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16. KEY

Approval Designator (F)	Reason for Transmittal (G)	Disposition (H) & (I)
E, S, Q, D OR N/A (See WHC-CM-3-5, Sec. 12.7)	1. Approval 2. Release 3. Information 4. Review 5. Post-Review 6. Dist. (Receipt Acknow. Required)	1. Approved 2. Approved w/comment 3. Disapproved w/comment 4. Reviewed no/comment 5. Reviewed w/comment 6. Receipt acknowledged

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(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN	(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN
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D L Scott D. L. Scott 5/24/99 Signature of EDT Originator / Date	N/A Authorized Representative for Receiving Organization / Date	N/A Design Authority/ Cognizant Manager / Date	Ctrl No. ○ Approved ○ Approved w/comments ○ Disapproved w/comments

S

Calculation of Unmitigated Release From Reverse Circulation Drilling of a Borehole Three Meters South of Borehole 41-15-09 Near SST 241-SX-115

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Abstract: To more fully characterize the vadose zone near Single Shell Tank 241-SX-115, another borehole will be drilled and sampled by using reverse circulation drilling equipment. Compressed air propels the drill and sweeps out cuttings. Dose calculations in this document are performed for an unmitigated airborne release from the drill string. Doses were found not to exceed TWRS risk guideline values.

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CALCULATION OF UNMITIGATED RELEASE FROM REVERSE CIRCULATION DRILLING OF A BOREHOLE THREE METERS SOUTH OF BOREHOLE 41-15-09 NEAR SST 241-SX-115

Prepared by:
Fluor Daniel Northwest, Inc.

For:
Lockheed Martin Hanford Co.

Date Published
May 1999

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ARF	airborne release fraction
Bq	bacquerel
Ci	curie
DR	damage ratio
HEDOP	Hanford Environmental Dose Overview Panel
HEPA	high efficiency particulate air
L	liter
LANL	Los Alamos National Laboratory
LPF	leak path factor
MAR	material at risk
R	breathing rate
rem	radiation effective man
RF	respirable fraction
Sv	seivert
TWRS	Tank Waste Remediation System
UD	inhalation unit dose

Calculation of Unmitigated Release from Reverse Circulation Drilling of a Borehole Three Meters South of Borehole 41-15-09 Near SST 241-SX-115

1.0 INTRODUCTION AND PURPOSE

It is known that undergound, single shell tank (SST) 241-SX-115 leaked 50,000 gallons of contaminated liquid to the soil. Now there is a campaign to more fully characterize the plume from that leak. To determine radionuclide concentrations in the vadose zone, boring into the soil and collecting samples of it are needed. It was decided to bore a new hole 3 m (9.8 ft) from existing borehole number 41-15-09, located near the south edge of the tank. Drilling and sampling will be done with the use of reverse circulation drilling, which uses compressed air to power the drill bit and sweep out drillings into separation and sampling equipment.

Prior to drilling, however, it was determined that safety assessment calculations were needed to find out if postulated releases from the drilling would pose unacceptable risk to onsite and offsite receptors. Unacceptable risk would require the design and construction of safety significant equipment for prevention or mitigation of the release.

2.0 PROCESS DESCRIPTION

A process flow diagram for reverse circulation drilling is shown in Figure 1. Arrows show the flow direction of air and air-solids streams. Air supplied by a compressor enters the drill string through an annulus. The drill bit cuttings are suspended by air and are blown through the center of the drill string into a cyclone separator and a Torit (a registered trademark of Donaldson Co., Inc., Minneapolis, MN), which are housed in a containment structure. Solids are collected in drums and periodically removed. The drums will be labeled to allow correlation of material with the depth from which it was removed in the borehole. A solids sample is collected in a sample sock for subsequent chemical and radiochemical analyses. With the aid of an exhaust fan, process air is HEPA filtered before it is exhausted to the atmosphere.

3.0 METHODOLOGY

It was decided that an analysis of an unmitigated release from the drilling operation is the best way to show upper-bound risk. An unmitigated release is defined here as a release where no credit is taken for air-solid separation equipment. Aerodynamically entrained contaminated soil is released directly to the atmosphere as if the piping connection from the drill to the separation equipment were completely severed or disconnected.

Airborne particles having a diameter of 10 microns or less are considered respirable by humans. Onsite and offsite individuals inhaling radioactive particles in the respirable size range would be at risk. As presented in *Airborne Release Fractions/Rates and Respirable Fractions for*

Nonreactor Nuclear Facilities (DOE 1994), the airborne source term is typically estimated by the following formula:

$$\text{Source term (Q)} = \text{MAR x DR x ARF x RF x LPF}$$

Where:

MAR = material at risk,
DR = damage ratio,
ARF = airborne release fraction,
RF = respirable fraction, and
LPF = leak path factor.

After the source term has been calculated, the doses from inhalation pathways are calculated. The dose formula, as provided in *Tank Waste Compositions and Atmospheric Dispersion Coefficients for Use in Safety Analysis Consequence Assessments* (Van Keuren 1996), is:

$$D(Sv) = Q\,(m^3) \times \chi/Q'(s/m^3) \times R(m^3/s) \times UD(Sv/m^3)$$

Where:

D = dose due to inhalation (Sv),
Q = respirable source term (m^3) calculated above,
χ/Q' = atmospheric dispersion coefficient (s/m^3),
R = breathing rate of receptor (3.3E-04 m^3/s), and
UD = inhalation unit dose (Sv/m^3).

For the onsite dose, the Hanford Tank Waste Remediation System (TWRS) risk evaluation guideline value, 0.5 rem, for an anticipated event was used. For offsite dose the risk evaluation guideline value of 0.1 rem was used (BIO 1999, Table 5.3.1-2).

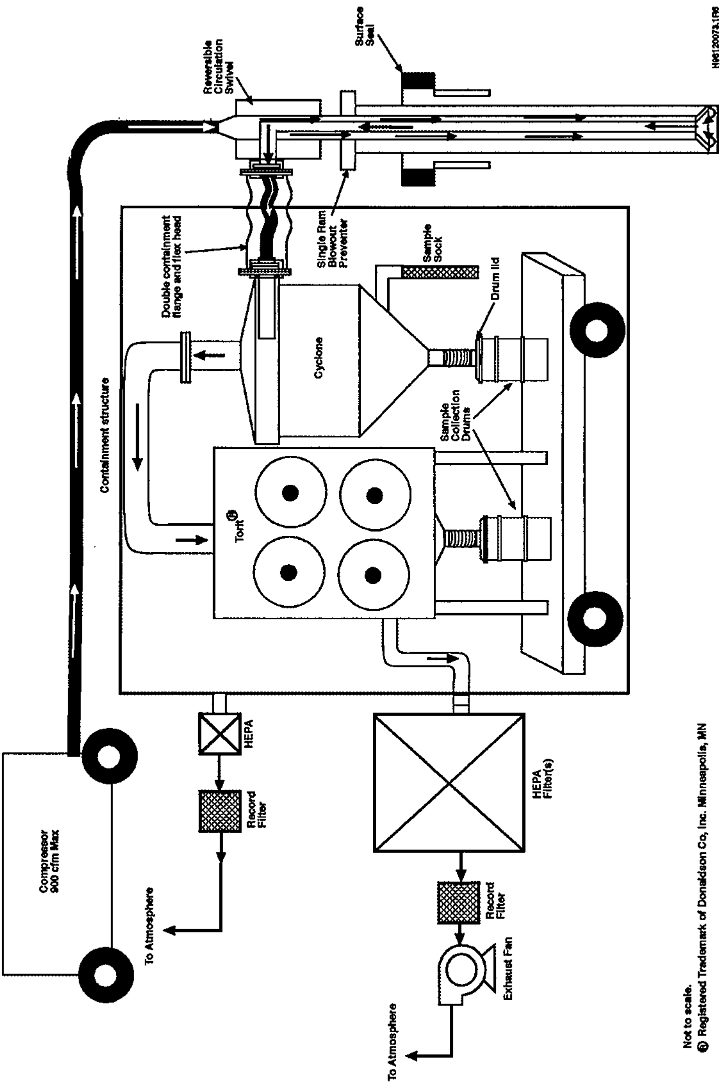

Figure 1. Process Flow Diagram

4.0 INPUT DATA AND ASSUMPTIONS

The material at risk (MAR) was taken as the volume of contaminated material intersected by the borehole at its maximum diameter, 10 inches (0.254 m), with an incremental borehole depth of 5 ft (1.524 m), since this amount is removed each time before sampling. Therefore the MAR was calculated as follows:

$$\begin{aligned} MAR &= [(\pi/4)(\text{max. diameter})^2](\text{borehole depth}) \\ &= [(\pi/4)(0.254\ \text{m})^2](1.524\ \text{m}) \\ &= 0.0772\ \text{m}^3 \end{aligned}$$

The damage ratio (DR) is the fraction of the material actually impacted by the accident. In this case, an unmitigated release is postulated, wherein no credit is taken for containment or filtration equipment, and all material is effected. Therefore:

$$DR = 1.$$

The ARF is that part of the material released which would actually become airborne. The stream of compressed air entrains all the MAR and ejects it in a finely divided state into the atmosphere at an elevation of at least 10 ft (3.048 m) above ground level; therefore,

$$ARF = 1.$$

The respirable fraction (RF) is the portion of the MAR that is less than or equal to 10 microns. The drilling process will remove the material small enough to be lifted by the air stream. Larger particles are broken up until they will be lifted. Even though grinding large particles by the drilling process would add some to the 10-micron fraction, the respirable contamination is not expected to be significantly larger because contamination is a surface phenomenon. For an equivalent mass, the surface area of the larger particles is relatively small when compared with the surface area of small particles. Analysis of Hanford site soils (Serne 1993) indicates that the sandy material is composed of 89% sand, 7% silt, and 4% clay. The analysis of this material indicates that 8% of the sandy material is composed of particles 10 microns or less. The drilling process would increase this value somewhat. A conservative number would be doubling the value; therefore,

$$RF = 0.16$$

The leak path factor (LPF) is the fraction of the material transported through the leak path taking into account any confinement deposition or filtration mechanism. In this case, the leak path will not provide any impedance of the material release; therefore,

$$LPF = 1$$

The source term Q is calculated as follows:

$$
\begin{aligned}
Q &= MAR \times DR \times ARF \times RF \times LPF \\
&= (0.0772\ m^3)(1)(1)(0.16)(1) \\
&= 0.0124\ m^3
\end{aligned}
$$

4.1 ESTIMATE OF RADIONUCLIDE CONCENTRATION IN SOILS AT DRYWELL 15-07 IN SX TANK FARM

The radionuclide concentrations in the most contaminated region of the soil column at Drywell 15-07 were estimated using recent spectral gamma logging results, Agnew's estimates of radionuclide concentrations in SX tank farm boiling waste tanks during the time period the tanks were thought to have leaked, and historical analytical data from the supernatant that leaked from SX-115. The concentration of Cs-137 in the supernatant that leaked from Tank SX-115 in March 1965 is reported in Raymond and Shdo (1966) to be 0.763 Ci/gallon. Spectral gamma logging on Drywell 15-07 in 1996 detected Cs-137 at a concentration of ~10 pCi/g at a depth of 58 feet (DOE-GJO, 1996). Cs-137 contamination was limited to a narrow region between 55 and 60 feet below ground surface. No other radionuclides were identified during the gamma logging of this drywell.

Steve Agnew, LANL, developed a leak volume estimate for four boiling waste tanks in the SX tank farm (Agnew 1998). As part of this effort, the chemical and radionuclide contents of four Tanks (SX-108, -109, -111, and -112) were estimated using the HDW model. The estimate of Tank SX-108 waste composition was used as a basis for the following calculations. (The ratios of radionuclides coming out of the Agnew estimates are based on ORIGEN code calculations for specific fuel batches processed at the REDOX Plant.)

For estimating radionuclide concentrations in soils at Drywell 15-07 the following assumptions were made:

1) The ratio of radionuclides estimated to be in Tank SX-108 at the time of the leak would reflect the radionuclide ratios in SX-115 at the time it leaked. Both tanks received similar REDOX high-level waste.

2) The composition of the supernatant leaked from Tank SX-115 is identical with the tank composition estimate.

3) Except for Tc-99, the ratios of radionuclides in the vadose zone at Drywell 15-07 (near Tank SX-115) are identical with the estimated waste composition in Tank SX-115 at the time of the leak.

4) The composition of the waste in Tank SX-115 at the time it leaked can be ratioed to Agnew's estimate of Tank SX-108 composition and the measured Cs-137 concentration in leaked Tank SX-115 supernatant reported in Raymond and Shdo (1966).

5) Agnew Tank SX-108 radionuclide concentrations are decayed to 1/1/94. Raymond and Shdo's Cs-137 supernatant analysis data were not decay-corrected.

6) Tc-99 at Drywell 15-07 was assumed to be the same concentration as that in the original plume resulting from the 50,000-gallon leak from Tank SX-115.

The major assumption associated with these calculations is that all radionuclides, with the exception of Tc-99, are attenuated to the same extent as Cs-137 through sorption on the soil. Tc-99 is assumed to be non-sorbed on the soil thus there is no mechanism for retardation or concentration in the soil. The "worst case" estimate for Tc-99 is that a plume would be encountered that contained the same concentration as that produced from the original 50,000 gallon leak. This Tc-99 concentration is based on a soil porosity of 30% and a specific gravity of 1.8 (Raymond and Shdo 1966).

4.2 CALCULATIONS TO ESTIMATE RADIONUCLIDE CONCENTRATIONS IN THE SOIL

1) The Cs-137 curie concentration in Tank SX-115 supernatant is converted from Ci/gal to Ci/L as follows:

$$(0.763 \text{ Ci/gal}) / (3.7854 \text{ L/gal}) = 0.2016 \text{ Ci/L}$$

Please realize that by not decay correcting the Raymond and Shdo Cs-137 data from Tank SX-115 supernatant, the estimated concentrations of radionuclides in the vadose zone at Drywell 15-07 are high (conservative) by a factor of approximately 2.

2) An equation is developed for estimating sorbing radionuclides in the soil column at Drywell 15-07 as follows:

$$\text{Rad conc in soil} = \frac{[\text{SX-108 rad conc, Ci/L}]}{[\text{Cs-137 in SX-108 supernatant}]} \times [\text{ of Cs-137 conc in soil, Ci/g}]$$

$$= \frac{(\text{SX-108 rad conc, Ci/L})}{[0.349 \text{ Ci/L}]} \times (1\text{E-11 Ci/g})$$

$$= (\text{SX-108 rad conc, Ci/L}) [(2.8648\text{E-11 Ci/g})/(\text{Ci/L})]$$

Now an example calculation for Sr-90 shows how the equation is used. From Table 1 the Sr-90 concentration in Tank SX-108 is 7.31E-02 Ci/L. Substituting this value into the above equation gives:

$$\text{Sr-90 conc in soil} = (7.31\text{E-02})\,(2.8648\text{E-11}) = 2.094\text{E-12 Ci/g}$$

Except for Tc-99, similar calculations were used to calculate the curie concentration of each radionuclide in the soil (see Table 1).

3) A conservative estimate of the Tc-99 curie concentration in the soil column at Drywell 15-07 is deduced as follows:

$$\text{Tc-99 lost from Tank SX-115} = 6.18\text{E-05 Ci/L} \times 50{,}000\text{ gal} \times 3.785\text{ L/gal}$$

$$= 11.7\text{ Ci Tc-99}$$

At 30% porosity, 2.24 gallons of liquid saturates 1 cubic foot of soil (Raymond and Shdo 1966); therefore, 50,000 gal / 2.24 gal/ft^3 = 22,321 ft^3 of soil is saturated by the 50,000 gal leak. The soil volume is converted to units of cm^3 as follows:

$$(22{,}321\text{ ft}^3)[(2.54\text{ cm/in})(12\text{ in/ft})]^3 = 6.32\text{E+8 cm}^3$$

Given a soil specific gravity of 1.8, the soil volume is converted to soil mass:

6.32E+08 cm^3 x 1.8 g/cm^3 = 1.14E+09 g of soil is saturated by the 50,000 gallon leak.

11.7 Ci Tc-99 / 1.14E+09 g = 1.03E-08 Ci/g Tc-99 is in the original plume from the Tank SX-115 leak event.

Table 1. Estimated Radionuclide Concentrations

Radionuclide	Tank SX-108 Concentration (Ci/L)	Tank SX-115 Concentration (Ci/L)	Drywell 15-07 Concentration (Ci/g)
Sr-90	7.31E-02	4.22E-02	2.09E-12
Y-90	7.31E-02	4.22E-02	2.09E-12
Tc-99	1.07E-04	6.18E-05	1.03E-08*
Cs-137	3.49E-01	2.02E-01	1.00E-11
Pu-239	1.90E-05	1.10E-05	5.44E-16
Pu-241	2.28E-05	1.32E-05	6.53E-16
Am-241	3.69E-05	2.13E-05	1.06E-15

*The Tc-99 concentration in Drywell 15-07 was estimated by assuming at a worst case that the Tc-99 could be the same as the Tc-99 concentration in the soil saturated by the 50,000 gallon leak. As suggested by Raymond and Shdo (1966), a soil porosity of 30% and a specific gravity of 1.8 was used in the calculation.

4.3 ADDITIONAL INPUT DATA

Dose conversion factors (EPA 1988) for each radionuclide in the soil are shown in Table 2, 4th column.

Drilling out an incremental 5-ft borehole length is not expected to take more than 8 hours. A release for this duration is considered acute and is used as a basis for selecting atmospheric dispersion coefficients. The atmospheric dispersion coefficient for a 200-Area Tank Farm onsite receptor at 100 m is 3.41E-02 s/m^3 (Van Keuren 1996, Table 4). For the offsite receptor (at the site boundary) the atmospheric dispersion coefficient is 2.83E-05 s/m^3 (Van Keuren 1996, Table 5). Both of these values are for an acute release without plume meander.

5.0 CALCULATION OF INHALATION UNIT DOSE

Excel spreadsheet software (version 5.0), a product of Microsoft Corporation, was used to calculate individual unit doses and the total inhalation unit dose (UD) as shown in Table 2. The following example calculation for Sr-90 illustrates how the individual unit dose values were calculated. First, the curie concentration for Sr-90 was converted to the appropriate units by multiplying by soil density.

$$(2.09\text{E-}12\ \text{Ci/g})(1.8\text{E+}6\ \text{g/m}^3) = 3.76\text{E-}06\ \text{Ci/m}^3$$

Next, the Sr-90 unit dose was calculated as follows:

$$UD_{Sr\text{-}90} = (3.76E\text{-}06\ Ci/m^3)(3.7E{+}10\ Bq/Ci)(6.47E\text{-}08\ Sv/Bq)$$

$$= 9.01E\text{-}03\ Sv/m^3$$

The sum of the individual unit doses, of course, gives the total inhalation unit dose, 1.56E+00 Sv/m^3.

Table 2. Calculation of Inhalation Unit Dose

Radionuclide	Curie Concentration in Soil (Ci/g)	Curie Concentration in Soil (Ci/m^3)	Dose Conversion Factor** (Sv/Bq)	Unit Dose (Sv/m^3)
Sr-90	2.09E-12	3.76E-06	6.47E-08	9.01E-03
Y-90	2.09E-12	3.76E-06	2.28E-09	3.17E-04
Tc-99	1.03E-08	1.85E-02	2.25E-09	1.54E+00
Cs-137	1.00E-11	1.80E-05	8.63E-09	5.75E-03
Pu-239	5.44E-16	9.80E-10	1.16E-04	4.21E-03
Pu-241	6.53E-16	1.18E-09	2.23E-06	9.70E-05
Am-241	1.06E-15	1.90E-09	1.20E-09	8.45E-08
		Total inhalation unit dose UD =		1.56E+00

**These values are taken from reference EPA 1988.

6.0 RESULTS - CALCULATION OF ONSITE AND OFFSITE INHALATION DOSES

The onsite dose is calculated as follows:

$$D_{onsite} = Q \times (\chi/Q')_{onsite} \times R \times UD$$
$$= (0.0124\ m^3)(3.41E\text{-}02\ s/m^3)(3.3E\text{-}04\ m^3/s)(1.56\ Sv/m^3)$$
$$= 2.18E\text{-}07\ Sv \text{ or } 2.18E\text{-}05\ rem$$

The offsite dose is calculated as follows:

$$D_{offsite} = Q \times (\chi/Q')_{offsite} \times R \times UD$$
$$= (0.0124\ m^3)(2.83E\text{-}05\ s/m^3)(3.3E\text{-}04\ m^3/s)(1.56\ Sv/m^3)$$
$$= 1.81E\text{-}10\ Sv \text{ or } 1.81E\text{-}08\ rem$$

7.0 CONCLUSIONS

For onsite dose, the TWRS risk evaluation guideline value is 0.5 rem for an anticipated accident. The onsite dose for dispersion of a 5-ft borehole depth increment, 2.18E-05 rem, is well below the risk guideline value. For offsite dose, the risk evaluation guideline value is 0.1 rem. The offsite dose, 1.81E-08 rem, is well below the risk guideline value. If material from a 20-ft depth of borehole were dispersed, the dose values would be 4 times greater; that is, 8.72E-05 rem onsite; 7.24E-08 rem offsite, which are also well below the risk evaluation guideline values. Furthermore, even with a respirable fraction of 1 and a release of a 20-ft borehole depth, the dose is less than risk evaluation guideline values. It is therefore concluded that no safety class or safety significant equipment is needed for this accident sequence.

8.0 REFERENCES

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FLUOR DANIEL NORTHWEST

TECHNICAL PEER REVIEWS

CHECKLIST FOR TECHNICAL PEER REVIEW

Document Reviewed:
Title: Calculation of Unmitigated Release from Reverse Circulation Drilling of a Borehole Three Meters South of Borehole 41-15-09 Near SST 241-SX-115
Author: David L. Scott
Date: May 21, 1999
Scope of Review: Entire Document

Yes	No*	NA	
[ ]	[ ]	[X] **	Previous reviews complete and cover analysis, up to scope of this review, with no gaps.
[X]	[ ]	[ ]	Problem completely defined.
[X]	[ ]	[ ]	Accident scenarios developed in a clear and logical manner.
[X]	[ ]	[ ]	Necessary assumptions explicitly stated and supported.
[ ]	[ ]	[X]	Computer codes and data files documented.
[X]	[ ]	[ ]	Data used in calculations explicitly stated in document.
[X]	[ ]	[ ]	Data checked for consistency with original source information as applicable.
[X]	[ ]	[ ]	Mathematical derivations checked including dimensional consistency of results.
[X]	[ ]	[ ]	Models appropriate and used within range of validity or use outside range of established validity justified.
[X]	[ ]	[ ]	Hand calculations checked for errors. Spreadsheet results should be treated exactly the same as hand calculations.
[ ]	[ ]	[X]	Software input correct and consistent with document reviewed.
[ ]	[ ]	[X]	Software output consistent with input and with results reported in document reviewed.
[X]	[ ]	[ ]	Limits/criteria/guidelines applied to analysis results are appropriate and referenced. Limits/criteria/guidelines checked against references.
[X]	[ ]	[ ]	Safety margins consistent with good engineering practices.
[X]	[ ]	[ ]	Conclusions consistent with analytical results and applicable limits.
[X]	[ ]	[ ]	Results and conclusions address all points required in the problem statement.
[X]	[ ]	[ ]	Format consistent with applicable guides or other standards.
[ ]		[X] **	Review calculations, comments, and/or notes are attached.
[X]	[ ]	[ ]	Traceability
[X]	[ ]	[ ]	Document approved (for example, the reviewer affirms the technical accuracy of the document).

JAMES C WILLIAMS [signature] — 5/21/99
Reviewer (printed name and signature) — Date

* All "no" responses must be explained below or on an additional sheet.

** Any calculations, comments, or notes generated as part of this review should be signed, dated, and attached to this checklist. Such material should be labeled and recorded in such a manner as to be intelligible to a technically qualified third party.

FLUOR DANIEL NORTHWEST

TECHNICAL PEER REVIEWS

HEDOP REVIEW CHECKLIST

Document Reviewed:
Title: Calculation of Unmitigated Release from Reverse Circulation Drilling of a Borehole Three Meters South of Borehole 41-15-09 Near SST 241-SX-115
Author: David L. Scott
Date: May 21, 1999
Scope of Review: Entire Document

Yes	No*	NA		
[✓]	[ ]	[ ]	1.	A detailed technical review and approval of the environmental transport and dose calculation portion of the analysis has been performed and documented.
[✓]	[ ]	[ ]	2.	Detailed technical review(s) and approval(s) of scenario and release determinations have been performed and documented.
[ ]	[ ]	[✓]	3.	HEDOP-approved code(s) were used.
[ ]	[ ]	[✓]	4.	Receptor locations were selected according to HEDOP recommendations.
[ ]	[ ]	[✓]	5.	All applicable environmental pathways and code options were included and are appropriate for the calculations.
[✓]	[ ]	[ ]	6.	Hanford site data were used.
[✓]	[ ]	[ ]	7.	Model adjustments external to the computer program were justified and performed correctly.
[ ]	[ ]	[✓]	8.	The analysis is consistent with HEDOP recommendations.
[ ]	[ ]	[✓]	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.)
[✓]	[ ]	[ ]	10.	Approval is granted on behalf of the Hanford Environmental Dose Overview Panel.

* All "no" responses must be explained below or on an additional sheet.

Brit E Hey [signature] — 5/21/99

HEDOP-Approved Reviewer (printed name and signature) — Date

COMMENTS (add additional signed and dated page if necessary):

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Calculation of Unmitigated Release from Reverse Circulation Drilling of a Borehole 3 m South of Borehole 41-15-09 near SST 241-SX-115		EDT No. 619980
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