NUCLEAR GROUP

DOCTYPE 061

CALCULATION COVER SHEET

1. Calculation No. LM-526

Page 1

2. ☒ LGS ☐ PBAPS

3. UNIT(S) 1&2

4. MOD/NCR/ECR No.: N/A Other:

5. Responsible Branch: SEAQ

6. Last Page No: Att 7 pages 734

7. ☐ Safety Related ☒ Non-Safety Related

8. Description: Determine worst case radiological impacts of using solids, taken from cooling tower basins, Holding Pond, and Spray Pond, as fill

9. System/Topic No.: 069, 011, 012, 068, 102, 701, 911

Structure: N/A

Component: N/A

RECORD OF REVISIONS

10. Rev. No.	11. Description of Revision	12. Vendor Calc. Number	Rev.	13. Assumptions Yes	No	14. Signatures Preparer	Reviewer	Approver/Date
0	Original	N/A	0	X		P.T. Reichert (RNI)	(RNI)	11/6/95
1	Assess actual location, layer area, groundwater transport	N/A	1	X		P.T. Reichert (RNI)	RNI	5/24/95
2	Address impacts of NUREG/CR 6512 (10/92) and NUREG 1500 for Decommissioning Considerations	N/A	2	X		P.T. Reichert (RNI)	(RNI)	11/13/95

15. Related Calc. Numbers — Provides Info to: N/A

Receives Info from: N/A

16. ☐ Manual ☒ Computer

Computer program and version: GASPAR (mc-011) Rev. 0

17. Provides Info to UFSAR/Tech. Spec: NONE

18. Total Pages: (DS use)

CALC. # LM-526 REV. 2

DCD # N/A DATE: _____

CALCULATION REVIEW CHECKLIST

MANUAL CALC.	COMPUTER CALC.		YES or N/A
X	X	CALCULATION IS THE APPROPRIATE BASIS FOR THE ACTIVITY	yes
X	X	CALCULATION ASSUMPTIONS, CONSIDERATIONS, AND METHODOLOGY CONFORM TO APPLICABLE DESIGN REQUIREMENTS	yes
X	X	SOURCES OF DATA AND FORMULAS WERE REVIEWED AND VERIFIED TO BE CORRECT AND COMPLETE	yes
X	X	INPUT DATA IS CORRECT AND USED PROPERLY	yes
X		THE ANALYTICAL METHOD USED IN THE CALCULATION HAS BEEN CONSIDERED AND IS PROPER FOR THE INTENDED USE	—
X		MATHEMATICAL ACCURACY HAS BEEN CHECKED AND IS CORRECT (INDICATE METHOD USED)	—
		A) COMPLETE CHECK OF EACH COMPUTATION	—
		B) SPOT CHECK OF SELECTED COMPUTATIONS	—
		C) PERFORMANCE OF ALTERNATE OR APPROXIMATION CALCULATION (ATTECHED)	—
X	X	CALCULATION RESULTS WERE CHECKED AGAINST APPLICABLE DESIGN CRITERIA AND WERE FOUND TO BE IN COMPLIANCE	yes
X	X	EXISTING CALCULATIONS REQUIRING REVISION AS A RESULT OF THIS CALCULATION HAVE BEEN IDENTIFIED & DOCUMENTED	NONE
	X	THE ANALYTICAL METHODS DESCRIBED IN THE COMPUTER CALCULATION SUMMARY IS PROPER FOR THE INTENDED USE	yes
X	X	ALL SYSTEM AND TOPIC NUMBERS ASSOCIATED WITH THE CALCULATION ARE LISTED	yes
—	X	COMPUTATIONAL ACCURACY HAS BEEN CHECKED AND IS CORRECT (INDICATE METHOD USED)	yes
		A) CHECK SAMPLE CALCULATION USING DATA OTHER THAN THAT USED IN THE SAMPLE	—
		B) PERFORMANCE OF ALTERNATE OR APPROXIMATION CALCULATION (ATTACHED)	—
		C) DESCRIBE OTHER METHOD USED: Rev 2 entailed changes to selected spreadsheet calculations These were checked for accuracy using applicable equations given on pages 21 and 22	yes
	X	PROGRAM USED IS APPROPRIATE, INPUT IS VALID, AND OUTPUT IS REASONABLE CONSIDERING THE INPUT	yes
X	X	BASE CALCULATION HAS BEEN REVIEWED AGAINST CURRENT DRAWING REVISIONS AND POSTED DCDs TO IDENTIFY SIGNIFICANT DIFFERENCES	N/A

The criteria listed above are the minimum criteria to be considered and are not intended to limit the initiative of the reviewer to consider other criteria.

Attributes applicable to manual and computer calculations are noted by an "X" in the appropriate column.

List the documents used to support this review. Review of similar calculations formatted to Revision 2 changes, Attachment 2 "Divider, Deviant sections" & new references used in Rev 2

REVIEWED BY: [signature] (RNI) DATE: 11-10-95

Raytheon
Engineers & Constructors

GENERAL COMPUTATION SHEET

PROJECT: LIMERICK GENERATING STATION - UNITS 1 & 2 COOLING TOWER, HOLDING POND AND SPRAY POND

SUBJECT: DETERMINE WORST CASE RADIOLOGICAL IMPACTS OF USING SOLIDS, TAKEN FROM THE COOLING TOWER BASINS, HOLDING POND, AND SPRAY POND, AS FILL

CALCULATION SET NO.			REV.	COMP. BY	CHK'D. BY
LM-526					
PRELIM.	FINAL	VOID	2	PDR DATE 11/10/95	TSV DATE 11-10-95
	X				
SHEET 3 OF 22				DATE	DATE
J.O. 7198.600					

CALCULATION CHANGES IN REVISION 2 TO LM-526

1. NUREG/CR-5512, dated Jan. 1990 was used in Rev. 0 and Rev. 1 as a basis for:

   a. Resuspension rates above the solids fill area.

   b. Dose conversion factors to determine whether the planned placement of these solids is compatable with eventual plant decommissioning.

   ⚠2

   NUREG/CR-5512 (1/90) has been superceded by NUREG/CR-5512 (10/92). The newer version still provides a basis for resuspension rate assumptions. Dose conversion factors are now obtained from NUREG-1500 (8/94), which is the "Working Draft Regulatory Guide on Release Criteria for Decommissioning: NRC Staff's Draft for Comment", and from Federal Guidance Reports 11 and 12.

2. This calculation provides a conservative "Level 1" Screening, as described in NUREG-1500, of the proposed limits on solids activities. This is done to confirm that these solids, as placed, will not interfere with plant decommissioning. Only the worst case "Residential Use Scenario" is evaluated.

3. Revise design criteria to delete reference to the holding pond, which does not collect runoff from the placement area.

4. An intruder dose is calculated.

5. Raytheon Cover Sheets, no longer required by procedure, are deleted.

6. The Action Request (A/R) to assure that solids placement operations are within the calculation bases is identified. This A/R also requires confirmation of results when the final regulatory guide on release criteria for decommissioning is issued.

7. The following pages are added, revised, or deleted in Rev. 2.

PAGE	CHANGE
1-14	Revised, Renumbered, or Reformatted
17-19	Revised
21-22	Revised
Attachment 4, pgs 1-23	Replaced
Attachment 4, pgs 24-41	Deleted
Attachment 5, pgs 1-13	Replaced
Attachment 5, pgs 14-16	Deleted

Raytheon Engineers & Constructors

GENERAL COMPUTATION SHEET

PROJECT: LIMERICK GENERATING STATION - UNITS 1 & 2 COOLING TOWER, HOLDING POND AND SPRAY POND

SUBJECT: DETERMINE WORST CASE RADIOLOGICAL IMPACTS OF USING SOLIDS, TAKEN FROM THE COOLING TOWER BASINS, HOLDING POND, AND SPRAY POND, AS FILL

CALCULATION SET NO.			REV.	COMP. BY	CHK'D. BY
LM-526					
PRELIM.	FINAL	VOID	2	RPR DATE 11/10/95	TSN DATE 11-10-95
	X				
SHEET 4 OF 22				DATE	DATE
J.O. 7198.600					

1.0 PROBLEM STATEMENT / PURPOSE OR OBJECTIVE OF CALCULATION

This calculation supports the use of flowable solids taken from the LGS holding pond, cooling tower basins, and spray pond as onsite fill. This material will be monitored to confirm that any radioactivity concentrations are not greater than PECO defined Solids Activity Limits that are on the order of ten (10) times the Effluent Lower Limits of Detectability (LLD). This calculation determines worst case radiological impacts, if the flowable solids radioactivity concentrations were at the Solids Activity Limits.

Radiological impact considered are:

(1) Airborne concentrations and doses due to wind borne erosion of the flowable solids pile. These concentrations will be compared with 10CFR20 [Ref.1] limits, and doses compared with 10CFR50 [Ref. 2] limits. It is desirable that these concentrations and doses should be negligible compared with these limits, to support the use of the Solids Activity Limits as screening criteria.

(2) Groundwater transport of activity to the Schuylkill River. No consideration of groundwater transport to well locations is necessary, since all offsite and onsite wells are upgradient from the locations where this flowable solids may be placed.

(3) Evaluation of water caused erosion impacts.

(4) Worst case dose rate to workers directly over the flowable solids, due to direct shine and inhalation.

(5) Dose to an unauthorized intruder onto the solids fill area.

(6) Worst case dose rate for a hypothetical residential use of the flowable solids placement area. This data will provide an indication of the potential for free release of the areas where these flowable solids are used, after plant decommissioning.

(7) Offsite doses due to airborne releases for pathways other than inhalation.

2.0 SUMMARY OF RESULTS AND CONCLUSIONS

This calculation analyzes radiological impacts of a conservatively characterized system for using flowable solids as onsite fill. Radioactivity in solids to be placed onsite will be less than the Solids Activity Limits, as described in Attachment 1.

Wind caused airborne releases from the fill area can cause only a negligible contribution to offsite doses. The calculated inhalation dose commitment to an individual at the site boundary is 1.82E-4 mrem/yr. Doses to other pathways, modeled using GASPAR, are all at or below 0.101 mrem/yr, with a very conservative isotopic mix.

Worst case concentrations in releases from the solids to groundwater will be near (2.93 MPC) the regulatory limits for effluents, even if all isotopes are at the Solids Activity Limits. Concentrations of about 0.021 of the 10CFR20 Maximum Permissable Concentration (MPC) will result at the site boundary when credit for the transit time of 194 years [based on Sr-90] is taken. No onsite or offsite wells will be impacted.

Potential release concentrations due to erosion will be less than an MPC.

Raytheon Engineers & Constructors

GENERAL COMPUTATION SHEET

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PROJECT: LIMERICK GENERATING STATION - UNITS 1 & 2 COOLING TOWER, HOLDING POND AND SPRAY POND

SUBJECT: DETERMINE WORST CASE RADIOLOGICAL IMPACTS OF USING SOLIDS, TAKEN FROM THE COOLING TOWER BASINS, HOLDING POND, AND SPRAY POND, AS FILL

Dose rates to operators during handling this material will be far below 10CFR20 restricted area limits. Airborne activity will also be negligible.

A The dose to a postulated unauthorized intruder with 24 hours/yr occupancy on the solids fill area would be 0.75 mrem.

Placement of these conservatively characterized flowable solids as fill should not interfere with plant decommissioning and free release. Some decay time may be necessary, depending on actual activity levels.

3.0 DESIGN BASES / INPUT / CRITERIA

3.1 DESIGN BASES / INPUT

The design bases for this calculation are:

(1) The fill area size upper bound is 70,000 sq. ft., and 1,120,000 cu. ft.;

(2) Radioactivity concentrations will be controlled to the proposed Solids Activity Limits. [See Section 5.1.2, and Attachment 1 for limit derivation.]

2 (3) The groundwater transport calculation basis assumes that the solids are placed in one (1) foot thick layers covering 70,000 sq. ft. Solids place in thicker layers over smaller areas would reduce the diluting infiltering water. Therefore, placements should be evaluated to assure that:

$$\text{FRACTION OF THE LIMIT FOR THE WORST CASE ISOTOPE} * \frac{\text{VOLUME OF SOLIDS PLACEMENT } (ft^3)}{\text{PLACEMENT AREA } (ft^2)}$$

is less than one (1).

(4) The area for solids placement will be located down-gradient from any offsite well, or onsite well used for other than groundwater sampling.

A/R A0970339 has been initiated to ensure that the above design bases are incorporated into appropriate PECO's programs and/or procedures.

3.2 DESIGN CRITERIA

(1) Doses to onsite personnel from any radioactivity in the flowable solids shall be within 10CFR20 limits and ALARA.

(2) Offsite airborne concentrations due to dusting from the flowable solids fill area shall be a very small fraction of 10CFR20 unrestricted area concentrations.

(3) Offsite doses due to dusting from the flowable solids area shall be a very small fraction of doses resulting from other sources at LGS.

(4) Groundwater concentrations, due to any radioactivity transport from the flowable solids, shall be less than 10CFR20, Appendix B limits, upon discharge to the Schuylkill River.

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GENERAL COMPUTATION SHEET

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PROJECT: LIMERICK GENERATING STATION - UNITS 1 & 2 COOLING TOWER, HOLDING POND AND SPRAY POND

SUBJECT: DETERMINE WORST CASE RADIOLOGICAL IMPACTS OF USING SOLIDS, TAKEN FROM THE COOLING TOWER BASINS, HOLDING POND, AND SPRAY POND, AS FILL

(2) (5) Activity in stormwater runoff shall have radioactivity concentration levels less than 10CFR20, Appendix B limits, upon discharge to the Schuylkill River.

(6) It is preferable that the flowable solids not require any additional handling upon LGS decommissioning, to allow free release of the flowable solids use area. Free release criteria published in the USNRC proposed rule on Radiological Criteria for Decommissioning [Ref. 3] shall be used in this determination.

4.0 ASSUMPTIONS / UNVERIFIED ASSUMPTIONS

4.1 ASSUMPTIONS

(2) (1) The total flowable solids removal rate is conservatively set at 70,000 ft^3 per year. A total of 16 placements are assumed for a total of 1,120,000 ft^3. This total allowance for the remaining 30 years of plant life is approximately 10 times the solids removed over the first 10 years of plant life. The compressed schedule of placement is used to maximize the calculated groundwater effects and to minimize potential that bases for this calculation could delay solids placement. See Section 5.1.1 for discussion of historical solids removal.

(2) These solids are unlikely to be spread over more than 70,000 ft^2 (1.61 acres). [See Section 3.1 & 5.1.3.] PTR 11/13/95 QA 11/13/95

4.2 UNVERIFIED ASSUMPTIONS

(2) The Dose Conversion Factors taken from NUREG-1500 should be verified as still accurate once the final regulatory guide on release criteria for decommissioning is issued. A/R A0970339 has been initiated to ensure that this verification is done.

5.0 DETAILS OF CALCULATIONS

5.1 MATERIALS HANDLED

5.1.1 FLOWABLE SOLIDS REMOVAL RATES

Flowable solids may be taken from the cooling tower basins, the holding pond, and the spray pond. Discussion with PECO personnel provided historical solids generation data, as discussed below.

(2) The most recent operation (1994) on the holding pond yielded 7,900 cu. ft. of material. This operation is expected to occur every three years.

(2) The cooling tower basins are expected to be the dominant source of material. The only historical operation on a cooling tower basin (Unit 1, 1991) yielded 68,000 cubic feet of dewatered sludge. Another cleaning may be required in 1998. The Unit 2 cooling tower appears less prone to flowable solids buildup and has never required cleaning.

The spray pond has not yet required flowable solids removal. The spray pond has a design margin of 3 inches of flowable solids, displacing 0.68 million gallons of water [UFSAR, Section 9.2.6.4.2.5]. Thus, if cleaning were ever required, and the entire margin were to be restored, approximately 91,000 cu. ft. of material would be removed.

For this analysis an enveloping assumption of 70,000 cubic feet of total material in each placement. To minimize the potential that the calculation could cause a delay in material placement, this amount is assumed to be deposited each year, for 16 years. This compressed schedule maximizes calculated concentrations in groundwater. The total assumed placement would be 1,120,000 cubic feet, which is more than 10 times that historically observed over the first 10 years of plant life. These values are expected to envelope any cooling tower and holding pond requirements. This is also a more realistic amount for a spray pond cleaning operation.

5.1.2 WORST CASE RADIOACTIVITY CONTENT

Little or no radioactivity has been found in these flowable solids in the past, and they have been disposed of as non-radioactive, non-hazardous wastes. To establish a conservative estimate of the amounts and isotopic breakdowns of the postulated radioactive material dispersed within the flowable solids, Table 1 was developed. This table shows (1) Solids Activity Limits which would be used as a screening criteria, for a range of isotopes which have been found in various plant process fluids and waste streams; and (2) the 10CFR20, Appendix B limits on effluent concentrations in air and water.

5.1.3 LOCATION AND LAYOUT FOR MATERIAL PLACEMENT

The location for the placement of this material has been selected to be in an area of approximately 1.5 acres in size and is to the northwest of the spray pond and southeast of the meteorology tower No. 1. For this analysis, the material is assumed to be spread over an area of not greater than 70,000 sq. ft. (1.61 acres).

5.2 POTENTIAL AIRBORNE RELEASES TO OFFSITE AREAS

5.2.1 AIRBORNE RELEASE MECHANISMS FROM FLOWABLE SOLIDS FILL AREA

Any airborne releases from the flowable solids fill area are expected to be due to wind caused dusting of this material. Attachment 2, taken from Reference 6, describes the physical processes involved, and the methods of assessment performed by the USNRC for uranium milling tailing piles.

Additionally, Ref. 7 indicates that an air dust loading of 10^{-4} gm/cu. meter can be used for airborne activity above the contaminated soil under normal dusty conditions. A loading of 5×10^{-4} gm/cu. meter can be used for soil being worked, such as might be the case for grading, or residential use gardening.

5.2.2 OFFSITE AIRBORNE CONCENTRATIONS AND INHALATION DOSES

Table 1A shows the resulting inhalation dose rate to an individual at the nearest site boundary to the solids fill, to be 1.82×10^{-4} mrem/yr, based on the above normal dust loading.

The inhalation dose rate above the fill is low enough to be considered a negligible contribution to offsite dose rates resulting from other LGS activities.

5.2.3 OFFSITE DOSES DUE TO INGESTION PATHWAYS

Attachment 7 is a GASPAR run output, calculating doses due to various ingestion pathways. X/Q values are based on several factors. Releases are assumed to be 370 gm/yr/sq. meter, conservatively based on uranium mill tailing analyses from Reference 6, and shown in Attachment 2, page 6. This yields a release of 2.406×10^{6} gm/yr, or 0.07625 gm/sec. [See Table 1B.]

Using the 10^{-4} gm/cu. meter normal dust loading, a X/Q of 1.312×10^{-3} sec/cu. meter is calculated. As shown in Table 1A, additional credit can be taken for wind direction frequency toward a location on the nearest site boundary, and for the additional lateral dispersion. No credit is taken for vertical dispersion or for any deposition effects in route to the site boundary. The X/Q is therefore adjusted by 0.103 to account for wind frequency and 0.68 for lateral dispersion, yielding an net X/Q of 9.189×10^{-5}.

Default pathway parameters are used and are conservative for the LGS site.

Doses from the GASPAR analysis in no case exceed 0.101 mrem/yr, and are extremely conservative.

5.3 RELEASES THROUGH GROUNDWATER

5.3.1 BEHAVIOR OF GROUNDWATER RELEASES

No consideration of groundwater transport to well locations is necessary, since all offsite and onsite wells are up-gradient from the location where these flowable solids may be placed. Only consideration of groundwater transport to the Schuylkill River is needed.

Removal of any radioactivity from the flowable solids fill to groundwater is the result of radionuclide leaching from the contaminated zone. The leached radioactivity is assumed to be carried by the infiltered water. Attachment 3 [Ref. 8], Equation E.4, is used to determine the infiltration rate. The annual average precipitation rate [P_r] used is from UFSAR Table 2.3.1.4, and is 43.9 inches of water. This would be 1.12 m/yr. The standard evapotranspiration and runoff coefficients [C_a and C_r] were used. No irrigation was assumed. The resulting infiltration rate is 0.448 m/yr. Over the 70,000 ft^2 fill surface, this provided a water flow of 2.91E+09 ml/yr.

Attachment 3, taken from Ref. 8, also provides a basis for assessing this leaching phenomena. Table 2A shows the derivation of leach rates from the solids.

Tabie 2B shows the ratio of the resulting concentration to 10CFR20, Appendix B Effluent Limits. Assuming that all material placements, for all isotopes, are at the Solids Activity Limits, the calculated releases to underlying groundwater is 2.93 MPC.

To determine the groundwater transport time the same methodology was used as was applied to radwaste tank spillages in UFSAR Section 2.4.13. The information below shows the application for both the radwaste tank and the solids area.

DETERMINATION OF ISOTOPE TRANSPORT TIME TO SCHUYLKILL RIVER FOR GROUNDWATER BORNE ACTIVITY:

130 Groundwater Elevation below Tank (ft) [UFSAR Analysis]
240 Groundwater Elevation below Solids Placement Area (ft) [UFSAR Fig. 2.4-15]
800 Tank Distance to River (ft.) [UFSAR Analysis]
1000 Solids Placement Area Distance to River (ft.) [UFSAR Figure 2.4-1]
105 Average River Elevation (ft.) [UFSAR Analysis]
390 Permeability of underlying material (ft/yr) [UFSAR Analysis]

	gradient	groundwater velocity (ft/yr)	groundwater travel time (yrs)	Sr-90 travel time (yrs)
Tank	0.03125	243.75	3.28	671
Solids	0.135	1053	0.950	194

As shown in Table 2B, it is expected that the additional decay in transit from below the fill area to the Schuylkill River will be sufficient to assure that discharges of groundwater would meet these limits.

It should also be noted that this groundwater flow of 2.91E+09 ml/yr will be diluted by an average of 1.60E+15 ml/yr of river flow (UFSAR Pg. 2.4-2, 1793 cfs * 3.16E+07 sec/yr *2.83E+04 ml/ft^3), for an average concentration reduction of 1.8E-06.

For the above reasons, the Groundwater pathway from the flowable solids is considered negligible.

5.4 RELEASES THROUGH EROSION

5.4.1 NORMAL RAINFALL CONDITIONS

The fill area is expected to be graded and seeded to minimize erosion. Erosion control fencing will also be used as appropriate.

For worst case evaluation purposes, erosion by way of runoff will contain one (1) percent by weight solids. A runoff coefficient of 0.2 is used, consistent with the groundwater assessment above. With the 1.12 m/yr precipitation rate, and a 6503 sq. m. area, the total water runoff would be 1.46E+09 ml/yr. Using the worst case 1 percent solid as a conservative upper bound, 1.46E+07 gm/yr of the fill material would be eroded. Note that this solids loading (10,000 ppm) is on the order of 100 times that typically in estuaries such as the Delaware [Ref 9].

For further illustration purposes, this erosion rate would yield a loss of about 0.38 percent of the nominal 70,000 ft^3 fill load each year, or about 1.2 mm average surface loss. Reference 9 estimates of soil loss for the Delaware River basin averages approximately 50 metric tonnes/sq. km, or only about 0.025 mm. The Schuylkill River Basin would be expected to be comparable.

A 1 percent slurry will yield a combined radionuclide concentration within 10CFR20, Appendix B limits, as shown in Table 6.

Given the demonstrated conservatism of runoff loading assumptions, and the resulting acceptability of calculated doses, the standard erosion control measures described above should be ample to assure that regulatory limits are not exceeded.

5.4.2 PROBABLE MAXIMUM PRECIPITATION (PMP) CONDITIONS

UFSAR Table 2.4-7 indicates that the initial 6 hour PMP is 26.8 inches of rainfall. Under PMP conditions, virtually all of this rainfall will run off.

The PMP rainfall 3 times the normal 8.8 inches (1.12 meters/yr * 0.2 runoff coef. * 39.4 in./meter) of rainfall runoff that was calculated to "run off with 1 percent" of the nominal fill load over a three year period as described in Section 5.4.1 above. Thus, concentrations leaving the fill area would be no

worse than the condition shown in Table 6, unless significantly more erosion occured. Additionally, this conclusion considers dilution only by rainfall falling directly on the 1.61 acre fill area. Runoff can be expected to actually mix with and be diluted by runoff from surrounding areas before discharging beyond the site boundary. The total site area is 595 acres. Therefore, for this severe event, average discharge concentrations, even with severe erosion, would be unlikely to exceed 10CFR20 Effluent Limits.

5.5 OCCUPATIONAL DOSE RATES DURING MATERIAL HANDLING

Table 3 shows external exposure dose rates for contact with the flowable solids fill, modeled as a semi-infinite slab. Also shown are calculated doses due to inhalation, based on suspended airborne activity commensurate with this material being worked.

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The worst case external exposure dose rate is less than 0.031 mrem/hr, and therefore this would not be considered a radiation area. The inhalation dose rates are such that respiratory protection would not be required.

5.6 DOSES TO AN INTRUDER

For the duration of the LGS license, the property containing the solids will remain under PECO control, and will be posted. This location is not in a frequently traveled area and an intruder is likely to be noticed in routine security patrols that cover the site. The dose to an intruder is conservatively determined by assuming that 8 hours is spent directly on the solids placement area, on three occasions in a year. The resulting dose would be 0.75 mrem.

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Radiological impact to an intruder, after the LGS decommissioning is enveloped by consideration of the residential use as described below.

5.7 RESIDENTIAL USE DOSE ASSESSMENTS

An additional concern with the use of flowable solids, is whether this material might require additional handling during plant decommissioning and eventual site free release. In order to determine this a "Level 1" screening of the activity limits is performed, as defined in NUREG-1500 [Ref. 10]. The worst case assumption is a residential use of the solids placement area. The evaluation determines dose rates as a function of time after shutdown and compares them with the 15 mrem/yr criterion for decommissioning. Dose conversion factors are from NUREG-1500, which implements the methodology described in NUREG/CR-5512 "Residual Radioactive Contamination from Decommissioning" [Ref. 7]. Relevant portions of these references are in Attachment 7.

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The limiting exposure scenario of residential use includes doses from:

2

(1) External gamma shine to resident, both inside and outside of the residence;

(2) Inhalation doses;

(3) Food ingestion from garden grown in this soil.

The doses from the surface soil scenario are given in Table 4, and are controlled by the last material deposit. The design criteria for free release is taken from Ref. 3, and requires that doses be less that 15 mrem/yr and ALARA below that level. Table 4 shows that, within 10 years of the last placement of material, the solids placement area would meet the residential use screening criterion.

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Raytheon Engineers & Constructors

GENERAL COMPUTATION SHEET

CALCULATION SET NO.			REV.	COMP. BY	CHK'D. BY
LM-526					
PRELIM.	FINAL	VOID	2	DATE 11/10/95	DATE 11-10-95
	X				
SHEET 11 OF 22				DATE	DATE
J.O. 7198.600					

PROJECT: LIMERICK GENERATING STATION - UNITS 1 & 2 COOLING TOWER, HOLDING POND AND SPRAY POND

SUBJECT: DETERMINE WORST CASE RADIOLOGICAL IMPACTS OF USING SOLIDS, TAKEN FROM THE COOLING TOWER BASINS, HOLDING POND, AND SPRAY POND, AS FILL

Use of this material as onsite fill is not expected to interfere with free release of the site, after plant decommissioning. This is because:

(1) Even with very conservative activity assumptions, the dose rates would be within decommissioning criteria within 10 years;

(2) The residual radioactivity is likely to be substantially less;

(3) The material in its final configuration will be easily surveyed and evaluated to confirm its acceptability for free release.

(4) Free release of this site within 10 years of shutdown is unlikely, given reasonably expected decommissioning schedules.

(5) This property is likely to have considerable value to PECO, even after shutdown, given available transmission and other facilities. Transfer of this property for residential use in any time frame of concern is unlikely.

The more likely scenario would be that the site would remain PECO property, in a free-release configuration, and requiring little or no maintenance. Doses to PECO employee would likely be on the order of the doses assessed for an intruder (< 1 mrem/yr), particularly with consideration of decay in place.

Impacts of PECO use of the free released site for a structure would be enveloped by the residential use scenario, since occupancy would be less than for a residence.

6.0 REFERENCES

(1) 10CFR20, "Standards for Protection Against Radiation", Appendix B.

(2) 10CFR50, Appendix I.

(3) USNRC Proposed Rule on Radiological Criteria for Decommissioning (Federal Register, Vol 59, pages 43200-43232, August 22, 1994.

(4) PECO supplied estimates of material taken from holding pond and cooling tower.

(5) LGS UFSAR, Current as of 11/01/94, as indicated in calculation text.

(6) NUREG-0706, "Final Generic Environmental Impact Statement on Uranium Milling", Volume III, Appendix G, Pages G-7 to G-11, Sept, 1980

(7) NUREG/CR-5512, "Residual Radioactive Contamination from Decommissioning" Vol. 1, Oct. 1992.

(8) ANL/EAD/LD-2, "Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD, Version 5.0", September 1993.

(9) Ecology and Restoration of the Delaware River Basin, Pennsylvania Academy of Sciences, 1988

(10) NUREG-1500, "Working Draft Regulatory Guide on Release Criteria for Decommissioning: NRC Staff's Draft for Comment", August 1994.

(11) Federal Guidance Report No. 11, "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion", 1988.

(12) Federal Guidance Report No. 12, "External Exposure to Radionuclides in Air, Water, and Soil", 1993.

7.0 LIST OF ATTACHMENTS

(1) PECO Provided Effluent LLD and Solids Activity Limits Derivations

(2) Reference 6.

(3) Appendix E, "Water Pathway Factors", of Reference 8.

(4) Portions of References 7 and 10 used in this calculation.

(5) Portions of 10CFR20, Appendix B.

(6) Computer Disclosure Sheet and Spreadsheet Verification

(7) GASPAR Run Output

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PROJECT: LIMERICK GENERATING STATION - UNITS 1 & 2 COOLING TOWER, HOLDING POND AND SPRAY POND

SUBJECT: DETERMINE WORST CASE RADIOLOGICAL IMPACTS OF USING SOLIDS, TAKEN FROM THE COOLING TOWER BASINS, HOLDING POND, AND SPRAY POND, AS FILL

TABLE 1A - ASSESSMENT OF INHALATION DOSE RATE ABOVE SOIL TAKEN FROM COOLING TOWER BASINS, SPRAY POND, & SETTLING POND, ASSUMING ALL ISOTOPES ARE AT THE SOLIDS ACTIVITY LIMIT

Nuclide	Solids Activity Limits uCi/g(dry)	10CFR20 App. B Limits Air uCi/ml	# Fraction of Air Limit	@ Annual Dose (TEDE) mrem
Fe-55	1E-05	3E-09	3.3E-07	1.7E-05
Mn-54	5E-06	1E-09	5.0E-07	2.5E-05
Co-58	5E-06	1E-09	5.0E-07	2.5E-05
Fe-59	5E-06	5E-10	1.0E-06	5.0E-05
Co-60	5E-06	5E-11	1.0E-05	5.0E-04
Zn-65	5E-06	4E-10	1.3E-06	6.3E-05
Sr-89	5E-07	2E-10	2.5E-07	1.3E-05
Sr-90	5E-07	6E-12	8.3E-06	4.2E-04
Mo-99	5E-06	2E-09	2.5E-07	1.3E-05
Cs-134	5E-06	2E-10	2.5E-06	1.3E-04
Cs-137	5E-06	2E-10	2.5E-06	1.3E-04
Ce-141	5E-06	8E-10	6.3E-07	3.1E-05
Ce-144	5E-06	2E-11	2.5E-05	1.3E-03
			5.3E-05	2.7E-03

2

Assuming airborne dust loading of 1.0E-04 g/cu. meter, for dusty outside conditions, per NUREG/CR-5512.

@ Given that the 10CFR20 concentration limits are those projected to yield 50 mrem/yr effective dose equivalent, the air total should correspond to an annual dose commitment of 2.7E-03 mrem/yr.

2

To credit dispersion to the site boundary the placement area is treated as having a lateral extent of no greater than 100 meters. A virtual source is then determined such that a single 22.5 degree sector would encompass the source. This virtual source would be at 250 meters back from the distributed source. The nearest site boundary to the placement area is approximately 400 ft, (120 M) from the placement area in between the ENE and NNE directions. At this distance winds from the SW and 1/2 of the SSW & WSW Sectors could cross the placement area and impact a receiver at the boundary. Based on UFSAR Table 2.3.2-2, the total wind frequency would be 0.047+0.5*(0.060+0.051) = 0.103. Therefore the dose above the placement area can be adjusted to account for wind frequency and also, additional lateral dispersion [250 / (120 + 250) = 0.68]. The resulting calculated annual dose [TEDE] is 2.6E-03 * 0.103 * 0.68 = 1.82E-04 mrem.

2

TABLE 1B - IDENTIFICATION OF AIRBORNE RELEASES

370 = (gm/m^2-yr) MASS AREAL RELEASE RATE

6503.2128 = AREA OF STORAGE (m^2)

2.41E+06 = MASS RELEASE RATE (GM/YR)

Nuclide	Solids Activity Limits uCi/g(dry)	Annual Release (Ci)	
Fe-55	1E-05	2.4E-05	
Mn-54	5E-06	1.2E-05	
Co-58	5E-06	1.2E-05	
Fe-59	5E-06	1.2E-05	
Co-60	5E-06	1.2E-05	
Zn-65	5E-06	1.2E-05	
Sr-89	5E-07	1.2E-06	
Sr-90	5E-07	1.2E-06	
Mo-99	5E-06	1.2E-05	
Cs-134	5E-06	1.2E-05	
Cs-137	5E-06	1.2E-05	
Ce-141	5E-06	1.2E-05	
Ce-144	5E-06	1.2E-05	

Areal release rate is that calculated in the Final Environmental Impact Statement on Uranium Milling. [NUREG-0706] and is considered conservative compared to this application.

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PROJECT: LIMERICK GENERATING STATION - UNITS 1 & 2 COOLING TOWER, HOLDING POND AND SPRAY POND

SUBJECT: DETERMINE WORST CASE RADIOLOGICAL IMPACTS OF USING SOLIDS, TAKEN FROM THE COOLING TOWER BASINS, HOLDING POND, AND SPRAY POND, AS FILL

TABLE 2A

APPLICATION OF ATTACHMENT 3, EQUATIONS E.3 - E.8 TO DETERMINE WORST CASE LEACH RATES

0.448 = Infiltration Rate (m/yr)

0.3048 = initial thickness of contamination zone (m)

2.25 = contaminated material nominal bulk density (gm/ml)

	Tbl. E.2 K sat	Tbl. E.2 THETA sat	Tbl. E.2 b	Eq. E.7 R sat	Eq. E.6 Theta (cz)	
Sand	5.55E+03	0.395	4.05	0.428	0.169	used below
Loamy sand	4.93E+03	0.410	4.38	0.453	0.186	
Sandy loam	1.09E+03	0.435	4.90	0.544	0.237	
Silty loam	2.27E+02	0.485	5.30	0.633	0.307	
Loam	2.19E+02	0.451	5.39	0.638	0.288	
Sandy clay loam	1.99E+02	0.420	7.12	0.702	0.295	
Silty clay loam	5.36E+01	0.477	7.75	0.772	0.368	
Clay loam	7.73E+01	0.476	8.52	0.773	0.368	
Sandy clay	6.84E+01	0.426	10.40	0.810	0.345	
Silty clay	3.26E+01	0.492	10.40	0.835	0.411	
Clay	4.05E+01	0.482	11.40	0.840	0.405	used below

Retardation Factor Determination for Elements of Interest

Element	Table E.3 K d (sand) (ml/g)	Table E.3 K d (clay) (ml/g)	Eq. E.8 R di (sand)	Eq. E.8 R di (clay)	Eq. E.3 L i (sand) (yr^-1)	Eq. E.3 L i (clay) (yr^-1)
Fe	100	1000	1332	5559	6.5E-03	6.5E-04
Mn	20	200	267	1113	3.3E-02	3.3E-03
Co	100	1000	1332	5559	6.5E-03	6.5E-04
Zn	2	20	28	112	3.1E-01	3.2E-02
Sr	3	30	41	168	2.1E-01	2.2E-02
Zr	100	1000	1332	5559	6.5E-03	6.5E-04
Cs	80	500	1066	2780	8.2E-03	1.3E-03
Ce	100	1000	1332	5559	6.5E-03	6.5E-04

Regarding flowable solids densities, the ground below the site is described in the UFSAR, Table 2.4-20, as having a bulk density of 2.65 gm/ml and a 0.05 porosity. The flowable solids are assumed to be similar material, except with a porosity of 0.3. This porosity is identified in Ref. 7, Page B.12, as a value applicable to only partially compacted soils. This value is used for the Ref. 7 waste/soil mixtures in drinking water scenario assessments. The resulting bulk densities for the flowable solids would be 1.95 gm/ml (totally dry), and 2.25 gm/ml (saturated).

TABLE 2B ASSESSMENT OF GROUNDWATER INGESTION DOSE RATE, ASSUMING ACTIVITY IS RELEASED FROM THE CONTAMINATED ZONE TO GROUNDWATER BASED ON APPLICABLE LEACH RATES, WITH CREDIT FOR DECAY, AND MIXED IN THE EXPECTED PRECIPITATION INFILTRATION. SIXTEEN LOADS ARE ASSUMED, WITH CREDIT FOR LOSSES BY DECAY AND LEACHING, UNTIL THE LAST LOAD IS PLACED.

1.95	- Nominal flowable solids density (gm/cc)
70,000	- Volume and Area of solids deposited every year (cu. ft. & sq. ft.)
1.98E+09	- Volume of solids deposited every year (ml)
6.50E+07	- Area of solids deposited (sq. cm.)
0.448	- Infiltration Rate (meters/yr)
2.91E+09	- Total Infiltration (ml/yr)

Nuclide	Solids Activity Limits uCi/g(dry)	Activity Loss Rates: Leach Rate (yr-1) *	Activity Loss Rates: Half Life (yr)	Decay + Leach Constant (-yr-1)	Activity at Placement (uCi)	Activity After 16 Placements (uCi)	10CFR20 APP. B Water uCi/ml	Release from Solids to Groundwater Fraction of Water Limit	Percent of MPC Total	Fraction of Water Limit with 194 yr of decay
Fe-55	1E-05	6.5E-03	2.7	-2.63E-01	3.9E+04	1.65E+05	1E-04	3.67E-03	0.13%	8.6E-25
Mn-54	5E-06	3.3E-02	0.856	-8.43E-01	1.9E+04	3.39E+04	3E-05	1.28E-02	0.44%	7.6E-71
Co-58	5E-06	6.5E-03	0.194	-3.58E+00	1.9E+04	1.99E+04	2E-05	2.22E-03	0.08%	2.1E-304
Fe-59	5E-06	6.5E-03	0.122	-5.69E+00	1.9E+04	1.94E+04	1E-05	4.33E-03	0.15%	0.0E+00
Co-60	5E-06	6.5E-03	5.27	-1.38E-01	1.9E+04	1.33E+05	3E-06	9.92E-02	3.38%	8.2E-13
Zn-65	5E-06	3.1E-01	0.688	-1.32E+00	1.9E+04	2.64E+04	5E-06	5.62E-01	19.15%	7.3E-86
Sr-89	5E-07	2.1E-01	0.138	-5.23E+00	1.9E+03	1.94E+03	8E-06	1.75E-02	0.60%	0.0E+00
Sr-90	5E-07	2.1E-01	29.12	-2.34E-01	1.9E+03	9.05E+03	5E-07	1.30E+00	44.49%	1.3E-02
Cs-134	5E-06	8.2E-03	2.06	-3.45E-01	1.9E+04	6.60E+04	9E-07	2.06E-01	7.04%	9.2E-30
Cs-137	5E-06	8.2E-03	30	-3.13E-02	1.9E+04	2.47E+05	1E-06	6.95E-01	23.71%	7.9E-03
Ce-141	5E-06	6.2E-03	0.089	-7.79E+00	1.9E+04	1.93E+04	3E-05	1.37E-03	0.05%	0.0E+00
Ce-144	5E-06	6.2E-03	0.778	-8.97E-01	1.9E+04	3.26E+04	3E-06	2.31E-02	0.79%	2.0E-77
							TOTAL MPC	2.93		0.021

* Worst case sand leach rate from Table 2A.

SUMMARY OF RESULTS Even with no credit for decay in transit to the site boundary, the activity level leaving the accumulated solids will only be 2.93 MPC. I-65, Sr-90, and Cs-137 dominated at this point in time.
Based on the calculated transit time to the Schuylkill River of 194 years, the activity at release would be 0.021 MPCs.
At this point in time the activity would be dominated by Sr-90. Cs-137, though shown above as making a noticable contribution at the River, will likely have a much longer transit time than Sr-90, and thus a lower impact.

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PROJECT: LIMERICK GENERATING STATION - UNITS 1 & 2 COOLING TOWER, HOLDING POND AND SPRAY POND

SUBJECT: DETERMINE WORST CASE RADIOLOGICAL IMPACTS OF USING SOLIDS, TAKEN FROM THE COOLING TOWER BASINS, HOLDING POND, AND SPRAY POND, AS FILL

TABLE 3 - ASSESSMENT OF DOSE RATE ABOVE SOIL TAKEN FROM THE LGS COOLING TOWER BASIN, SPRAY POND, & HOLDING POND, ASSUMING THAT ALL ISOTOPES ARE AT SOLIDS ACTIVITY LIMIT ** [OCCUPATIONAL DOSE ASSESSMENT]

Nuclide	Solids Activity Limits uCi/g(dry)	*	External Dose Rate mrem/hr	#	Inhalation Dose Rate mrem/hr
Fe-55	1E-05	0.00E+00	0.0E+00	7.26E-10	1.6E-08
Mn-54	5E-06	2.76E-17	3.0E-03	1.81E-09	2.0E-08
Co-58	5E-06	3.19E-17	3.5E-03	2.94E-09	3.3E-08
Fe-59	5E-06	4.09E-17	4.4E-03	4.00E-09	4.4E-08
Co-60	5E-06	8.68E-17	9.4E-03	5.91E-08	6.6E-07
Zn-65	5E-06	1.98E-17	2.1E-03	5.51E-09	6.1E-08
Sr-89	5E-07	4.86E-20	5.3E-07	1.12E-08	1.2E-08
Sr-90	5E-07	3.77E-21	4.1E-08	3.51E-07	3.9E-07
Mo-99	5E-06	4.75E-18	5.1E-04	1.07E-09	1.2E-08
Cs-134	5E-06	5.07E-17	5.5E-03	1.25E-08	1.4E-07
Cs-137	5E-06	1.83E-17 @	2.0E-03	8.63E-09	9.6E-08
Ce-141	5E-06	1.70E-18	1.8E-04	2.42E-09	2.7E-08
Ce-144	5E-06	3.84E-19	4.2E-05	1.01E-07	1.1E-06
		Total =	3.1E-02	Total =	2.6E-06

\# Inhalation Committed Effective Dose Conversion Factors from FGR Report 11 [Ref. 11], Table 2.1. (Sv/Bq inhaled) (use highest effective value (from D,W,Y class)

Dose assumes dust loading over pile of 5E-4 gm/cu. meter. This corresponds to conditions where soil is being worked.

* Soil Volume Source External Dose Rate Conversion Factors from FGR Report 12 [Ref. 12] Table III.7 for soil contaminated to an infinite depth. (Sv/sec per Bq/m^3)

@ Uses daughter product Ba-137m (95% yield) conversion factor.

** See page 22 for formulae

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PROJECT: LIMERICK GENERATING STATION - UNITS 1 & 2 COOLING TOWER, HOLDING POND AND SPRAY POND

SUBJECT: DETERMINE WORST CASE RADIOLOGICAL IMPACTS OF USING SOLIDS, TAKEN FROM THE COOLING TOWER BASINS, HOLDING POND, AND SPRAY POND, AS FILL

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TABLE 4 - RESIDENTIAL (SURFACE SOIL) SCENARIO WITH CREDIT FOR DECAY*

Nuclide	Solids Activity Limits uCi/g(dry)	T 1/2 (yrs)	Soil Conc. (pCi/g) @ 15 mrem/yr Residential Scenario#	Residential Use Doses (mrem/yr) # Decay Time 0 (yrs)	10 (yrs)	20 (yrs)	30 (yrs)
Fe-55	1E-05	2.7	1.11E+04	1.4E-02	1.0E-03	8.0E-05	6.1E-06
Mn-54	5E-06	0.856	1.22E+01	6.1E+00	1.9E-03	5.7E-07	1.7E-10
Co-58	5E-06	0.194	2.57E+01	2.9E+00	8.9E-16	2.7E-31	8.2E-47
Fe-59	5E-06	0.122	3.20E+01	2.3E+00	5.0E-25	1.0E-49	2.2E-74
Co-60	5E-06	5.27	2.97E+00	2.5E+01	6.8E+00	1.8E+00	4.9E-01
Zn-65	5E-06	0.688	1.22E+01	6.1E+00	2.6E-04	1.1E-08	4.6E-13
Sr-89	5E-07	0.138	2.54E+03	3.0E-03	4.5E-25	7.0E-47	1.1E-68
Sr-90	5E-07	29.12	1.14E+01	6.6E-01	5.2E-01	4.1E-01	3.2E-01
Mo/Tc-99	1.8E-13	2.13E+05	5.24E+01	5.2E-08	5.2E-08	5.2E-08	5.2E-08
Cs-134	5E-06	2.06	4.90E+00	1.5E+01	5.3E-01	1.8E-02	6.3E-04
Cs-137	5E-06	30	1.07E+01	7.0E+00	5.6E+00	4.4E+00	3.5E+00
Ce-141	5E-06	0.089	8.81E+02	8.5E-02	1.3E-35	1.9E-69	2.9E-103
Ce-144	5E-06	0.778	1.52E+02	4.9E-01	6.7E-05	9.0E-09	1.2E-12
			Totals =	66	13	6.7	4.3

Based on Dose Equivalance Factors for Residential Use (Surface Soil) Scenario supplied in NUREG-1500, Table B-2.

For this scenario, the Mo-99 (measured to LLD) is assumed to have been completely converted to Tc-99 for dose purposes.

* see page 22 for formulae

JCS 11/13/95

RTR 11/13/95

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PROJECT: LIMERICK GENERATING STATION - UNITS 1 & 2
COOLING TOWER, HOLDING POND AND SPRAY POND

SUBJECT: DETERMINE WORST CASE RADIOLOGICAL IMPACTS OF USING SOLIDS, TAKEN FROM THE COOLING TOWER BASINS, HOLDING POND, AND SPRAY POND, AS FILL

TABLE 5 is Deleted in Rev. 2,
since Residential Use Scenario is more
limiting than a Drinking Water Scenario

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PROJECT: LIMERICK GENERATING STATION - UNITS 1 & 2 COOLING TOWER, HOLDING POND AND SPRAY POND

SUBJECT: DETERMINE WORST CASE RADIOLOGICAL IMPACTS OF USING SOLIDS, TAKEN FROM THE COOLING TOWER BASINS, HOLDING POND, AND SPRAY POND, AS FILL

TABLE 6 - RUNOFF BORNE RADIOACTIVITY CONCENTRATIONS

1.46E+07 = SOLIDS IN RUNOFF (gm/yr)

1.46E+09 = RUNOFF (ml/yr)

Nuclide	Solids Activity Limits uCi/g(dry)	10CFR20 APP. B Water uCi/ml	Runoff Activity Conc. uCi/ml	Fraction of Limit
Fe-55	1E-05	1E-04	1.0E-07	1.0E-03
Mn-54	5E-06	3E-05	5.0E-08	1.7E-03
Co-58	5E-06	2E-05	5.0E-08	2.5E-03
Fe-59	5E-06	1E-05	5.0E-08	5.0E-03
Co-60	5E-06	3E-06	5.0E-08	1.7E-02
Zn-65	5E-06	5E-06	5.0E-08	1.0E-02
Sr-89	5E-07	8E-06	5.0E-09	6.3E-04
Sr-90	5E-07	5E-07	5.0E-09	1.0E-02
Mo-99	5E-06	2E-05	5.0E-08	2.5E-03
Cs-134	5E-06	9E-07	5.0E-08	5.6E-02
Cs-137	5E-06	1E-06	5.0E-08	5.0E-02
Ce-141	5E-06	3E-05	5.0E-08	1.7E-03
Ce-144	5E-06	3E-06	5.0E-08	1.7E-02
			Total =	1.7E-01

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PROJECT: LIMERICK GENERATING STATION - UNITS 1 & 2 COOLING TOWER, HOLDING POND AND SPRAY POND

SUBJECT: DETERMINE WORST CASE RADIOLOGICAL IMPACTS OF USING SOLIDS, TAKEN FROM THE COOLING TOWER BASINS, HOLDING POND, AND SPRAY POND, AS FILL

EQUATIONS FOR TABLES (SPREADSHEETS) 1A-6

Table 1A

Column 5: $$\frac{\text{Solids Act. Lmt}\left[\frac{\mu Ci}{gm}\right] * \text{Airborne } 1\times10^{-4}\frac{gm}{m^3} * 10^{-6}\left[\frac{m^3}{ml}\right]}{\text{Air Limit (Col. 3)}\left[\frac{\mu Ci}{ml}\right]}$$

Table 1B

Column 3: $\text{Solids Act Lmt}\left[\frac{\mu Ci}{gm}\right] * 2.41\times10^{6}\left[\frac{gm}{Yr}\right] * 10^{-6}\left[\frac{Ci}{\mu Ci}\right]$

TABLE 2A All data and equations used are as referenced to Attachment 3

TABLE 2B

Column 5: $-\text{Leach Rate}\left[\frac{1}{Yr}\right] - \frac{\ln 2}{\text{half life}}\left[\frac{1}{Yr}\right]$

Column 6: $\text{Solids Act. Limit}\left[\frac{\mu Ci}{gm}\right] * 1.95\left[\frac{gm}{cc}\right] * 1.98+10^{9}\left[\frac{cc}{Yr}\right]$

Column 7: $\text{Column 6 Value}\left[\mu Ci\right] * \sum_{t=0}^{15} e^{t * \text{Col. 5}}$

Column 9: $\text{Column 7}\left[\mu Ci\right] * \text{Leach Rate (Col 3)}\left[\frac{1}{Yr}\right]$

Column 10 - obvious. $-.155 * \frac{\ln 2}{1 \text{ hr}}$

Column 11: $\text{Column 9}\left[\text{unitless}\right] * e$

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PROJECT: LIMERICK GENERATING STATION - UNITS 1 & 2 COOLING TOWER, HOLDING POND AND SPRAY POND

SUBJECT: DETERMINE WORST CASE RADIOLOGICAL IMPACTS OF USING SOLIDS, TAKEN FROM THE COOLING TOWER BASINS, HOLDING POND, AND SPRAY POND, AS FILL

EQUATIONS FOR TABLES (SPREADSHEETS) 1A-6, cont'd

Table 3

Column 4:

Solids Act Lmt $\left[\frac{\mu Ci}{gm}\right]$ * Col. 3 $\left[\frac{Sv \cdot m^3}{sec\ Bq}\right]$ * 3600 $\left[\frac{sec}{hr}\right]$ * 24 $\frac{hr}{day}$ * 10^6 $\left[\frac{pCi}{\mu Ci}\right]$

* 2.505 $\times 10^8$ [to convert from $\frac{Sv\ m^3}{day\ Bq}$ to $\frac{mrem \cdot gm}{hr\ pCi}$] ← Ref. 7 Table 6.11

= dose rate in $\frac{mrem}{hr}$

Column 6:

Solids Act. Lmt $\left[\frac{\mu Ci}{gm}\right]$ * Col. 5 $\left[\frac{Sv}{Bq\ inhaled}\right]$ * 5×10^{-4} $\left[\frac{gm}{m^3}\right]$ * 3.7×10^4 $\left[\frac{Bq}{\mu Ci}\right]$ * 10^5 $\frac{mrem}{Sv}$

* 1.2 $\frac{m^3}{hr}$ = dose rate in $\frac{mrem}{hr}$

(Breathing Rate from Ref 7, Table 6.23)

TABLE 4 λ (not shown) = decay constant = $\frac{\ln 2}{T_{1/2}}$

Column 5: Solids Act. Lmt. $\left[\frac{\mu Ci}{gm}\right]$ * 10^6 $\left[\frac{pCi}{\mu Ci}\right]$ / Col. 4 (Note) $\left[\frac{pCi/gm}{15\ mrem/yr}\right]$

= ANNUAL dose [mrem]

Column 6; 7; 8: Column 5 $\left[\frac{mrem}{yr}\right]$ * $e^{-\lambda * decay\ time}$

Note: Column 4 must be divided by 15 (see units) to yield annual dose in mrem.

TABLE 5 deleted by Rev. 2.

TABLE 6

Column 4: At 1% by weight in solids, the runoff activity would be 1% of the Solids Activity Limit.

Column 5: Simply the runoff Activity divided by the 10 CFR 20 LIMIT.