PA-9.2 Cuttings and Cavings Normalized Releases

Figures PA-100, PA-101, and PA-102 show the CCDFs for normalized releases due to cuttings and cavings for replicates R1, R2, and R3. The releases in each replicate are very similar; Figure PA-103 compares the mean and quantile CCDFs for cuttings and cavings releases for each replicate.

The increase in cuttings and cavings releases at a probability of 0.003 in each replicate is due to a few waste streams with very high radioactivity that are present in the updated inventory (Appendix DATA, Attachment F). These waste streams maintain significant radioactivity during the 10,000-year period. For example, a single waste stream (LA-TA-58-48, oil/vermiculate waste from ^{238}Pu heat source fabrication) has a concentration of radioactivity of 4.05 EPA units/m^3 at 100 years after repository closure, decaying to 1.95 EPA units/m^3 by 10,000 years (Fox 2003). This waste stream maintains high radioactivity concentration over time because it contains high quantities of longer-lived radioisotopes, principally ^{239}Pu and ^{240}Pu. The radioactivity concentrations in this waste stream can lead to cuttings and cavings releases exceeding 1 EPA unit for a single intrusion.

The volume of the LA-TA-58-48 waste stream (31 m^3) implies a probability of 31/168,500 = 0.00018 that this waste stream is selected as one of the three waste streams contributing to the cuttings and cavings release for a single intrusion. However, in any future of the repository, roughly six intrusions are expected (Dunagan 2003b), implying that 18 waste streams are selected for cuttings and cavings releases. The mean probability that the LA-TA-58-48 waste stream is selected at least once for cuttings and cavings releases is estimated to be

$$1-\left(1-0.00018\right)^{18}=0.0033\ ;$$

thus, the increase in releases at a probability of about 0.003 in Figure PA-100, Figure PA-101, and Figure PA-102.

Figure PA-103 compares the mean, median, 90th, and 10th quantiles for each replicate's distribution of CCDFs for cuttings and cavings releases. The statistical measures of each replicate's distribution of CCDFs are quite similar, indicating that the sample size of 100 elements in each replicate is sufficient to estimate the distribution of CCDFs. Figure PA-104 shows the 95 percent confidence interval about the overall mean of the CCDFs for cuttings and cavings releases. The upper and lower confidence intervals nearly coincide with the overall mean, showing that the overall mean is estimated quite accurately.

Section PA-8.5.1 presents a sensitivity analysis for cuttings and cavings release volumes, and shows that the uncertainty in total cuttings and cavings volumes arises almost entirely from the uncertainty in waste shear strength (WTAUFAIL; see Table PA-17). Cuttings and cavings releases are computed by multiplying the volume released by the average concentration of radioactivity in the three selected CH-TRU waste streams (see Section PA-3.7). However, the uncertainty in the radioactivity in the cuttings and cavings materials is stochastic uncertainty, and is thus represented by the shape of the individual CCDFs in Figures PA-100, PA-101, and

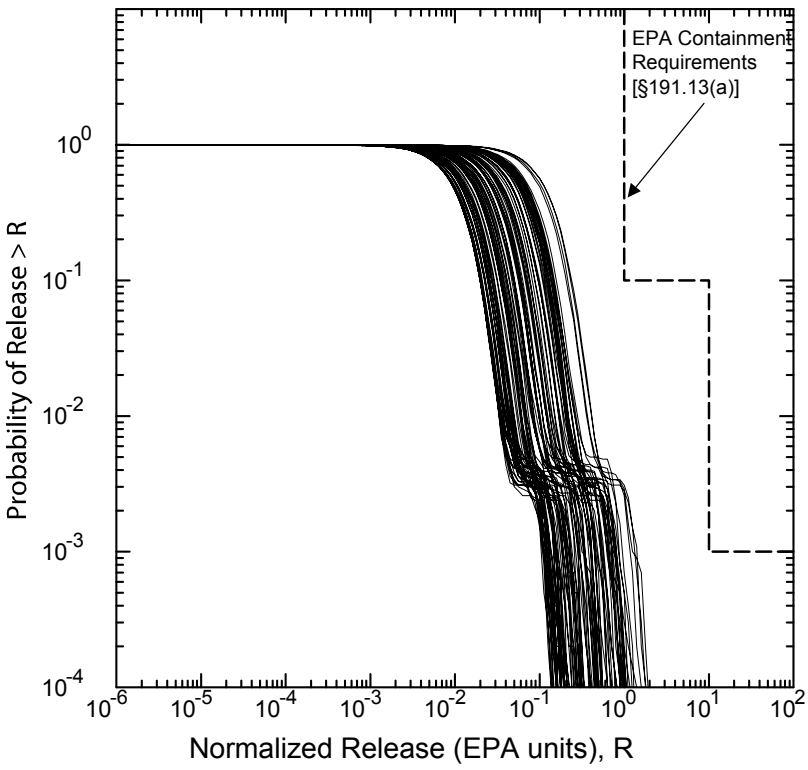

Figure PA-100. Cuttings and Cavings Releases, Replicate R1.

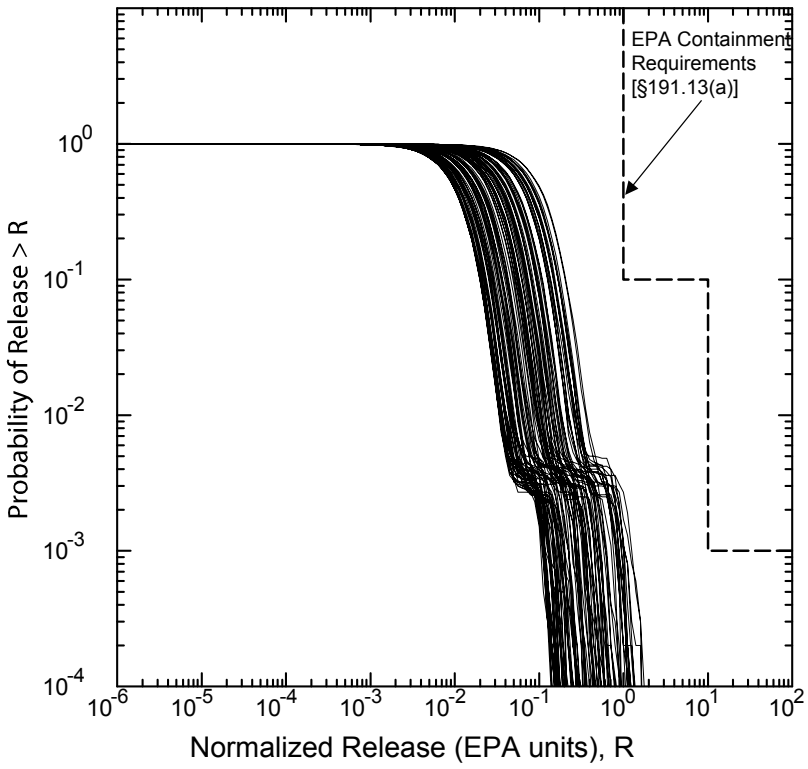

Figure PA-101. Cuttings and Cavings Releases, Replicate R2.

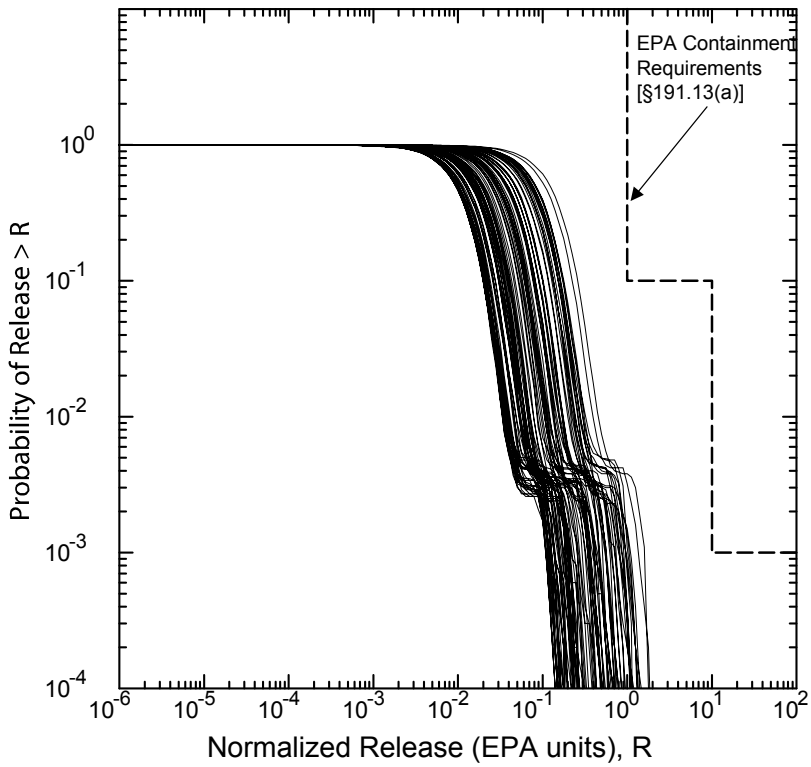

Figure PA-102. Cuttings and Cavings Releases, Replicate R3.

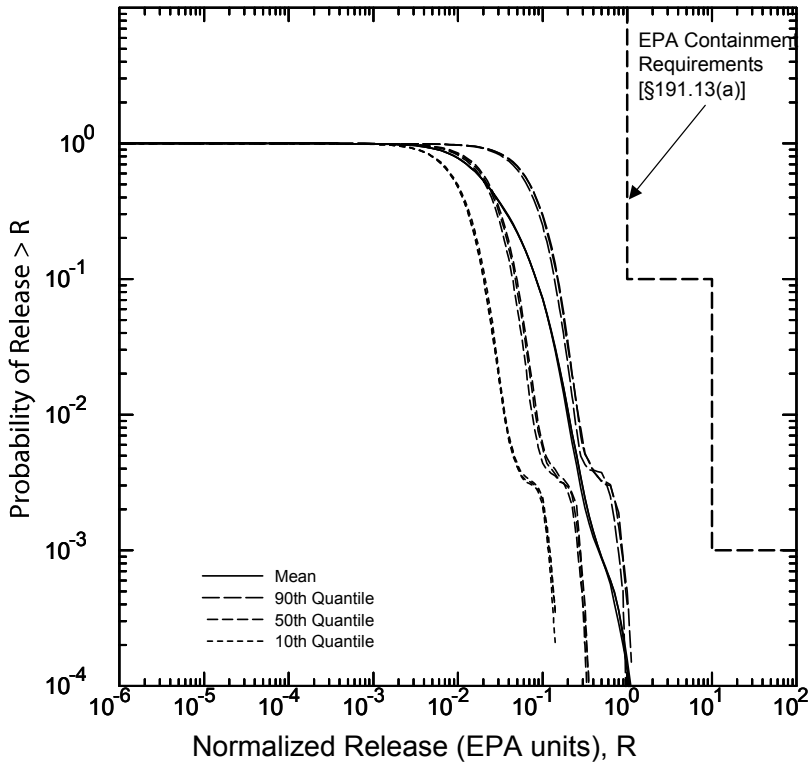

Figure PA-103. Mean and Quantile CCDFs for Cuttings and Cavings Releases, All Replicates.

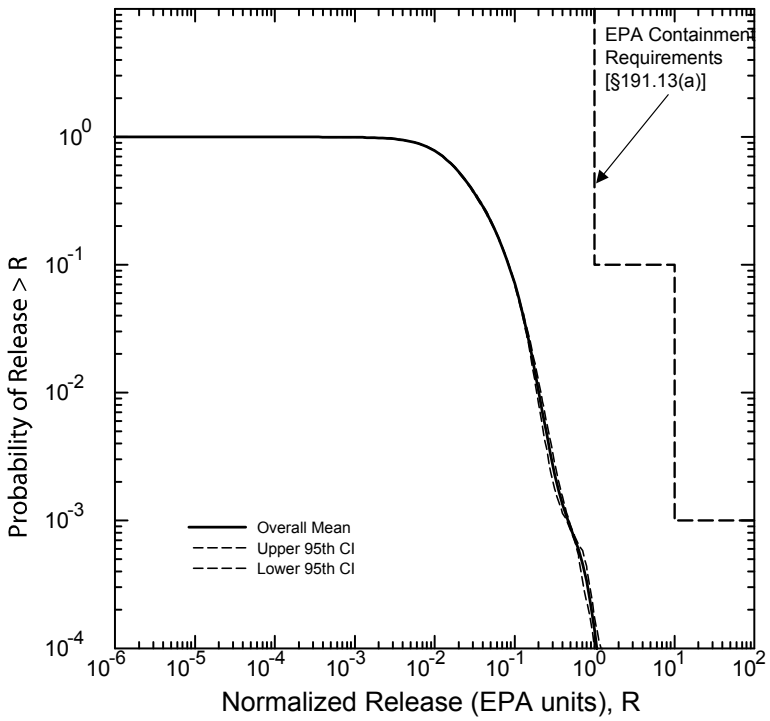

Figure PA-104. Confidence Interval on Overall Mean CCDF for Cuttings and Cavings Releases.

PA-102. Consequently, the uncertainty in mean cuttings and cavings releases is due to the subjective uncertain in the cuttings and cavings volume, as demonstrated in Figure PA-105, which demonstrates the high correlation between mean cuttings and cavings releases and the uncertainty in waste shear strength.

PA-9.3 Spallings Normalized Releases

Figures PA-106, PA-107, and PA-108 show the CCDFs for normalized releases due to spallings for replicates R1, R2, and R3. The releases for each replicate are very similar; Figure PA-109 compares the mean and quantile CCDFs for spallings releases for each replicate and indicates that the distribution of spallings releases are similar in each replicate. Figure PA-110 shows the 95 percent confidence interval about the overall mean of the CCDFs for spallings releases. Although the confidence interval for spallings releases is broader than that shown in Figure PA-104 for cuttings and cavings releases, the overall mean is quite similar to the upper confidence interval, particularly at low probabilities. This result provides confidence that the true mean CCDF for spallings releases does not lie far to the right of the overall mean computed from the three replicates, and thus remains far below the release limits.

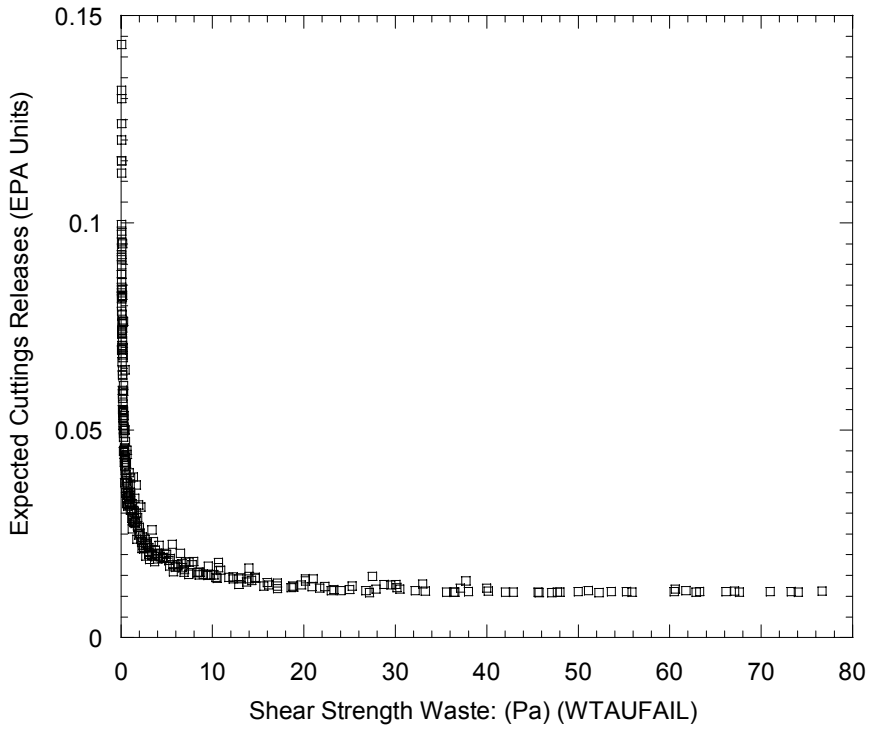

Figure PA-105. Uncertainty in Cuttings and Cavings Releases Due to Waste Shear Strength, All Replicates.

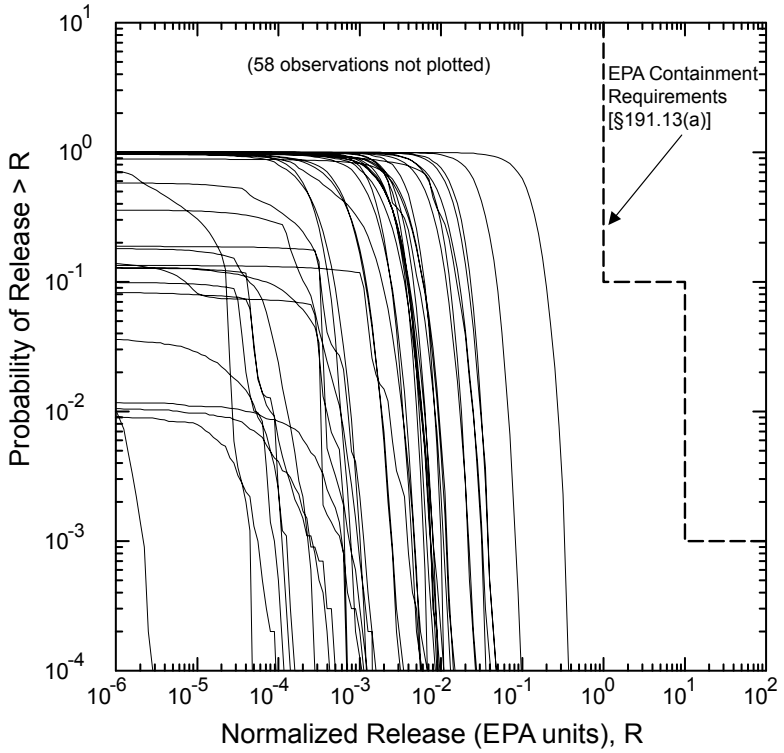

Figure PA-106. Spallings Releases, Replicate R1.

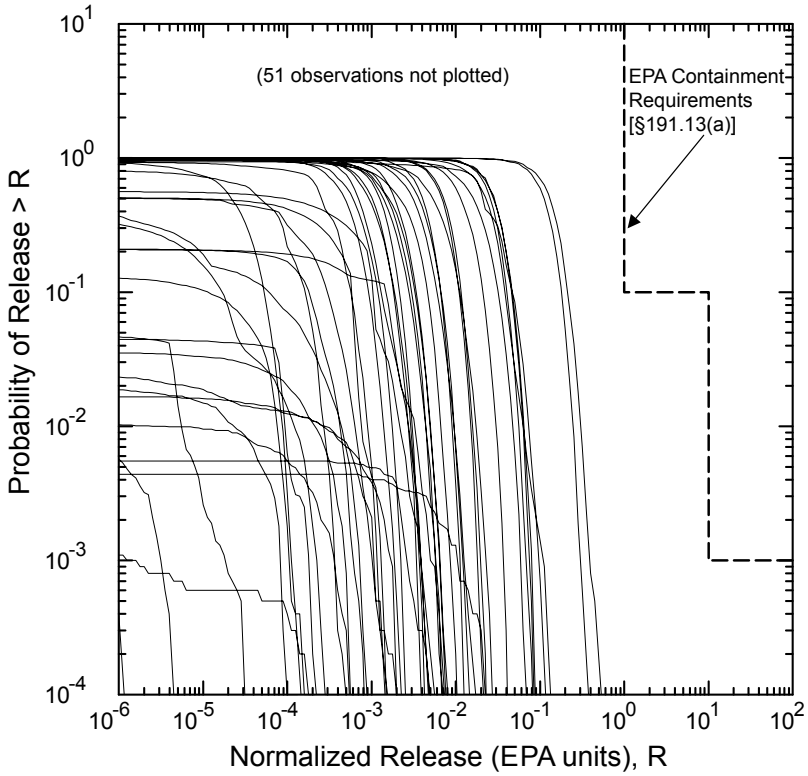

Figure PA-107. Spallings Releases, Replicate R2.

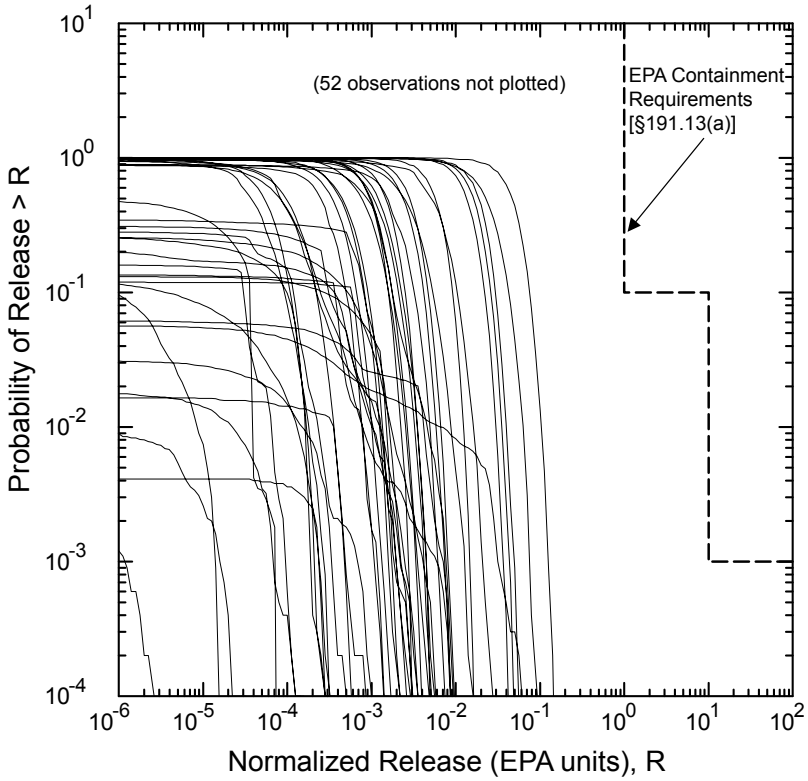

Figure PA-108. Spallings Releases, Replicate R3.

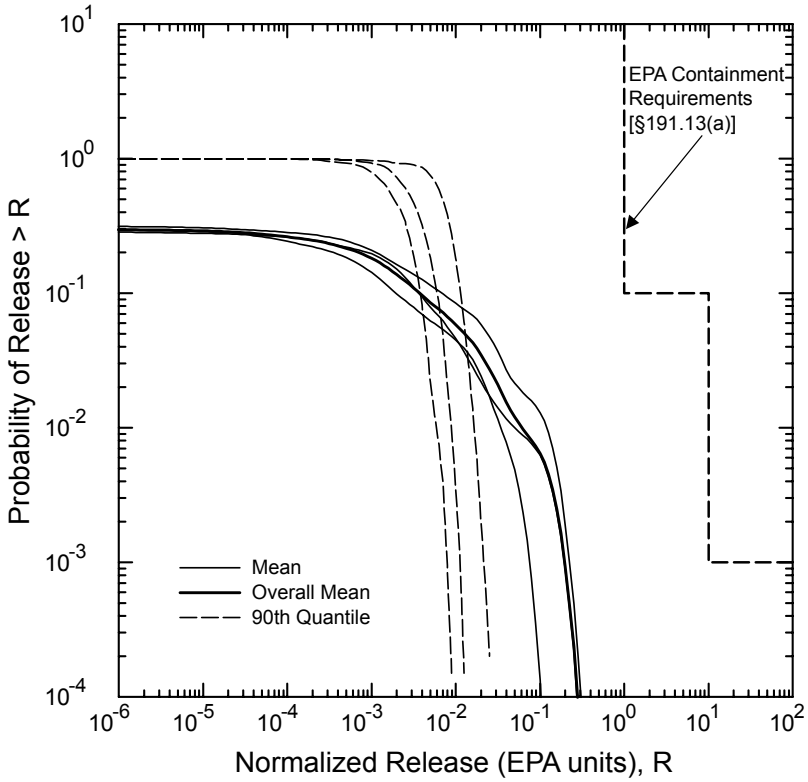

Figure PA-109. Mean and Quantile CCDFs for Spallings Releases, All Replicates.

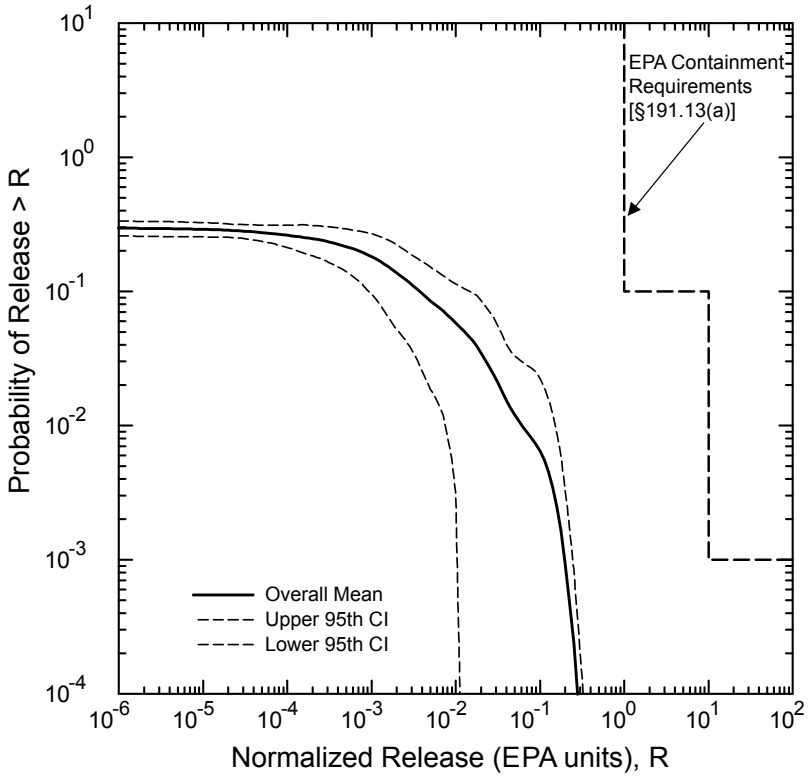

Figure PA-110. Confidence Interval on Overall Mean CCDF for Spallings Releases.

Section PA-8.5.2 presents a sensitivity analysis for spallings release volumes, and shows that the uncertainty in total spall volumes arises from the uncertainty in microbial action (WMICDFLG; see Table PA-17) and the uncertain spall volume from a single intrusion (see RNDSPALL in Table PA-17 and the discussion in Section PA-8.5.2). Since spall releases are computed by multiplying the volume released by the average concentration of radioactivity in the CH-TRU waste at the time of intrusion, the uncertainty in spalling releases is due to the same parameters that contribute to uncertainty in total spall volumes.

PA-9.4 Normalized Direct Brine Releases

Figures PA-111, PA-112, and PA-113 show the CCDFs for normalized direct brine releases for replicates R1, R2, and R3. The releases for each replicate are very similar; Figure PA-114 compares the mean and quantile CCDFs for each replicate; the 10th quantile for normalized DBRs does not plot on the scale of Figure PA-114. Figure PA-115 shows the 95 percent confidence interval about the overall mean of the CCDFs for DBRs, and shows that the overall mean is estimated reasonably well.

Section PA-8.5.3 provides an analysis identifying the sensitivity of the volume of brine released from a single intrusion to the uncertain parameters in the analysis. The sensitivity analysis showed that direct brine release volumes are most sensitive to uncertainty in pressure and brine saturation in the waste, which in turn, are most sensitive to microbial action in the waste (WMICDFLG; see Table PA-17) and borehole permeability (BHPERM).

As described in Section PA-6.8.5, DBRs are computed by multiplying the volume of brine released by the concentration of radionuclides in the brine. A stepwise regression analysis (summarized in Table PA-30) determined that the uncertainty in mean DBR is dominated by the parameters that influence the DBR volumes (WMIDFLG, the indicator for microbial action; BPINTPRS, the pressure in the Castile brine reservoir; PBRINE, the probability of an intrusion hitting the Castile brine reservoir; and WRBRNSAT, the residual brine saturation in the waste). The uncertainty in radionuclide concentration has a lesser influence on mean direct brine release, as only a single related parameter entered the analysis (WSOLAM3C, the uncertainty in the solubility of Am(III) in Castile brine). Figure PA-116 illustrates the sensitivity of mean DBR to DBR volume and to the most influential uncertain parameter, the indicator for microbial action (WMICDFLG). The figure shows that the mean DBRs is roughly proportional to the mean DBR volume among subsets of vectors with or without microbial action.

PA-9.5 Transport Normalized Releases

Figures PA-117 and PA-118 show the CCDFs for normalized releases due to transport through the Culebra for replicates R1 and R3. No transport releases larger than 10^{-6} EPA units occurred in replicate R2. Since the transport releases are small and statistically rare, no confidence intervals or sensitivity analyses are provided.

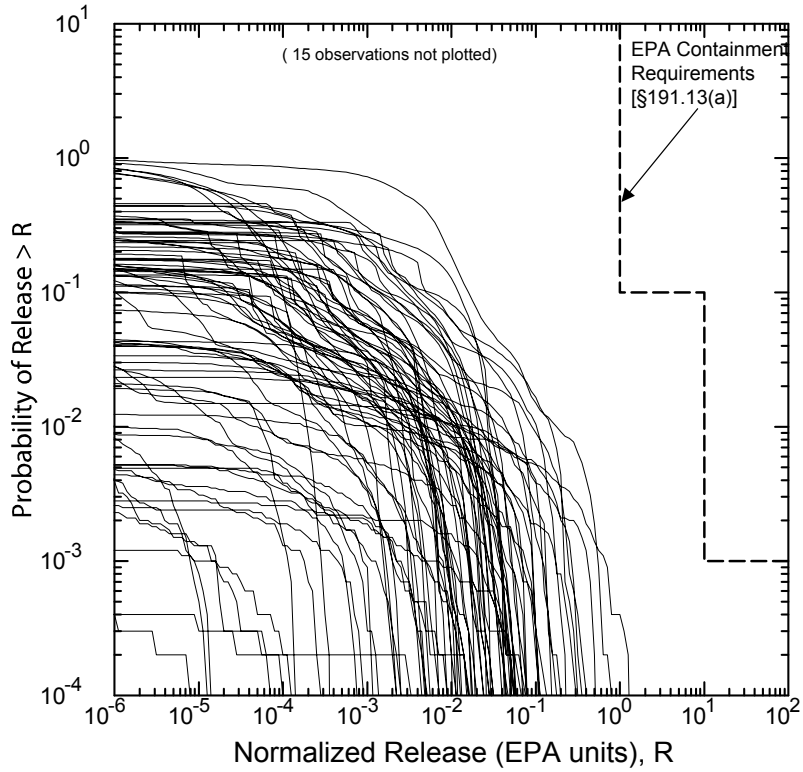

Figure PA-111. DBRs, Replicate R1.

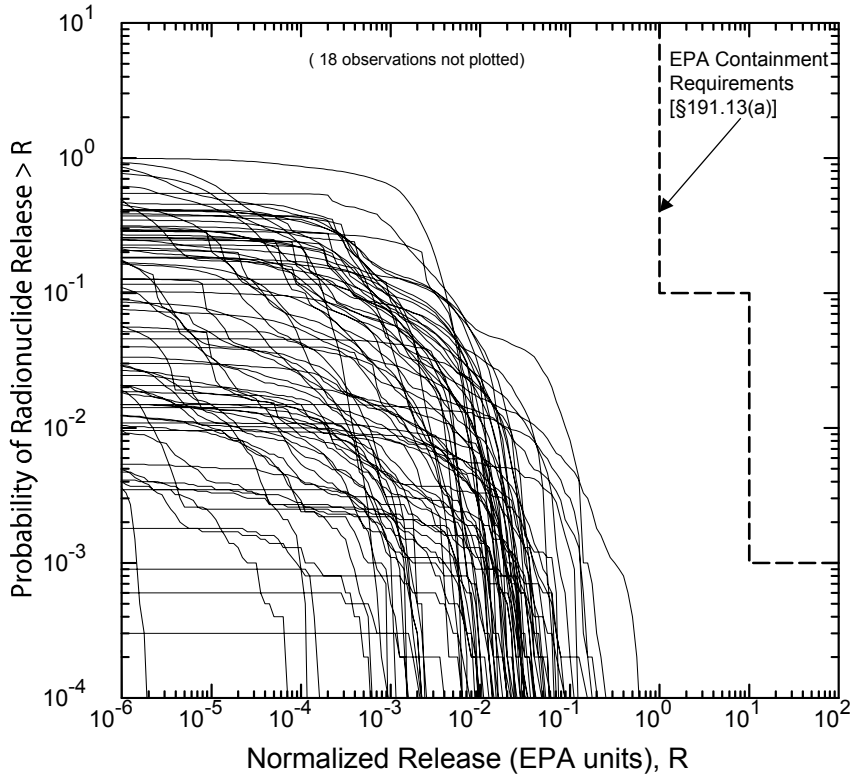

Figure PA-112. DBRs, Replicate R2.

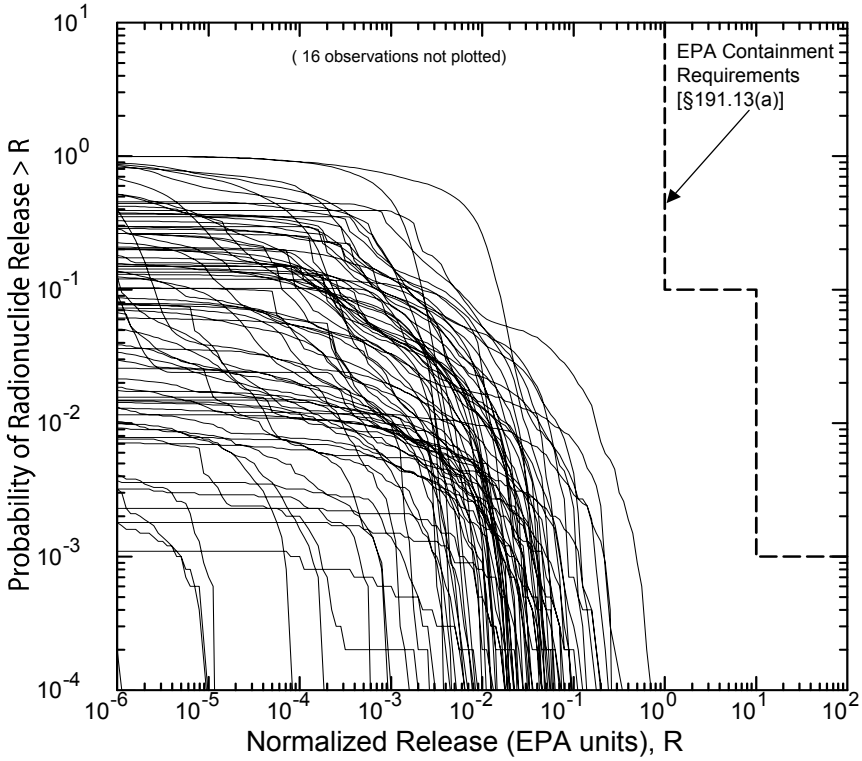

Figure PA-113. DBRs, Replicate R3.

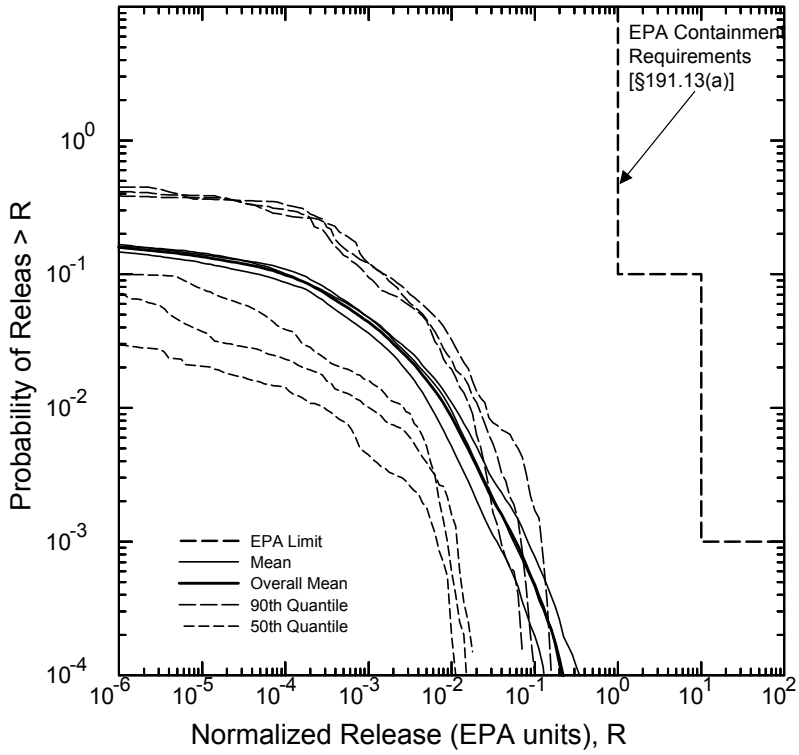

Figure PA-114. Mean and Quantile CCDFs for DBRs, All Replicates.

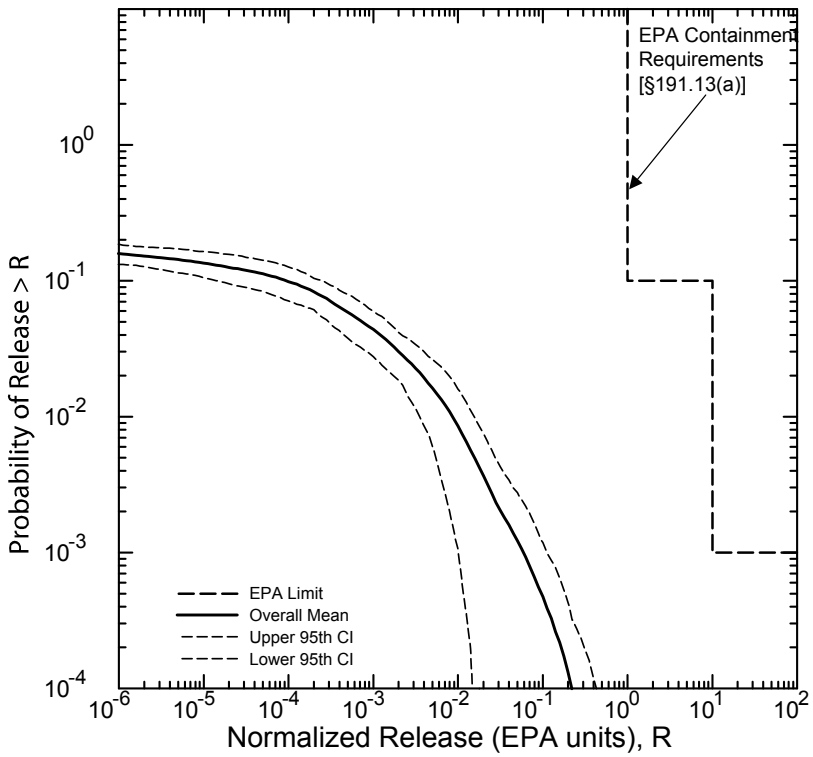

Figure PA-115. Confidence Interval on Overall Mean CCDF for DBRs.

Table PA-30. Stepwise Regression Analysis for Mean Total DBRs

Step[1]	Expected Normalized Release		
	Variable[2]	SRRC[3]	R^2 [4]
1	WMICDFLG	–0.473	0.158
2	BPINTPRS	0.441	0.343
3	PBRINE	0.361	0.475
4	WSOLAM3C	0.212	0.516
5	WRBRNSAT	–0.197	0.555

[1] Steps in stepwise regression analysis
[2] Variables listed in order of selection in regression analysis
[3] Standardized Rank Regression Coefficient in final regression model
[4] Cumulative R^2 value with entry of each variable into regression model

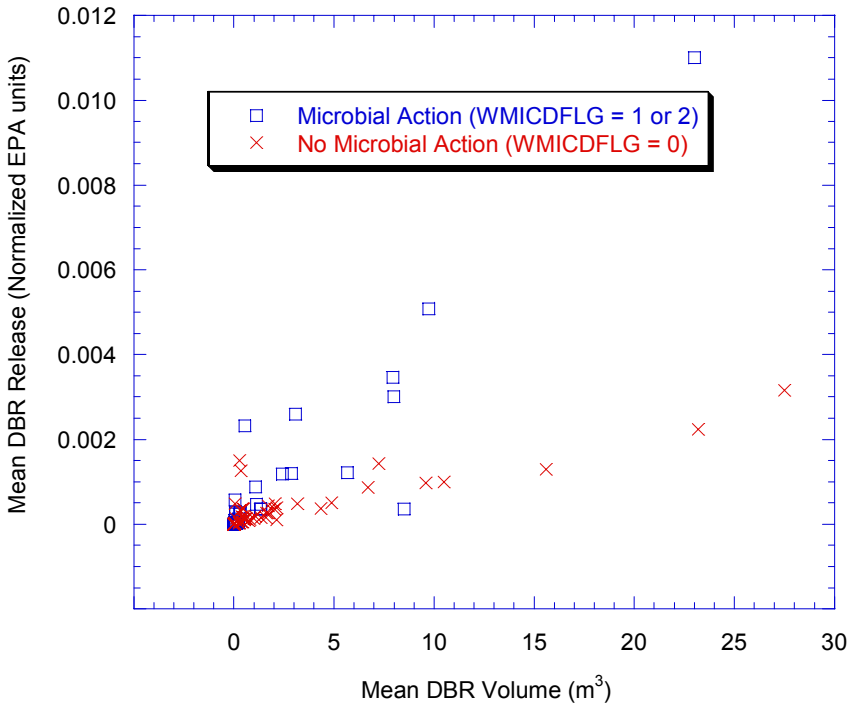

Figure PA-116. Sensitivity of DBRs.

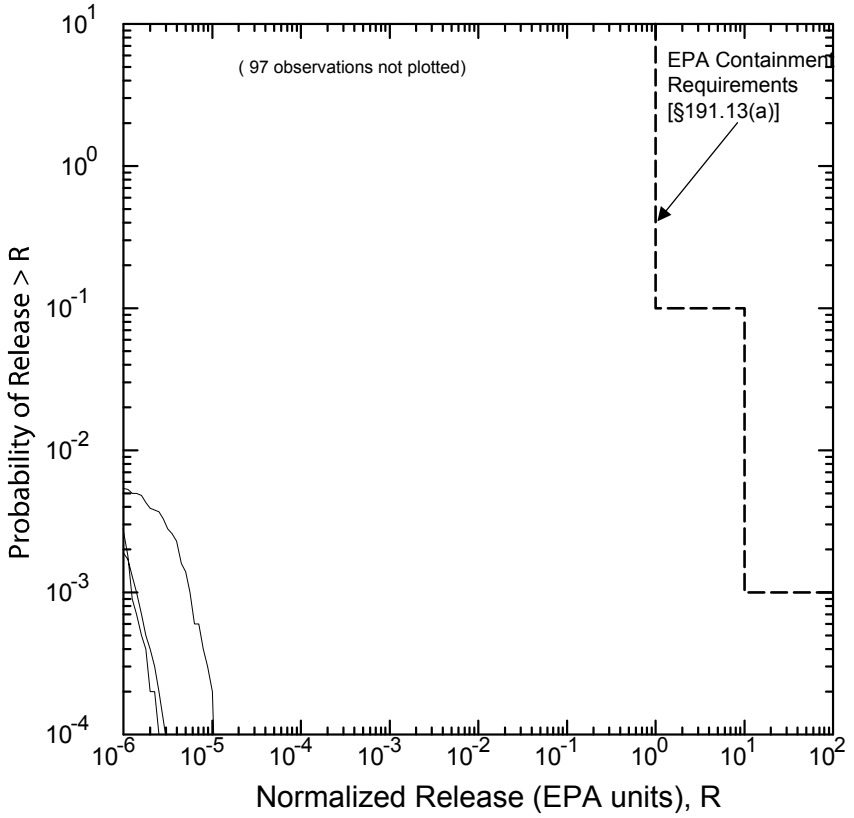

Figure PA-117. Transport Releases Through the Culebra, Replicate R1.

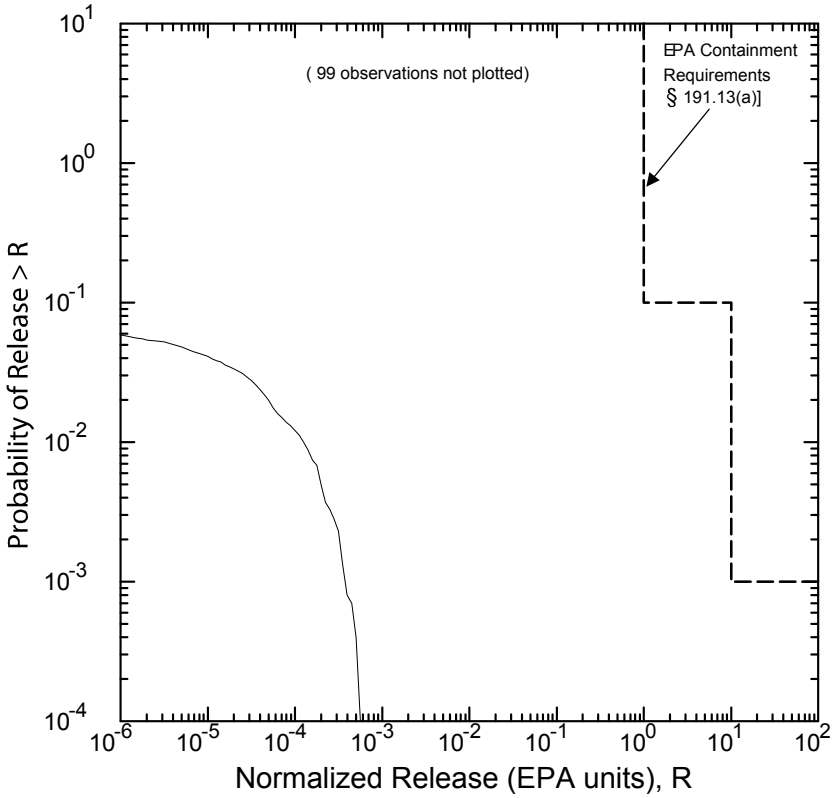

Figure PA-118. Transport Releases Through the Culebra, Replicate R3.

PA-9.6 Sensitivity Analysis for Total Normalized Releases

Uncertainty in total normalized releases is largely due to uncertainty in waste shear strength (WTAUFAIL; see Table PA-17). Table PA-31 lists the results of a stepwise regression between mean total normalized releases and the uncertain parameters in the analysis; waste shear strength (WTAUFAIL) is highly correlated with the uncertainty in mean total normalized releases. Figure PA-119 shows the relationship between the uncertainty in total releases and the uncertainty in WTAUFAIL for all replicates.

Table PA-31. Stepwise Regression Analysis for Mean Total Normalized Release

Step[1]	Variable[2]	SRRC[3]	R^2 [4]
1	WTAUFAIL	-0.95657	0.91958
2	WMICDFLG	0.10221	0.92999
3	DOMEGA	0.10542	0.93897
4	SPALVOL	0.07349	0.94419

[1] Steps in stepwise regression analysis
[2] Variables listed in order of selection in regression analysis
[3] Standardized Rank Regression Coefficient in final regression model
[4] Cumulative R2 value with entry of each variable into regression model

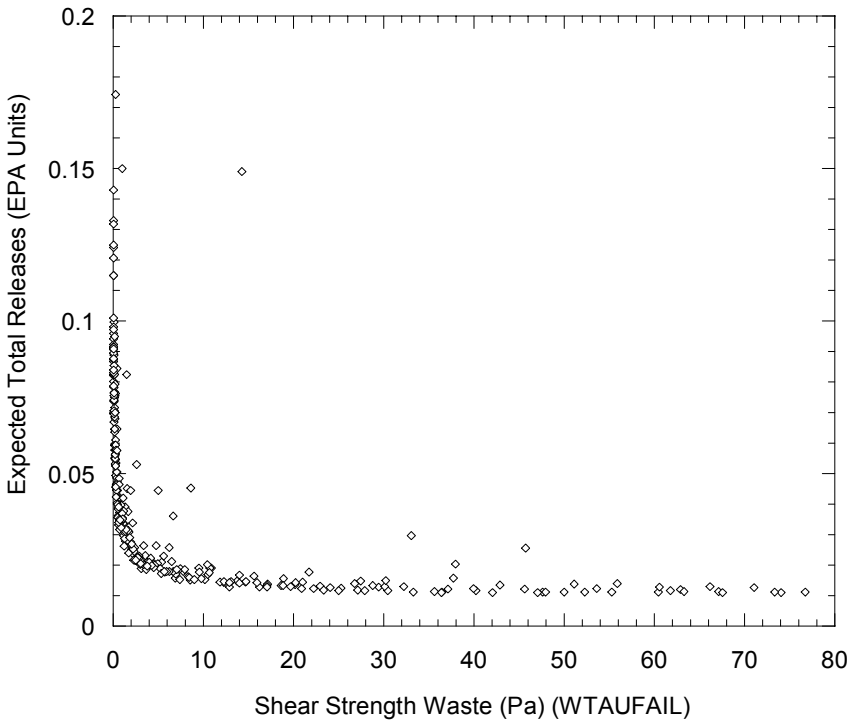

Figure PA-119. Uncertainty in Mean Total Releases Due to Waste Shear Strength, All Replicates.

As shown in Section PA-9.1, cuttings and cavings releases constitute most of the total releases from the repository. As shown in Section PA-8.5.1, most of the uncertainty in cuttings and cavings releases arises from uncertainty in waste shear strength (WTAUFAIL). Thus, uncertainty in WTAUFAIL dominates uncertainty in total releases.

The remaining uncertainty in total releases is primarily due to uncertainty in the spallings releases. Figure PA-120 compares total releases and cuttings and cavings releases for replicate R1, and shows that almost all of the total releases are due to cuttings and cavings. For replicate R1, Figure PA-121 shows the uncertainty in total releases that is not due to uncertainty in cuttings and cavings, and demonstrates that most of the remaining uncertainty arises from uncertainty in spallings releases. This figure shows that spallings releases account for almost all of the variability in the difference between the total releases and cuttings and cavings releases. The small amount of uncertainty in total releases that is not due to cuttings and cavings or spallings arises from uncertainty in the other components of total releases (i.e. DBR and transport releases). Since the three replicates are statistically similar (Figure PA-95), these conclusions hold for all replicates.

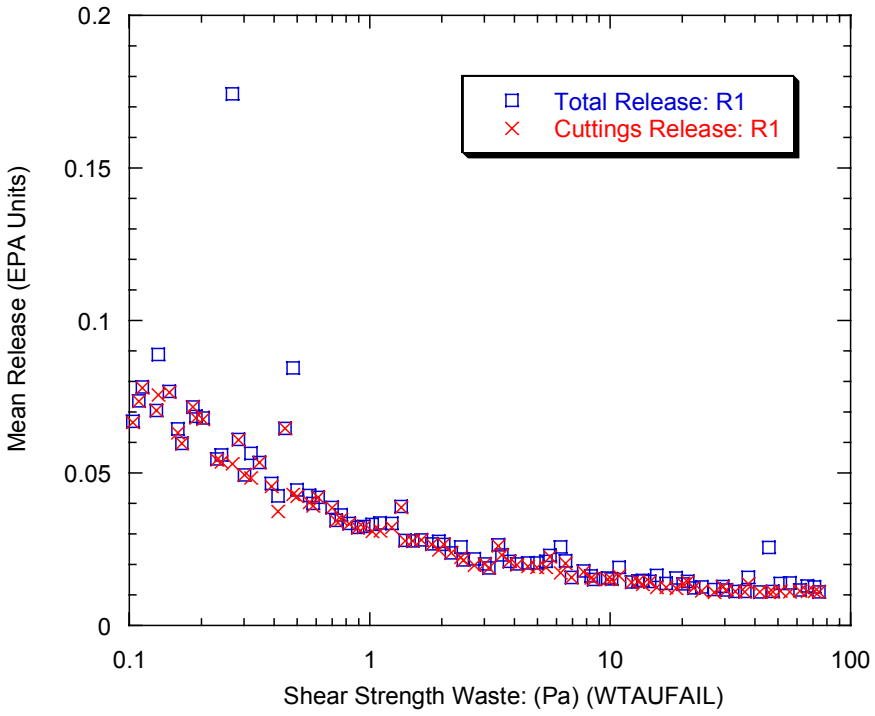

Figure PA-120. Comparison of Mean Total Releases to Mean Cuttings and Cavings Releases, Replicate R1.

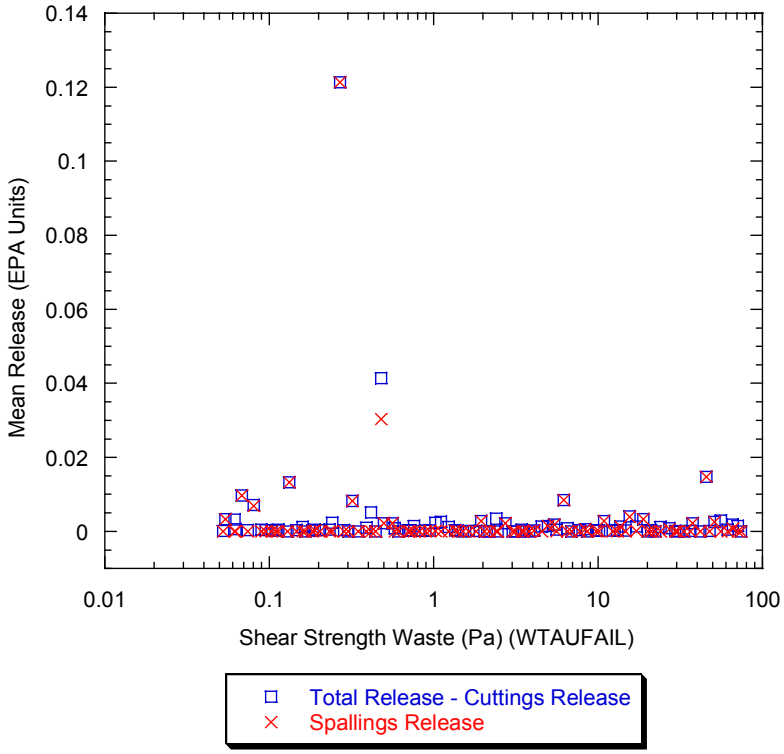

Figure PA-121. Comparison of Mean Total Releases Minus Mean Cuttings Releases to Spall Releases, Replicate R1.

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