> pressure rating of the packaging shall be established by the container supplier by testing or analysis. The maximum allowable <u>operating</u> pressure limit shall be specified in the SARP.

The SARP shall analyze the effects of gas generation and develop appropriate operational controls, such as transfer time limits, venting through HEPA filters (just prior to transport), inerting the void space, etc.

5.1.8 Containment

The packaging shall be designed, constructed, and prepared for shipment so that when subjected to normal conditions, the package containment boundary shall remain leaktight in accordance with the ANSI N14.5 (ANSI 1987) definition of "leaktight." If the package design incorporates a venting feature, the leakage rate evaluation shall be made with the vent(s) sealed.

The packaging shall be designed, constructed, and prepared for shipment so that when subjected to accident conditions, the criteria of Section 5.1.2.2 are met.

5.2 ALARA

The packaging and transport system are to be designed to minimize radiation and hazardous material exposure to operating personnel and shall be consistent with the requirements of WHC-IP-1043 (Berglund 1995).

5.3 TRANSPORTATION SAFETY CLASS

The transportation safety class of the packaging and transport system has been determined by a transportation safety class analysis presented in Appendix B. This analysis assumed the total failure of the packaging system and the release of all of its contents to the environment at the worst possible location on the transportation route. An airborne release fraction was then applied to the material at risk to determine the airborne quantity. For the shipment of the K Basin sludge, the worst-case release location is within the 100 K Area, just outside the basins.

The results of the transportation safety class analysis are documented in Nelson (1996), attached as Appendix B. The analysis concludes that at least one "safety class" (formerly described as "Safety Class 1" per WHC-CM-4-46, *Nonreactor Facility Safety Analysis Manual*) barrier is required for shipping a package containing K East Basin sludge.

5.4 MAINTENANCE, TOOLING, AND SPARES

Ease and minimization of maintenance shall be designed into the transport system. Special tools, vendor spare parts, and maintenance data to operate, replace, or repair the system shall be provided.

5.5 QUALITY ASSURANCE

Controls shall be established for the design, fabrication, inspection, and testing of the packaging and transportation system and shall be in accordance with WHC-CM-4-2 and WHC-IP-0705 (1995).

6.0 REFERENCES

10 CFR 71, 1994, "Packaging and Transportation of Radioactive Material," Parts 71.71 "Normal Conditions of Transport", and Table A-1 effective April 1996, and 71.37 and Subpart H, "Quality Assurance," *Code of Federal Regulations*, as amended.

29 CFR 1910, 1994, "Occupational Safety and Health Standards," *Code of Federal Regulations*, as amended.

49 CFR 172, 1994, "Transportation," Subpart F, "Placarding," *Code of Federal Regulations*, as amended.

49 CFR 393, 1994, "Protection Against Shifting or Falling Cargo," Subpart I, *Code of Federal Regulations*, as amended.

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HSRCM-1, *Hanford Site Radiological Control Manual*, Pacific Northwest National Laboratory, Richland, Washington.

IAEA, 1990, *Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material*, 3rd Edition, International Atomic Energy Agency, Vienna, Austria.

Mercado, J. E., 1994, *Report on Equivalent Safety for Transportation and Packaging of Radioactive Materials*, WHC-SD-TP-RPT-001, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Nelson, J. V., 1996, *Transportation Safety Class Analysis* (internal memo 8M730-JVN-96-004 to J. R. Green, January 19), Westinghouse Hanford Company, Richland, Washington.

Precechtel, D. R., 1995, *Parametric Study on Sludge Transportation Cost as a Function of Source Term* (internal memo DRP-95-001 to M. J. Wiemers, September 12), Westinghouse Hanford Company, Richland, Washington.

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WHC-CM-1-10, *Safety Manual*, Westinghouse Hanford Company, Richland, Washington.

WHC-CM-2-14, *Hazardous Material Packaging and Shipping*, Westinghouse Hanford Company, Richland, Washington.

WHC-CM-4-2, *Quality Assurance Manual*, Westinghouse Hanford Company, Richland, Washington.

WHC-CM-4-29, *Nuclear Criticality Safety Manual*, Westinghouse Hanford Company, Richland, Washington.

WHC-CM-4-46, *Nonreactor Facility Safety Analysis Manual*, Westinghouse Hanford Company, Richland, Washington.

WHC-IP-0705, *Quality Assurance Program Plan for the Hazardous Materials Transportation and Packaging Program*, Westinghouse Hanford Company, Richland, Washington.

APPENDIX A

ORIGEN2 INPUT FILES FOR TOTAL SOURCE AND WORST SOURCE

The following is the Origen2 input file that was used to calculate the total source additional actinides included in Table 6 of the packaging design criteria.

Origen2 Input File for Total Source

```
-1
-1
-1
TIT     TOTAL K Basin Source, WATER BREHM
LIP     0 0 0
LIB     0 1 2 3 381 382 383 9 3 0 1 43
PHO     101  102  103  10
INP     -1  1  -1  -1  1  1
MOV     -1   1 0   1.0
BUP
DEC       1.0              1  2  4  1
DEC       5.0              2  3  4  0
DEC      10.0              3  4  4  0
DEC      50.0              4  5  4  0
DEC     100.0              5  6  4  0
DEC     200.0              6  7  4  0
DEC       1.0              7  8  5  0
DEC       2.0              8  9  5  0
DEC       5.0              9 10  5  0
DEC      10.0             10 11  5  0
DEC      20.0             11 12  5  0
BUP
CUT     5  1.E-20  7  1.E-20  9  1.E-20  -1
RDA     ACTIVATION PRODUCTS OUTPUT TABLE OPTIONS
OPTL     8 8 8 8 7 8 7 8 7 8 7 8 8 8 8 8 8 8 8 8 8 8 8 8
RDA     FISSION PRODUCTS OUTPUT TABLE OPTIONS
OPTF     8 8 8 8 7 8 7 8 7 8 7 8 8 8 8 8 8 8 8 8 8 8 8 8
RDA     ACTINIDE AND DAUGHTER OUTPUT TABLE OPTIONS
OPTA     8 8 8 8 7 8 7 8 7 8 7 8 8 8 8 8 8 8 8 8 8 8 8 8
OUT      12 1 -1  0
STP 4
1   010030 2.479E-08 270600 3.378E-02 000000 0.000E+00 000000 0.000E+00
3   380900 1.303E+01 390900 3.267E-03 551370 1.553E+01 561371 2.375E-06
3   631540 1.474E-01 631550 4.881E-02 000000 0.000E+00 000000 0.000E+00
2   942380 5.149E+00 942390 5.586E+03 942400 0.838E+03 942410 7.337E+01
2   942420 1.525E+01 952410 2.992E+02 922340 1.396E+02 922350 1.647E+04
2   922360 1.996E+03 922380 1.931E+06 000000 0.000E+00 000000 0.000E+00
0
END
```

The following is the Origen2 input file that was used to calculate the worst source additional actinides included in Table 7 of the packaging design criteria.

Origen2 Input File for Worst Source

```
-1
-1
-1
TIT     MAX K Basin Source, WATER BREHM
LIP     0 0 0
LIB     0 1 2 3 381 382 383 9 3 0 1 43
PHO     101  102  103  10
INP     -1  1  -1  -1  1  1
MOV     -1   1 0   1.0
BUP
DEC       1.0              1  2  4  1
DEC       5.0              2  3  4  0
DEC      10.0              3  4  4  0
DEC      50.0              4  5  4  0
DEC     100.0              5  6  4  0
DEC     200.0              6  7  4  0
DEC       1.0              7  8  5  0
DEC       2.0              8  9  5  0
DEC       5.0              9 10  5  0
DEC      10.0             10 11  5  0
DEC      20.0             11 12  5  0
BUP
CUT     5  1.E-20  7  1.E-20  9  1.E-20  -1
RDA     ACTIVATION PRODUCTS OUTPUT TABLE OPTIONS
OPTL     8 8 8 8 7 8 7 8 7 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8
RDA     FISSION PRODUCTS OUTPUT TABLE OPTIONS
OPTF     8 8 8 8 7 8 7 8 7 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8
RDA     ACTINIDE AND DAUGHTER OUTPUT TABLE OPTIONS
OPTA     8 8 8 8 7 8 7 8 7 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8
OUT      12 1 -1  0
STP 4
1    010030 6.616E-10 270600 1.487E-03 000000 0.000E+00 000000 0.000E+00
3    380900 6.158E-01 390900 1.544E-04 551370 7.393E-01 561371 1.130E-07
3    631540 6.571E-03 631550 2.153E-03 000000 0.000E+00 000000 0.000E+00
2    942380 2.924E-01 942390 3.171E+02 942400 4.746E+01 942410 4.158E+00
2    942420 8.638E-01 952410 1.110E+01 922340 7.601E+00 922350 0.897E+03
2    922360 1.087E+02 922380 1.051E+05 000000 0.000E+00 000000 0.000E+00
0
END
```

APPENDIX B

TRANSPORTATION SAFETY CLASS ANALYSIS FOR SHIPMENT OF SLUDGE FROM K EAST BASIN

Westinghouse Hanford Company — **Internal Memo**

From: Nuclear Physics and Shielding — 8M730-JVN-96-004
Phone: 376-4480 H0-35
Date: January 19, 1996
Subject: TRANSPORTATION SAFETY CLASS ANALYSIS FOR SHIPMENT OF SLUDGE FROM K EAST BASIN

To: [redacted]

cc:

J. G. Field	G1-11
J. Greenborg	H0-35
A. L. Ramble	A3-38
JVN File/LB	

References: See Attachment 1.

Introduction

The K East Basin is used for under water storage of irradiated fuel from Hanford production reactors. During its lifetime of four decades, up to 68 cubic meters of radioactive particulate matter has settled to the bottom of the basin as sludge. Plans are to remove this sludge, transport it to the 200 East Area, and store it there in double-shell tanks. Shipment payloads will consist of sludge, plus basin and process water.

This report provides a safety class analysis for the shipment of the sludge and contaminated water from the K East Basin.

Source Term

The source term in this analysis is divided into two classes: radioactive sludge and contaminated water from the basin. In quantifying the source term in section 2 of the K East Basin Sludge PDC), it was assumed that each shipment will consist of 30 percent sludge and 70 percent water by volume. The worst-case source terms for the sludge, water, and their sum are listed in Tables 1. Curie inventories in the sludge were specified by radionuclide as May 1993 values. The radionuclide activities in the sludge that are listed in Table 1 have been decayed two years and eight months (to January 1996 levels) using the Microshield program (Ref. 1). Activities in the water were specified as 1995 values. These data were not decay corrected, and thus, the radionuclide inventories listed in Table 1 for the water were taken directly from section 2 of the PDC.

The total activity of the sludge source in Table 1 is 730 Ci (2.7×10^{13} Bq). The total activity of the contaminated water is over three orders of magnitude less at 0.18 Ci (6.6×10^{9} Bq). As will be discussed later, the water source term is insignificant in comparison with the sludge source term.

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January 19, 1996

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Table 1. K East Basin Sludge, Water, and Total Source Terms for Worst-Case Shipment

Radionuclide	Radionuclide Inventory (curies)		
	Sludge[a]	Water[b]	Total
^{3}H		$6.4x10^{-6}$	$6.4x10^{-6}$
^{60}Co	$1.2x10^{0}$		$1.2x10^{0}$
^{90}Sr	$7.9x10^{1}$	$3.5x10^{-2}$	$7.9x10^{1}$
^{90}Y	$7.9x10^{1}$	$3.5x10^{-2}$	$7.9x10^{1}$
^{137}Cs	$6.0x10^{1}$	$5.5x10^{-2}$	$6.0x10^{1}$
^{137m}Ba	$5.7x10^{1}$	$5.5x10^{-2}$	$5.7x10^{1}$
^{154}Eu	$1.4x10^{0}$		$1.4x10^{0}$
^{155}Eu	$6.9x10^{-1}$		$6.9x10^{-1}$
^{231}Th	$1.9x10^{-3}$		$1.9x10^{-3}$
^{234}Th	$3.5x10^{-2}$		$3.5x10^{-2}$
^{233}Pa	$3.2x10^{-5}$		$3.2x10^{-5}$
^{234}Pa	$5.7x10^{-5}$		$5.7x10^{-5}$
^{234m}Pa	$3.5x10^{-2}$		$3.5x10^{-2}$
^{234}U	$4.8x10^{-2}$	$5.2x10^{-7}$	$4.8x10^{-2}$
^{235}U	$1.9x10^{-3}$	$2.1x10^{-8}$	$1.9x10^{-3}$
^{236}U	$7.0x10^{-3}$	$7.7x10^{-8}$	$7.0x10^{-3}$
^{238}U	$3.5x10^{-2}$	$3.9x10^{-7}$	$3.5x10^{-2}$
^{238}Pu	$4.9x10^{0}$	$4.2x10^{-5}$	$4.9x10^{0}$
^{239}Pu	$2.0x10^{1}$	$1.9x10^{-4}$	$2.0x10^{1}$
^{240}Pu	$1.1x10^{1}$	$1.9x10^{-4}$	$1.1x10^{1}$
^{241}Pu	$3.8x10^{2}$		$3.8x10^{2}$
^{242}Pu	$3.3x10^{-3}$		$3.3x10^{-3}$
^{241}Am	$4.0x10^{1}$	$8.7x10^{-4}$	$4.0x10^{1}$
Total	$7.3x10^{2}$	$1.8x10^{-1}$	$7.3x10^{2}$

a Sludge source was decayed to January 1996 from the May 1993 values in section 2 of the PDC.

b Activities of radionuclides in the water source were taken directly from section 2 of the PDC. These data were based on 1994 and 1995 assessments.

J. R. Green
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Discussion and Results

As outlined in Reference 2, the event considered is an unmitigated release, which has been interpreted as release of 100% of the source from any packaging. The doses to be calculated are the Committed Effective Dose Equivalent (CEDE) to the maximally exposed offsite and onsite individuals with only inhalation and external exposure considered. The onsite individual is assumed to be located 100 m away from the release, while the offsite individual is assumed to be located at the site boundary. Since an offsite receptor could be a boater in the Columbia River, the near bank of the river was considered as part of the boundary. The point of release was assumed to be near the K East Basin because of its proximity to the site boundary (the Columbia River).

The computer code GXQ (Ref. 3) was used to calculate atmospheric dispersion coefficients (Ψ/Q) for a comprehensive set of distances and directions from the assumed release point to the site boundary, and for a distance of 100 m from the release point in all directions. The input file for this GXQ run is listed in Attachment 2. Meteorological data used were the 1983 to 1991 averages by area. The largest Ψ/Q values that were not exceeded more than 0.5% of the time were selected for further use in this analysis.

The computer code GENII (Ref. 4) was then used to calculate the dose to the affected individuals. The input file for the GENII run is listed in Attachment 3. For assessment of the safety class, only the inhalation and direct radiation pathways for the maximally exposed members of the population are considered. The following libraries were accessed:

GENII Default Parameter Values (28-Mar-90 RAP)
Radionuclide Library - Times<100 years (23-July-93 PDR)
External Dose Factors for GENII in person Sv/yr per Bq/n (8-May-90 RAP)
Worst-Case Solubilities, Yearly Dose Increments (23-Jul-93 PDR).

Jofu Mishima, in his study of release fractions (Ref. 5), has a bounding airborne release fraction (ARF) of 5.0×10^{-5} for the free-fall spill of slurries from a height of 3 m. The corresponding respirable fraction (RF) is 0.8. The ARFxRF value of 4.0×10^{-5} was applied to the doses computed by GENII for the sludge source.

Appropriate ARF and RF bounding values for the contaminated water are 2.0×10^{-4} and 0.5, which are given in Reference 5 for the free-fall spill of aqueous solutions from a height of 3 m. The ARFxRF value (1.0×10^{-4}) for the aqueous solutions is a factor of 2.5 times higher than the corresponding value for slurries. However, with the exception of tritium, the quantity of each radionuclide in the water is more than three orders of magnitude less than in the sludge, and the amount of tritium in the water is insignificant compared to the curie inventory in the sludge. Consequently, a GENII calculation of the negligible doses from the contaminated water was not done.

In the worst case scenario, the hypothesized spill would result in a drop of less than three meters. However, Reference 5 provides bounding values for only a three-meter drop. Thus, the conservative three-meter data were used.

J. R. Green
Page 4
January 19, 1996

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As indicated above, the product of the ARF and RF values for slurries ($4.0x10^{-5}$) was applied to the results of the GENII run, which was made for the entire sludge source term. The GENII results were also multiplied by appropriate Ψ/Q values from GXQ. The highest Ψ/Q value for an offsite receptor is $1.8x10^{-3}$ sec/m^3 at a location on the near bank of the Columbia River, 790 m west of the postulated accident site at the K East Basin. The highest Ψ/Q value for an onsite receptor 100 m from the accident site is 7.3 x 10^{-2}sec/m^3.

The committed effective doses, formerly named the committed effective dose equivalent (CEDE), from the sludge source term are tabulated in Table 2. These are 50-year committed doses. The maximally exposed organ is the bone surfaces from inhalation of ^{241}Am. The data in Table 2 are inhalation doses only, because they dominate the doses from direct radiation. The doses from the contaminated water are also insignificant by comparison, as previously discussed.

The offsite CEDE, 0.0085 Sv (0.85 rem), is less than 25 rem, but greater than 0.5 rem. Thus, at least one Safety Class 1 (SC 1) barrier is required (Ref. 2) for shipping a package containing K East sludge having the activity given in Table 1.

Table 2. Transportation Safety Class Analysis Doses

Individual	CEDE, Sv (rem)	Organ*, Sv (rem)
Onsite	$3.5x10^{-1}$ ($3.5x10^{1}$)	$6.4x10^{0}$ ($6.4x10^{2}$)
Offsite	$8.5x10^{-3}$ ($8.5x10^{-1}$)	$1.6x10^{-1}$ ($1.6x10^{1}$)

* The controlling organ is the bone surfaces from ^{241}Am inhalation.

J. V. Nelson
J. V. Nelson, Principal Scientist
Nuclear Physics and Shielding

Concurrence: J. Greenborg
J. Greenborg, Manager

llp

Attachments 6

REFERENCES

1. *Microshield 3 Manual*, Grove Engineering, Inc., April 1988.

2. *Westinghouse Hanford Company Standard Engineering Practices Manual*, WHC-CM-6-1, *Safety Classification Section*, EP-1.4, Rev. 1, December 1991.

3. B. E. Hey, *GXQ 4.0 Users' Guide*, WHC-SD-GN-SWD-30002, Rev. 1, December 1994.

4. B. A. Napier, D. 1. Strenge, R. A. Peloquin and J. V. Ramsdell, *GENII - The Hanford Environmental Dosimetry Software System*, PNL-6584, November 1988.

5. J. Mishima, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities*, DOE-HDBK-3010-94, U. S. Department of Energy, December 1994.

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ATTACHMENT 2
Page 1 of 2

GXQ Input File

```
Input title line
c GXQ Ver. 4.0 Input for KE-Basin boater & worker
c   mode
    1
c
c MODE CHOICE:
c mode = 1 then X/Q based on Hanford site specific meteorology
c mode = 2 then X/Q based on atmospheric stability class and wind speed
c mode = 3 then X/Q plot file is created
c
c LOGICAL CHOICES:
c   ifox  inorm icdf  ichk  isite ipop
    t     f     f     f     f     f
c ifox  = t then joint frequency used to compute frequency to exceed X/Q
c       = f then joint frequency used to compute annual average X/Q
c inorm = t then joint frequency data is normalized (as in GENII)
c       = f then joint frequency data is un-normalized
c icdf  = t then cumulative distribution file created (CDF.OUT)
c       = f then no cumulative distribution file created
c ichk  = t then X/Q parameter print option turned on
c       = f then no parameter print
c isite = t then X/Q based on joint frequency data for all 16 sectors
c       = f then X/Q based on joint frequency data of individual sectors
c ipop  = t then X/Q is population weighted
c       = f then no population weighting
c
c X/Q AND WIND SPEED ADJUSTMENT MODELS:
c   ipuff idep  isrc  iwind
    0     0     0     0
c DIFFUSION COEFFICIENT ADJUSTMENT MODELS:
c   iwake ipm   iflow ientr
    0     0     0     0
c EFFECTIVE RELEASE HEIGHT ADJUSTMENT MODELS:
c  (irise igrnd)iwash igrav
    0     0     0     0
c ipuff = 1 then X/Q calculated using puff model
c       = 0 then X/Q calculated using default continuous plume model
c idep  = 1 then plume depletion model turned on (Chamberlain model)
c isrc  = 1 then X/Q multiplied by scalar
c       = 2 then X/Q adjusted by wind speed function
c iwind = 1 then wind speed corrected for plume height
c iwake = 1 then NRC RG 1.145 building wake model turned on
c       = 2 then MACCS virtual distance building wake model turned on
c ipm   = 1 then NRC RG 1.145 plume meander model turned on
c       = 2 then 5th Power Law plume meander model turned on
c       = 3 then sector average model turned on
c iflow = 1 then sigmas adjusted for volume flow rate
c ientr = 1 then method of Pasquill used to account for entrainment
c irise = 1 then MACCS buoyant plume rise model turned on
c       = 2 then ISC2 momentum/buoyancy plume rise model turned on
c igrnd = 1 then Mills buoyant plume rise modification for ground effects
c iwash = 1 then stack downwash model turned on
c igrav = 1 then gravitational settling model turned on
c       = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c                  reference                    frequency
c   release        anemometer     mixing        to
c   height         height         height        exceed
c   hs(m)          ha(m)          hm(m)         Cx(%)
c   ___________    ___________    ___________   ___________
    0              10             1000          .5
c
c   initial        initial                                    gravitational
c   plume          plume          release       deposition    settling
c   width          height         duration      velocity      velocity
c   Wb(m)          Hb(m)          trd(hr)       vd(m/s)       vg(m/s)
c   ___________    ___________    ___________   ___________   ___________
    0              0              1             0.001         0.001
c
c                  initial        initial                     convective
c   ambient        plume          plume         release       heat release
```

```
c    temperature    temperature    flow rate    diameter    rate(1)
c    Tamb(C)        T0(C)          V0(m3/s)     d(m)        qh(w)
c    ___________    ___________    _________    ________    _______
     20             22             0            1           0
c
c (1) If zero then buoyant flux based on plume/ambient temperature difference.
c
c    X/Q            Wind
c    scaling        Speed
c    factor         Exponent
c    c(7)           a(7)
c    ___________    ___________
     1              .78
c
c RECEPTOR DEPENDENT DATA (no line limit)
c FOR MODE     make          RECEPTOR DEPENDENT DATA
c 1 (site specific)          sector distance receptor-height
c 2 (by class & wind speed) class windspeed distance offset receptor-height
c 3 (create plot file)       class windspeed xmax imax ymax jmax xqmin power
c
c RECEPTOR PARAMETER DESCRIPTION
c sector = 0, 1, 2... (all, S, SSW, etc.)
c distance = receptor distance (m)
c receptor height = height of receptor (m)
c class = 1, 2, 3, 4, 5, 6, 7 (P-G stability class A, B, C, D, E, F, G)
c windspeed = anemometer wind speed (m/s)
c offset = offset from plume centerline (m)
c xmax = maximum distance to plot or calculate to (m)
c imax = distance intervals
c ymax = maximum offset to plot (m)
c jmax = offset intervals
c xqmin = minimum scaled X/Q to calculate
c power = exponent in power function step size
  1    25490   0
  2    25820   0
  3    17940   0
  4     1320   0
  5      790   0
  6      620   0
  7      590   0
  8      610   0
  9      760   0
 10     1110   0
 11     3220   0
 12    10730   0
 13    11110   0
 14    14410   0
 15    30250   0
 16    31330   0
  0      100   0
```

Input File for GENII Run

```
######################### Program GENII Input File ############ 8 Jul 88 ####
Title: KE Basin sludge source - Worker/Boater - Report by radionuclide #3
     \GENII\kbsnslw3.in                           Created on 01-05-1995 at 10:55
OPTIONS======================== Default =====================================
F     Near-field scenario?       (Far-field)    NEAR-FIELD: narrowly-focused
F     Population dose?          (Individual)                release, single site
T     Acute release?              (Chronic)     FAR-FIELD:  wide-scale release,
      Average Individual data set used                      multiple sites
                                 Complete                                Complete
TRANSPORT OPTIONS============ Section    EXPOSURE PATHWAY OPTIONS===== Section
T  Air Transport                   1     F  Finite plume, external        5
F  Surface Water Transport         2     T  Infinite plume, external      5
F  Biotic Transport (near-field) 3,4     F  Ground, external              5
F  Waste Form Degradation (near) 3,4     F  Recreation, external          5
                                         T  Inhalation uptake             5,6
REPORT OPTIONS======================     F  Drinking water ingestion      7,8
F  Report AEDE only                      F  Aquatic foods ingestion       7,8
T  Report by radionuclide                F  Terrestrial foods ingestion   7,9
F  Report by exposure pathway            F  Animal product ingestion      7,10
F  Debug report on screen                F  Inadvertent soil ingestion

INVENTORY ###################################################################

 4    Inventory input activity units: (1-pCi  2-uCi  3-mCi  4-Ci  5-Bq)
 0    Surface soil source units (1- m2  2- m3  3- kg)
      Equilibrium question goes here

      --------|----Release Terms------|----------Basic Concentrations---------|
      Use when| transport selected    | near-field scenario, optionally       |
      --------|-----------------------|---------------------------------------|
      Release |       Surface Buried  |        Surface Deep    Ground  Surface|
      Radio-  |Air    Water   Waste   |Air     Soil    Soil    Water   Water  |
      nuclide |/yr    /yr     /m3     |/m3     /unit   /m3     /L      /L     |
      --------|------- ------- -------|------- ------- ------- ------- -------|
      CO60     1.2E+00                 0.0E+00
      SR90     7.9E+01                 0.0E+00
      Y 90     7.9E+01                 0.0E+00
      CS137    6.0E+01                 0.0E+00
      EU154    1.4E+00                 0.0E+00
      EU155    6.9E-01                 0.0E+00
      PU238    4.9E+00                 0.0E+00
      PU239    2.0E+01                 0.0E+00
      PU240    1.1E+01                 0.0E+00
      PU241    3.8E+02                 0.0E+00
      AM241    4.0E+01                 0.0E+00
      U 234    4.8E-02                 0.0E+00
      U 235    1.9E-03                 0.0E+00
      U 236    7.0E-03                 0.0E+00
      U 238    3.5E-02                 0.0E+00
      TH231    1.9E-03                 0.0E+00
      TH234    3.5E-02                 0.0E+00
      PA233    3.2E-05                 0.0E+00
      PA234    5.7E-05                 0.0E+00

      --------|----Derived Concentrations-----|
      Use when|  measured values are known    |
      --------|-------------------------------|
      Release |Terres. Animal  Drink   Aquatic|
      Radio-  |Plant   Product Water   Food   |
      nuclide |/kg     /kg     /L      /kg    |
      --------|------- ------- ------- -------|

TIME ########################################################################

1     Intake ends after (yr)
50    Dose calc. ends after (yr)
0     Release ends after (yr)
0     No. of years of air deposition prior to the intake period
0     No. of years of irrigation water deposition prior to the intake period

FAR-FIELD SCENARIOS (IF POPULATION DOSE) ####################################
```

```
0          Definition option: 1-Use population grid in file POP.IN
0                             2-Use total entered on this line

NEAR-FIELD SCENARIOS ##########################################################

           Prior to the beginning of the intake period: (yr)
0            When was the inventory disposed?  (Package degradation starts)
0            When was LOIC?  (Biotic transport starts)
0          Fraction of roots in upper soil (top 15 cm)
0          Fraction of roots in deep soil
0          Manual redistribution: deep soil/surface soil dilution factor
0          Source area for external dose modification factor (m2)
TRANSPORT ######################################################################
           ====AIR TRANSPORT==================================SECTION 1=====
                   0-Calculate PM          |0         Release type (0-3)
 1         Option: 1-Use chi/Q or PM value |F         Stack release (T/F)
                   2-Select MI dist & dir  |0         Stack height (m)
                   3-Specify MI dist & dir |0         Stack flow (m3/sec)
1.0        Chi/Q or PM value               |0         Stack radius (m)
0          MI sector index (1=S)           |0         Effluent temp. (C)
0          MI distance from release point (m)|0       Building x-section (m2)
T          Use jf data, (T/F) else chi/Q grid|0       Building height (m)

           ====SURFACE WATER TRANSPORT========================SECTION 2=====
0          Mixing ratio model: 0-use value, 1-river, 2-lake
0          Mixing ratio, dimensionless
0          Average river flow rate for: MIXFLG=0 (m3/s), MIXFLG=1,2 (m/s),
0          Transit time to irrigation withdrawl location (hr)
           If mixing ratio model > 0:
0            Rate of effluent discharge to receiving water body (m3/s)
0            Longshore distance from release point to usage location (m)
0            Offshore distance to the water intake (m)
0            Average water depth in surface water body (m)
0            Average river width (m), MIXFLG=1 only
0            Depth of effluent discharge point to surface water (m), lake only

           ====WASTE FORM AVAILABILITY========================SECTION 3=====
0          Waste form/package half life, (yr)
0          Waste thickness, (m)
0          Depth of soil overburden, m

           ====BIOTIC TRANSPORT OF BURIED SOURCE==============SECTION 4=====
T          Consider during inventory decay/buildup period (T/F)?
T          Consider during intake period (T/F)?  | 1-Arid non agricultural
0          Pre-Intake site condition.............| 2-Humid non agricultural
                                                 | 3-Agricultural

EXPOSURE #######################################################################

           ====EXTERNAL EXPOSURE==============================SECTION 5=====
           Exposure time:                 |  Residential irrigation:
0            Plume (hr)                   | T        Consider: (T/F)
0            Soil contamination (hr)      | 0        Source: 1-ground water
0            Swimming (hr)                |                  2-surface water
0            Boating (hr)                 | 0        Application rate (in/yr)
0            Shoreline activities (hr)    | 0        Duration (mo/yr)
0          Shoreline type: (1-river, 2-lake, 3-ocean, 4-tidal basin)
0          Transit time for release to reach aquatic recreation (hr)
1.0        Average fraction of time submersed in acute cloud (hr/person hr)

           ====INHALATION=====================================SECTION 6=====
8766.0     Hours of exposure to contamination per year
0          0-No resus-  1-Use Mass Loading          2-Use Anspaugh model
0            pension      Mass loading factor (g/m3)  Top soil available (cm)

           ====INGESTION POPULATION===========================SECTION 7=====
0          Atmospheric production definition (select option):
0            0-Use food-weighted chi/Q, (food-sec/m3), enter value on this line
             1-Use population-weighted chi/Q
             2-Use uniform production
             3-Use chi/Q and production grids (PRODUCTION will be overridden)
0          Population ingesting aquatic foods, 0 defaults to total (person)
0          Population ingesting drinking water, 0 defaults to total (person)
F          Consider dose from food exported out of region (default=F)

           Note below: S* or Source: 0-none, 1-ground water, 2-surface water
```

3-Derived concentration entered above

==== AQUATIC FOODS / DRINKING WATER INGESTION==========SECTION 8====

F Salt water? (default is fresh)

USE ? T/F	FOOD TYPE	TRAN-SIT hr	PROD-UCTION kg/yr	-CONSUMPTION- HOLDUP da	RATE kg/yr		DRINKING WATER
F	FISH	0.00	0.0E+00	0.00	0.0	0	Source (see above)
F	MOLLUS	0.00	0.0E+00	0.00	0.0	T	Treatment? T/F
F	CRUSTA	0.00	0.0E+00	0.00	0.0	0	Holdup/transit(da)
F	PLANTS	0.00	0.0E+00	0.00	0.0	0	Consumption (L/yr)

====TERRESTRIAL FOOD INGESTION======================SECTION 9=====

USE ? T/F	FOOD TYPE	GROW TIME da	--IRRIGATION-- S *	RATE in/yr	TIME mo/yr	YIELD kg/m2	PROD-UCTION kg/yr	--CONSUMPTION-- HOLDUP da	RATE kg/yr
F	LEAF V	0.00	0	0.0	0.0	0.0	0.0E+00	0.0	0.0
F	ROOT V	0.00	0	0.0	0.0	0.0	0.0E+00	0.0	0.0
F	FRUIT	0.00	0	0.0	0.0	0.0	0.0E+00	0.0	0.0
F	GRAIN	0.00	0	0.0	0.0	0.0	0.0E+00	0.0	0.0

====ANIMAL PRODUCTION CONSUMPTION===================SECTION 10====

USE ? T/F	FOOD TYPE	---HUMAN---- CONSUMPTION RATE kg/yr	HOLDUP da	TOTAL PROD-UCTION kg/yr	DRINK WATER CONTAM FRACT.	---STORED FEED--- DIET FRAC-TION	GROW TIME da	-IRRIGATION-- S *	RATE in/yr	TIME mo/yr	YIELD kg/m3	STOR-AGE da
F	BEEF	0.0	0.0	0.00	0.00	0.00	0.0	0	0.0	0.00	0.00	0.0
F	POULTR	0.0	0.0	0.00	0.00	0.00	0.0	0	0.0	0.00	0.00	0.0
F	MILK	0.0	0.0	0.00	0.00	0.00	0.0	0	0.0	0.00	0.00	0.0
F	EGG	0.0	0.0	0.00	0.00	0.00	0.0	0	0.0	0.00	0.00	0.0
						---FRESH FORAGE---						
	BEEF					0.00	0.0	0	0.0	0.00	0.00	0.0
	MILK					0.00	0.0	0	0.0	0.00	0.00	0.0

##

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ATTACHMENT 4
Page 1 of 1

CHECKLIST FOR INDEPENDENT TECHNICAL REVIEW

DOCUMENT REVIEWED
NUMBER: 8M730-JVN-96-004
TITLE: TRANSPORTATION SAFETY CLASS ANALYSIS FOR SHIPMENT OF SLUDGE FROM K EAST BASIN

Reviewer(s): D. E. Lessor

I. Method(s) of Review

- (X) Input data checked for accuracy
- ( ) Independent calculation performed
- ( ) Hand calculation
- ( ) Alternate computer code: ____________
- ( ) Comparison to experiment or previous results
- ( ) Alternate method (define) ____________

II. Checklist (either check or enter NA if not applied)

- (NA) Task completely defined
- (NA) Activity consistent with task specification
- (NA) Necessary assumptions explicitly stated and supported
- (NA) Resources properly identified and referenced
- (NA) Resource documentation appropriate for this application
- (X) Input data explicitly stated
- (X) Input data verified to be consistent with original source
- (NA) Geometric model adequate representation of actual geometry
- (NA) Material properties appropriate and reasonable
- (NA) Mathematical derivations checked including dimensional consistency
- (X) Hand calculations checked for errors
- (NA) Assumptions explicitly stated and justified
- (NA) Computer software appropriate for task and used within range of validity
- (NA) Use of resource outside range of established validity is justified
- (X) Software runstreams correct and consistent with results
- (X) Software output consistent with input
- (NA) Results consistent with applicable previous experimental or analytical findings
- (NA) Results and conclusions address all points and are consistent with task requirements and/or established limits or criteria
- (NA) Conclusions consistent with analytical results and established limits
- (NA) Uncertainty assessment appropriate and reasonable
- ( ) Other (define) ____________

III. Comments: ____________

IV. REVIEWER: D. E. Lessor 1-24-96

8M730-JVN-96-004
ATTACHMENT 5
Page 1 of 1

CHECKLIST FOR INDEPENDENT TECHNICAL REVIEW

DOCUMENT REVIEWED
NUMBER: 8M730-JVN-96-004
TITLE: TRANSPORTATION SAFETY CLASS ANALYSIS FOR SHIPMENT OF SLUDGE FROM K EAST BASIN

Reviewer(s): P. D. Rittmann

I. Method(s) of Review

- (X) Input data checked for accuracy
- (X) Independent calculation performed
- (X) Hand calculation
- ( ) Alternate computer code:
- ( ) Comparison to experiment or previous results
- ( ) Alternate method (define)

II. Checklist (either check or enter NA if not applied)

- (✓) Task completely defined
- (✓) Activity consistent with task specification
- (✓) Necessary assumptions explicitly stated and supported
- (✓) Resources properly identified and referenced
- (✓) Resource documentation appropriate for this application
- (✓) Input data explicitly stated
- (✓) Input data verified to be consistent with original source
- (✓) Geometric model adequate representation of actual geometry
- (✓) Material properties appropriate and reasonable
- (na) Mathematical derivations checked including dimensional consistency
- (✓) Hand calculations checked for errors
- (✓) Assumptions explicitly stated and justified
- (✓) Computer software appropriate for task and used within range of validity
- (na) Use of resource outside range of established validity is justified
- (✓) Software runstreams correct and consistent with results
- (✓) Software output consistent with input
- (✓) Results consistent with applicable previous experimental or analytical findings
- (✓) Results and conclusions address all points and are consistent with task requirements and/or established limits or criteria
- (✓) Conclusions consistent with analytical results and established limits
- (na) Uncertainty assessment appropriate and reasonable
- (na) Other (define)

III. Comments:

IV. REVIEWER: Paul Rittmann 1-25-96

8M730-JVN-96-004
ATTACHMENT 6
Page 1 of 1

HEDOP REVIEW CHECKLIST
for
Radiological and Nonradiological Release Calculations

Document Reviewed:

TRANSPORTATION SAFETY CLASS ANALYSIS FOR SHIPMENT OF SLUDGE FROM K EAST BASIN

Submitted by: J. V. Nelson Date Submitted: January 18, 1996

Scope of Review: Entire Document

YES	NO*	N/A		
[X]	[ ]	[ ]	1.	A detailed technical review and approval of the environmental transport and dose calculation portion of the analysis has been performed and documented.
[X]	[ ]	[ ]	2.	Detailed technical review(s) and approval(s) of scenario and release determinations have been performed and documented.
[X]	[ ]	[ ]	3.	HEDOP-approved code(s) were used.
[X]	[ ]	[ ]	4.	Receptor locations were selected according to HEDOP recommendations.
[X]	[ ]	[ ]	5.	All applicable environmental pathways and code options were included and are appropriate for the calculations.
[X]	[ ]	[ ]	6.	Hanford site data were used.
[X]	[ ]	[ ]	7.	Model adjustments external to the computer program were justified and performed correctly.
[X]	[ ]	[ ]	8.	The analysis is consistent with HEDOP recommendations.
[ ]		[X]	9.	Supporting notes, calculations, comments, comment resolutions, or other information is attached. (Use the "Page 1 of X" page numbering format and sign and date each added page.)
[X]	[ ]		10.	**Approval is granted on behalf of the Hanford Environmental Dose Overview Panel.**

* All "NO" responses must be explained and use of nonstandard methods justified.

Reviewer Name: Paul D. Rittmann, B.A., M.S., Ph.D., C.H.P.
(print or type)

Paul Rittmann 1-25-96

HEDOP-Approved Reviewer (Signature) Date

DISTRIBUTION SHEET

To	From	Page 1 of 1
Distribution	Packaging Engineering	Date 05/01/96
Project Title/Work Order		EDT No. 615806
Packaging Design Criteria for the K East Basin Sludge Transportation System (WHC-SD-TP-PDC-035)		ECN No. N/A

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
S. A. Brisbin	R3-48	X			
J. G. Field	G1-11	X			
J. E. Geary	S5-07	X			
J. R. Green	G1-11	X			
C. R. Hoover	G1-11	X			
D. W. McNally	G1-11	X			
F. W. Moore	X3-85	X			
D. R. Precechtel	R3-48	X			
W. J. Schlauder	S7-84	X			
S. S. Shiraga	G1-11	X			
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C. A. Thompson	R3-85	X			
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