NRC Request Q-6

Provide support for release rates (i.e., cumulative release) from grout and cement so that staff can make a determination that dose criteria specified in 10 CFR 20.1402 is not underestimated. The support should consider: (i) the trenches are in the zone of a fluctuating water table, (ii) some amount of advective flow could occur in fractures and contact planes of different materials, (iii) downward migration both by diffusion and advection, and (iv) selections of literature inputs that do not lead to underestimates of dose. Alternatively, provide justification that the uncertainty in the input values is encompassed in the release rate.

FCS Response

(i) *The trenches are in the zone of a fluctuating water table.*

The grout that was emplaced is assumed to be free of any major fractures that would allow flow through the entire section of backfilled grout. For this reason, the impact of the fractures would be to increase the surface area of the grout exposed to water during the times of total saturation. It is expected that the fracture surface area for the emplaced grout would be a small percentage of the total surface area and therefore be a small contributor to the total release. Diffusion coefficients in cement systems vary by orders of magnitude in the literature due to variations in composition, water to cement ratio, and additives. Selection of diffusion coefficient values at the high end of the measured values and the assumption of continual saturation are meant to cover uncertainties in the release rate including minor fracturing.

(ii) *Some amount of advective flow could occur in the fractures and contact planes.*

This may occur due to water table fluctuations. As stated above, the amount of fracture area as compared to the total surface area is anticipated to be small and have a minor impact on total release. After grout emplacement, there was minimal water flow into the building. The potential release for this is analyzed in section 3.

(iii) *Downward advection by both diffusion and advection.*

Below the emplaced grout, removal of the embedded pipes led to fracturing of the cement in the basemat of the building. This could lead to rapid flow through these fractures as the water table rose and fell. As contaminants are released they will travel downward through the fractures subject to chemical retardation effects during the drainage phase of the fluctuation.

After excavation of the trenches and prior to filling them with grout, water inflow was observed in the Auxiliary Building east trench area in March 2024 due to a rise in the water table. Inflow was not observed in the stressing gallery trenches. The inflow in the east trenches occurred over approximately a one-week period. Inflow was observed at several small locations in Trench 16 (Figure 1) and one location in Trench 14. Figure 2 shows the grid used to define trench locations, and Table 1 lists the area inflow was observed and the area over which inflow occurred. The total trench area in the east trench zone is 325 m^2.

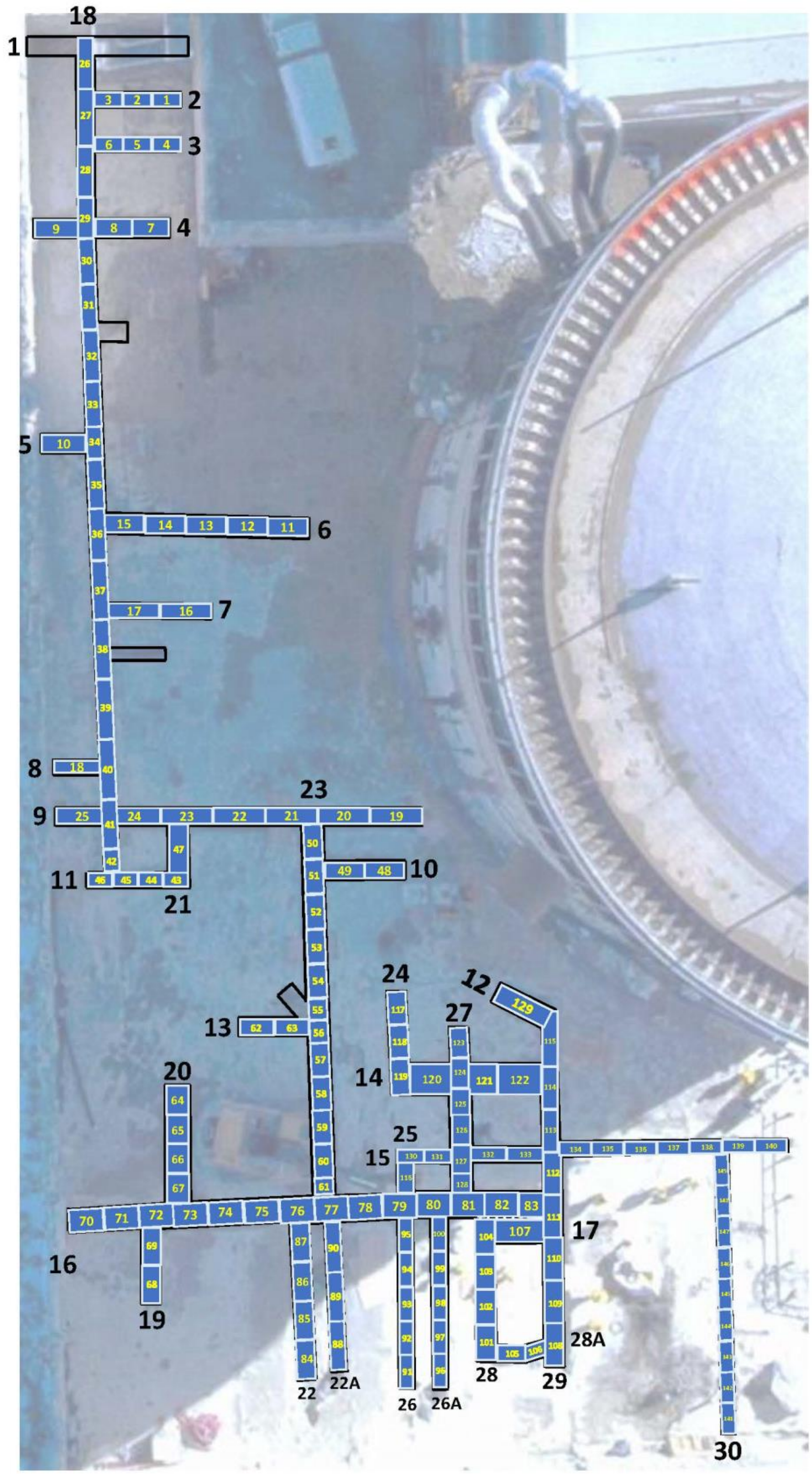
Table 1 – East Trench locations and leakage area

Trench	Size ft^2	Size m^2
16 – G82/83	4	.37
16 – G81/82	2.5	.23
16 - G72	6	.557
16 - G76/77	6	.557
14 – G122	2	.18
Total	20.5	1.9

After capping the inflow was greatly reduced limiting inflow to 15 – 20 gallons.

Figure 1 – Wetted areas of Trench 16 after infiltration event

Figure 2 – East Area Trench Map



Conceptual Model

The model assumes that the entire inventory of the wetted region is released and enters a drinking water well within one year. This is a conservative assumption due to the fact that nuclides in the cement matrix would have to migrate to a fracture via diffusion and then migrate out of the fracture due to advection. While migrating out of the fracture, sorption would occur, increasing the time to reach the well and reducing the contaminant concentration.

The dose is calculated using the measured mixture fraction of the contamination, the DCGLs for the trench, and the dose conversion factors that include drinking water as well as irrigation and contamination of contaminated foods grown on-site. To account for all nuclides and constraining the DCGLs of all nuclides to provide a 25 mrem/yr dose for the mix fraction, the 25 mrem/yr concentrations for the sum of fractions equal to 1 is calculated as:

Equation 1

$$D_{25i} = \frac{w_i}{\sum \frac{w_i}{DCGL_i}}$$

Where D_{25i} (pCi/m^2) is the mixture fraction of contaminant i, w_i, normalized to the sum over all contaminants of the mixture fraction of contaminant i, divided by the DCGL of contaminant i.

The basic equation for the calculation is:

Equation 2

$$D_i = D_{25i} * A * \frac{DCF_i}{WW}$$

Where:

D_i = dose from contaminant i in well water
D_{25i} = mix fraction normalized DCGL (pCi/m^2) (e.g., the inventory)
A = the area of leakage (m^2) (2 m^2, Table 1)
DCF_i = dose conversion factor for contaminant i in well water (mrem/yr per pCi/L)
WW = well water volume (1/yr)

Table 2 contains the mixture fraction for the Auxiliary Building trenches, the dose conversion factors for each nuclide, and the mix fraction normalized concentrations to reach 25 mrem/yr. Table 3 contains the area, well water volume, and dose for each nuclide. The total dose, releasing the entire inventory, is 4.7 mrem/yr, which is less than the 25 mrem/yr dose standard.

Table 2 – Mixture fraction, DCGLs, and 25 mrem concentrations for each nuclide

Nuclide	Mix Fraction	DCGL (pCi/m^2)	25 mrem concentrations (pCi/m^2)
Am-241	3.55E-04	3.67E+09	1.46E+05
C-14	4.14E-02	6.82E+12	1.70E+07
Ce-144	2.31E-05	2.60E+09	9.48E+03
Cm-243/244	1.32E-03	8.55E+08	5.42E+05
Cm-243/244	1.32E-03	9.51E+09	5.42E+05
Co-58	7.52E-09	3.47E+08	3.09E+00
Co-60	4.16E-02	3.69E+07	1.71E+07
Cs-134	3.67E-03	6.98E+07	1.51E+06
Cs-137	1.57E-01	1.67E+08	6.45E+07
Eu-152	1.16E-04	8.21E+07	4.76E+04
Eu-154	6.72E-03	7.60E+07	2.76E+06
Eu-155	4.59E-05	3.24E+09	1.88E+04
Fe-55	7.37E-03	3.70E+13	3.03E+06
H-3	4.00E-01	1.86E+09	1.64E+08
Ni-59	1.88E-03	3.02E+13	7.70E+05
Ni-63	1.77E-01	3.43E+13	7.26E+07
Np-237	2.31E-04	4.54E+08	9.48E+04
Pu-238	5.66E-03	5.92E+09	2.32E+06
Pu-239	1.79E-05	5.33E+09	7.35E+03
Pu-240	1.79E-05	5.33E+09	7.35E+03
Pu-241	1.77E-03	2.65E+11	7.28E+05
Sb-125	6.71E-05	2.58E+08	2.75E+04
Sr-90	4.28E-03	1.96E+10	1.76E+06
Tc-99	1.49E-01	4.36E+10	6.13E+07

Table 3 – Nuclide, wetted area, well volume, and calculated dose

Nuclide	Area (m2)	Well Water Volume (l/yr)	mrem/y
Am-241	2.00E+00	4.55E+06	1.28E-01
C-14			2.00E-02
Ce-144			3.20E-05
Cm-243/244			3.24E-01
Cm-243/244			2.59E-01
Co-58			1.32E-09
Co-60			1.90E-01
Cs-134			5.73E-02
Cs-137			1.94E+00
Eu-152			7.58E-05
Eu-154			6.40E-03
Eu-155			6.79E-06
Fe-55			5.61E-04
H-3			3.29E-03
Ni-59			1.20E-04
Ni-63			3.10E-02
Np-237			1.04E-01
Pu-238			1.78E+00
Pu-239			6.27E-03
Pu-240			6.27E-03
Pu-241			1.26E-02
Sb-125			1.80E-05
Sr-90			8.51E-02
Tc-99			3.13E-02
		sum mrem/y	4.99E+00

(iv) *However, staff noted that eight of the radionuclides (comprising four elements) are orders of magnitude smaller than values contained in a similar table of recommended generic diffusion coefficient values in BNL 2016 (Table 5, TSD 14-031 Revision 1, Basement Fill Model Evaluation of Maximum Radionuclide Concentrations for Initial Suite of Radionuclides Zion Station Restoration Project, ML16211A379).*

In the Zion analysis (Table 5, TSD 14-031 Revision 1), the conceptual model included backfill to sorb radionuclides released from cement. Backfill, although planned for Fort Calhoun, was not taken into consideration in the current analysis. Backfill substantially reduces the activity in solution of the 8 radionuclides (isotopes of Np, Pu, Am, and Cm). In the Zion analysis, cement diffusion coefficients were set to the value for Cs-137 for these nuclides, as the backfill provided a sufficient reduction in water concentration of these nuclides. The actual diffusion coefficients for these nuclides will be several orders of magnitude lower than that of Cs. In the Fort Calhoun analysis, cement diffusion coefficients were based on measured data of the highest values found in the literature.