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Our ref: HEM-12-121
Date: October 17, 2012

Subject: FURTHER INFORMATION FOR THE FINAL RESPONSES DATED JULY 24, 2012, TO NRC REQUESTS FOR ADDITIONAL INFORMATION DATED MAY 1, 2012, ON THE JANUARY 16, 2012, HEMATITE 20.2002 ALTERNATE DISPOSAL REQUEST (LICENSE NO. SNM-00033, DOCKET NO. 070-00036)

Reference 1) Westinghouse (Copp) letter HEM-12-88 to NRC (Document Control Desk), dated July 24, 2012 “Final Responses to NRC Requests for Additional Information Dated May 1, 2012, on the January 16, 2012, Hematite 20.2002 Alternate Disposal Request”

2) NRC (Hayes) letter to Westinghouse (Copp), dated May 1, 2012, “NRC Request for Additional Information from Westinghouse on the January 16, 2012, Hematite 20.2002 Alternate Disposal Request”

3) Westinghouse (Rood) letter HEM-12-2 to NRC (Document Control Desk), dated January 16, 2012, “Request for Additional Alternate Disposal Approval and Exemptions for Specific Hematite Decommissioning Project Waste at US Ecology Idaho”

Reference 1 transmitted the final responses to the U.S. Nuclear Regulatory Commission (NRC) requests for additional information (RAIs) in Reference 2. The RAIs were on the Reference 3 request from Westinghouse Electric Company LLC (Westinghouse) for additional alternate disposal approval and exemptions at the US Ecology Idaho facility.

During an NRC inspection the week of September 24, 2012, the NRC identified some comments on Reference 1 that required further information for the purposes of clarity, consistency, and specificity. Enclosure 1 contains those comments, responses to the comments, and the page changes to the applicable documents from Reference 1 based on those responses. Enclosures 2 through 4 are spreadsheets that support the responses to the comments.

Subsequent to the week of the NRC inspection, the document “Nuclear Criticality Safety Assessment of Sub-Surface Structure Decommissioning at the Hematite Site,” Revision 1, was identified as being required for the NRC docket. A copy is provided as Enclosure 5. The word processing software introduced error statements on pages 26 and 40. On page 26 the referenced section is 1.4.3, and on page 40 the referenced sections are 2.4.2 and 2.4.3.

Please contact Dennis Richardson of my staff at 314-810-3376 should you have questions or need any additional information.

Respectfully,

Robert D. Copp
Director, Hematite Decommissioning Project

Enclosures:
1) Responses and Related Document Page Changes to NRC Comments on the Additional 20.2002 Request Documents Submitted via Westinghouse Letter HEM-12-88, dated July 24, 2012
2) Spreadsheet, "99th Percentile Piping.xlsx"
3) Spreadsheet, "99th Percentile Soil.xlsx"
4) Spreadsheet, "Core Sample Data.xlsx"
5) Nuclear Criticality Safety Assessment of Sub-Surface Structure Decommissioning at the Hematite Site, Revision 1, November 2011

cc:
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Enclosure 1 to HEM-12-121

**Responses and Related Document Page Changes to
NRC Comments on the Additional 20.2002 Request Documents
Submitted via Westinghouse Letter HEM-12-88, dated July 24, 2012**

**Westinghouse Electric Company LLC
US Ecology Idaho, Inc.**

Westinghouse Electric Company LLC, Hematite Decommissioning Project

Docket No. 070-00036

**Responses and Related Document Page Changes to
NRC Comments on the Additional 20.2002 Request Documents
Submitted via Westinghouse Letter HEM-12-88, dated July 24, 2012**

The NRC conducted an inspection at the Hematite Decommissioning Project (HDP). During this inspection NRC provided comments on HDP's responses (letters HEM-12-67 and HEM-12-88) to requests for additional information (RAI) concerning the Westinghouse request for additional 20.2002 alternate disposal approval and exemptions at the US Ecology Idaho (USEI) facility.

During the inspection, HDP provided information relative to the NRC's comments, including conceptually how specific pages to three documents enclosed with HEM-12-88 would be revised. This enclosure contains the NRC comments, HDP's responses, and specific page changes to the three documents enclosed with HEM-12-88.

One of the three documents has been identified as Enclosure 1 to HEM-12-2 and then Enclosure 1 to HEM-12-88, even though the title and subject did not change. To facilitate page changes, this document has been given a fixed number, HDP-TBD-WM-908. A new section 11 for references has been added since that list of references needed to be carried forward from Westinghouse letter HEM-12-2.

Enclosure 4 to Westinghouse letter HEM-12-88 (Sampling Plan for Piping Destined for USEI) was incorporated into the new HDP-TBD-WM-908 as Attachment 11. Since there were changes on this Sampling Plan, Attachment 11 is included in this submittal.

Enclosure 3 (Sampling Plan for Concrete and Asphalt) to Westinghouse letter HEM-12-88 was incorporated into HDP-TBD-WM-908 as Attachment 12. There were no changes between Attachment 12 to HDP-TBD-WM-908 and the Enclosure 3 of HEM-12-88, so no page changes from this Attachment 12 are included in this submittal.

The NRC comments and responses were grouped together when the resolution affected the same page changes to any of the three documents.

NRC Comment:

CH-2, Section 5.2.1, Soil Characterization Upper Confidence Limit, CH-3, Section 5.2.1, Soil Sampling Contingency Plan Table, and CH-5, Section 5.2.1, Delineation between the soil in the previous and current request, Page 2 and 4 of 167. Explain how the upper confidence limit is determined. Provide a technical basis for the 1.5 factor. Explain how the action levels that applied to the first 20.2002 which have been repeated are valid for the combined material from both 20.2002s.

NRC Comment:

CH-3 – Clarification is needed on how the updated action levels were generated.

Westinghouse Response:

Section 5.1 of HDP-TBD-WM-908 was revised to add an explanation for how the upper confidence limit was determined, the technical basis for the 1.5 factor, and the reason the actions levels are valid for combined materials. This explanation was placed in section 5.1 since 5.2.1 is specific to soil and the explanation applies to all materials to be sent to USEI.

Table 2, which was in Section 5.2.1, has been moved to a new section 5.2.5. A row for concrete that was in Appendix R to HDP-TBD-WM-906 was added to Table 2. The limit for individual soil samples was revised from 599 to 573 pCi/g when additional soil sample results were included. The additional soil sample results were from samples of archived soil corings from historic borings under the process buildings and from samples taken of the soil immediately below more recent concrete slab corings. The limits for individual piping samples were revised from 5783 and 1118 to 162 and 125 pCi/g, respectively. These limits changed due to excluding piping sample results from sections of piping that were excluded from shipment to USEI (excluded piping shown in Appendix G to HDP-TBD-WM-906). The spreadsheets containing the recalculations are provided as enclosures 2, 3, and 4 to Westinghouse letter HEM-12-121.

With the new discussion in section 5.1 and the move of Table 2 to section 5.2.5, paragraphs 2-4 of section 5.2.1 were consolidated into one paragraph to avoid redundant and potentially conflicting text.

NRC Comment:

CH-6 and HEM-12-88 – In HEM-12-88 it is noted that “the samples from each sampling location will be analyzed for uranium by gamma spectroscopy and for Tc-99.” Clarification is needed on how the Tc-99 will be analyzed and/or the plans for disposition to an offsite laboratory.

Westinghouse Response:

Section 5.2 of HDP-TBD-WM-908 has been revised to add the method for Tc-99 sample, which is consistent with the methodology currently employed for USEI samples, and to add the disposition of the excess portion of the sample that is not destroyed in the analysis.

NRC Comment:

CH-8, Section 5.2.2, Future Characterization of Piping, Page 15 of 167. Does this response indicate that Westinghouse commits to performing biased sampling for Tc-99 in the piping? Does this response indicate that only pipes that are high in uranium will be sampled in a biased way for Tc-99? If so, what is the technical basis?

NRC Comment:

GEN-1, SA-2 – Regarding the sampling of piping, the response to GEN-1 states that “the only material for which surrogate radionuclides will be used is the HEPA equipment that is identified in Table 8-1 of HDP-TBD-WM-906 in which case U-235 will be used as an indicator of Tc-99 activity,” and the response to SA-2 noted that “Tc-99 concentrations will be determined by radiological sample analysis, as will U-235 and U-238 concentrations (gamma spectroscopy).” However, Enclosure 4 to HEM-12-88 states in the sampling plan for piping destined to USEI that “for batches of piping to be disposed at the USEI facility…the Tc-99 content will be determined through the application of a scaling factor based on batch sampling and laboratory analysis for uranium and Tc-99.” Clarification is needed on the planned Tc-99 analysis scaling factor, which appears (from HEM-12-88) to be using uranium as a surrogate radionuclide.

Westinghouse Response:

Section 5.2.2 of HDP-TBD-WM-908 and Enclosure 4 of Westinghouse letter HEM-12-88 have been revised to describe Westinghouse's commitments to random and biased sampling for piping, and the basis for each sampling approach.

Section 5.2.2 of HDP-TBD-WM-908 has also been revised to clarify the use of the Tc-99 to uranium ratio as an estimator for the mass of scale on the piping.

The sentence at the end of section 5.2.2 of HDP-TBD-WM-908 was intended to apply to concrete slabs rather than piping. A new section 5.2.4 has been added to address the concrete slabs and include this sentence.

Attachment 4, "Sampling Plan for Piping Destined for USEI," to Westinghouse letter HEM-12-88 has been revised to reflect the requirements in the revised section 5.2.2 of HDP-TBD-WM-908. In addition, this document is now Attachment 11 to HDP-TBD-WM-908, as reflected on the Table of Contents.

Table of Contents

Attachments
(Since Revision 2 is for the main body of this Safety Assessment for Additional Hematite Project Waste at USEI, the attachments are not included except for new attachments 11 and 12)

1) Characterization Data Summary in Support of Additional USEI Alternate Disposal Request, HDP-TBD-WM-906
2) Input Parameters, Microshield®[1] Software 7.02, Westinghouse Electric Company LLC, (08-MSD-7.02-1424).
3) Case Files, Microshield® Software 7.02, Westinghouse Electric Company LLC, (08-MSD-7.02-1424).
4) RESRAD Input Parameters
5) RESRAD Case Files
6) Intruder Dose Calculations – Construction Scenario
7) Intruder Dose Calculations – Intruder Well Drilling Scenario
8) Intruder Dose Calculations – Chronic Exposure for Intruder Well Drilling Scenario
9) HDP and USEI Occupational Injury and Illness Data
10) Nuclear Criticality Safety Assessment of the US Ecology Idaho (USEI) Site for Land Fill Disposal of Decontamination and Decommissioning Waste from the Hematite Site.
11) Sampling Plan for Piping Destined for USEI (to be incorporated into HDP-PR-WM-905, *Waste Sampling Methods, Labeling and Custody*)
12) Sampling Plan for Concrete and Asphalt (to be incorporated into HDP-OPS12-WP-023, *Concrete and Asphalt Radiological Characterization: Process Buildings, South and West Vault Floors, Pads and Roadways*)

[1] MicroShield® is a trademark of Grove Software, Inc., registered in the U.S. and other countries.

Table 1, Expected Radionuclides in Westinghouse Hematite Waste

Shipped Volume (m^3)	U-234 (Ci)	U-235 (Ci)	U-238 (Ci)	Tc-99 (Ci)
22848	2.2	0.1	0.4	0.3

The material contingency plan limits (Section 5.2.5) are summed between the Amendment 58 request and this additional request, and the data from both requests will be cumulatively counted against the new limits. The method of arriving at the new limits is:

- In the 20.2002 request approved in Amendment 58 to SNM-33, the total quantity of Tc-99 (based on the mean concentration) was 1 Ci. This quantity corresponded to a post closure dose of 1.9 mrem to the maximally exposed individual. A quantity limit based on the upper 95 percent confidence interval on the mean of 1.6 Ci was selected since it corresponded to a post closure dose of 3 mrem. The 3 mrem and 1.6 Ci values were selected to maintain the dose at the 95% upper confidence level on the mean within the 'few millirem' criterion of NUREG 1757.
- The total quantity of Tc-99 included in the additional 20.2002 request is 0.3 Ci, which corresponds to a post closure dose of 0.8 mrem. Within the additional 20.2002 request, Westinghouse again imposed a limitation on the Tc-99 inventory at the 95 percent upper confidence interval on the mean. The value of 0.45 Ci, which corresponds to a dose of 1.2 mrem, for the additional 20.2002 request was selected to be consistent with the methodology approved in Amendment 58 that ensures the dose to the public at the 95 percent upper confidence interval on the mean is maintained within the 'few millirem standard.'
- Cumulatively , the total Tc-99 inventory for both requests will be maintained at or below 1.3 Ci (1.0 + 0.3 Ci) and the value at the 95 percent confidence interval on the mean will be maintained below 2.05 Ci (1.6 + 0.45 Ci). This will ensure that the dose to the public based on the mean inventory is maintained below 2.7 mrem and below 4.2 mrem at the 95 percent upper confidence interval on the mean. Both of these values are within the 'few millirem' criterion in NUREG 1757 for 20.2002 requests.

The average total activity concentration (sum of all nuclides and progeny) for this waste is approximately 110 pCi/g or approximately 4 percent of USEI's 3,000 pCi/g total activity concentration limit. Less than 5% of the waste from Westinghouse is expected to contain concentrations of hazardous constituents identified in 40 CFR 261.24, including tetrachloroethylene, trichloroethylene, vinyl chloride, arsenic, mercury, or lead.

5.2. Waste Characterization Plan

Detailed characterization data and an accompanying analysis is contained in Attachment 1. Based on the analysis contained in that document and Westinghouse letters HEM-12-67 and HEM-12-88, additional characterization will be performed and the results evaluated prior to shipment of soils, piping, and concrete/asphalt materials covered under this request. The results of these surveys will be used to determine the associated radionuclide inventory. Attachment 1 identifies that no additional sampling will be performed to determine the uranium content of the specific miscellaneous equipment, which are identified in Table 8.1.

As stated in this same attachment, sampling will be performed to verify (and update if necessary) the Tc-99 / Uranium ratio used to determine the Tc-99 content of these materials.

Sample analysis for Tc-99 will be consistent with the methodology currently employed for USEI samples, which is inductively coupled plasma mass spectrometry. Since this analysis is destructive, the sample aliquot is not returned; however, the excess portion of the sample is returned.

5.2.1. Soils

Westinghouse will subject soils, which may include spent limestone used as backfill, associated with this request to the same sampling plan that was detailed in Reference 6 and will use the same radiological controls and programmatic elements detailed in Reference 2. The Tc-99 soil concentrations and variability associated with this request are lower than in the Reference 7 approval. The mean Tc-99 concentration and standard deviation associated with soils considered in this request are 13 pCi/g and 36 pCi/g respectively (Attachment 1). The mean Tc-99 concentration and standard deviation used to develop the sampling approach approved by Reference 7 are 27 pCi/g and 225 pCi/g respectively (Reference 6).

The approach used to sample soils associated with this request will be identical to that approved by Reference 7 (See Reference 6, Attachment 1, Section 10 and Appendix A), and the sample results will be compared to the combined contingency plan limits (Section 5.2.5)

5.2.2. Piping

As indicated in Attachment 1, piping from under Building 240 and 260 will be excluded from this request. Table 3, below, provides a summary of the sampling data for the remainder of the piping. Note that the samples represent concentrations in materials contained within the piping and does not consider the overall mass of the piping walls.

Table 3, Sample Summary Data from Piping for USEI Disposal

Parameter	**Tc-99** (pCi/g)	**U-234** (pCi/g)	**U-235** (pCi/g)	**U-238** (pCi/g)
No. Samples	10	10	10	10
Average	33	1479	57	209
Minimum	2	0	0	0
Maximum	174	6944	258	766
St. Dev.	52	2225	84	292

The piping eligible for disposal at USEI will be sampled based on a random approach or a biased approach, depending on whether the piping requires segregation and evaluation at an MAA/WEA. The segregation to an MAA/WEA is required by Nuclear Criticality Safety Controls based on field instrument gamma results.

For piping that does not require segregation and evaluation at an MAA/WEA, the sampling approach was developed considering that a batch of piping would consist of approximately 100 m^3 of material. This volume is equivalent to that of a rail car. The material in a single rail car was considered an appropriate batch of material since that is the unit of volume upon which waste management decisions are based. Accordingly, the number of samples required to ensure that the median concentration within that batch is less than the maximum observed value was determined using Visual Sampling Plan (True Average vs. Fixed Threshold, where the data is neither considered normal nor symmetrical). This analysis was performed for each of the four nuclides Tc-99, U-234, U-235, and U-238. The resultant number of samples required was 14 or one sample per 7.1 m^3. This is equivalent to 1 sample per 250 ft^3. Based on this analysis, HDP will collect a minimum of one sample per 250 ft^3 of piping and will analyze each sample by gamma spectroscopy and for Tc-99. Prior sampling indicated no relationship between Tc-99 concentration in piping and uranium. For this reason, biased sampling will not be performed for piping materials that do not require segregation and evaluation at an MAA/WEA.

Materials planned for disposal at USEI that are extracted from the in-situ population because they require evaluation at an MAA/WEA will be sampled in order to determine the Tc-99 concentration for the purpose of inventory tracking. This is being done since this material will not be included in the population subjected to the random sampling protocol. For piping that exceeds field screening levels and is sent to an MAA/WEA, biased sampling will be performed for each batch of materials processed through the MAA/WEA. The biased sampling described in the *Sampling Plan for Piping Destined for USEI* (Attachment 11) involves taking 4 aliquots to generate the sample. Laboratory analysis of the sample will be for both uranium and Tc-99.

Since determining the total mass of surface deposits in the piping would be problematic, a Tc-99 to total uranium ratio will be used to determine the total inventory of Tc-99 in the piping. In effect, the amount of total uranium is being used to represent the mass of surface deposits in the piping. Tc-99 to total uranium ratio for that batch will be established from the sample results. This ratio will be multiplied by the total amount of uranium in the batch as determined by the assay at an MAA. The 4 aliquots being used to generate the sample are sufficient to generate a valid scaling factor for that particular batch. As discussed in Section 6.5 of HDP-TBD-WM-906, only 13 percent of the Tc-99 inventory (based on current sample data) is considered for disposal at USEI since certain piping associated with Buildings 240 and 260 have been excluded from disposal at USEI.

5.2.3. Miscellaneous Equipment

The only miscellaneous equipment that is addressed in this request is listed in Table 8.1 of Attachment 1. Characterization data for this material is described in Attachment 1. The Tc-99 scaling factor will be verified through analysis of swipe samples from these items prior to shipment. The associated Tc-99 inventory will be adjusted as necessary based on this data.

5.2.4. Concrete/Asphalt Slabs

Existing characterization data for both concrete and asphalt materials associated with this application are contained in Attachment 1. As stated in section 6.6 of Attachment 1, additional sampling on a systematic grid will be performed and used as a basis for determination of the activity in material prior to it being shipped. The location of the samples and sampling approach are contained in Attachment 12. As discussed in section 6.6 of HDP-TBD-WM-906, Westinghouse will review these sample results prior to shipment of the concrete.

5.2.5. Contingency Plans

Post data collection data analysis will be implemented to determine whether they are adequate in both quality and quantity to support the primary objective of sampling. Specific requirements for this data analysis are contained in sections 6.6 and 7.2 of HDP-TBD-WM-906.

The additional soil for this additional 20.2002 request will be handled in the same way as the prior application (Reference 6, Attachment 1, Section 10) and as such the total Tc-99 inventory is increased to reflect the additional material. These effectively result in this additional inventory being an extension of the prior request and as such the prior action levels which relate to soil are still applicable. Additional action levels specific to piping are included as well. The following Contingency Plan Table (Table 2) considers both the proposed and approved 20.2002 requests:

Table 2, Contingency Plan Table

Prior to shipment, the following conditions will be evaluated, combining results for this and the 20.2002 request approved in Amendment 58 to SNM-33:

Parameter	Action Level	How Monitored	Actions
Total Quantity of Tc-99 shipped to USEI (mean)	>1.3 Ci	Running total activity (both shipped and pending shipment), based on laboratory sample results prior to shipment	• Reanalyze composite sample and/or analyze individual aliquots used to create the composite sample; • Resample stockpile and re-evaluate[a]; • Ship material to alternate facility.
95% Upper Confidence Level of the mean Tc-99 shipped to USEI (UCL(0.95)).	>2.05 Ci	Running confidence interval (both shipped and pending shipment) based on laboratory sample data prior to shipment	• Reanalyze composite sample and/or analyze individual aliquots used to create the composite sample; • Resample stockpile and re-evaluate[a]; • Ship material to alternate facility.
Total activity contribution from all radionuclides within individual railcar	>3000 pCi/g > 40 □R/hrb	Laboratory sample results for stockpile evaluated at 95% UCL prior to shipment Gamma radiation levels on railcars prior to shipment.	• Analyze additional aliquot of composite sample; • Unload railcar (at HDP) and re-load with material containing lower concentration (either blended or alternate material from onsite waste stream)a; • Ship material to alternate facility.
Unexpected Tc-99 results for stockpile samples (soil)	>99th percentile of the site wide dataset (573 pCi/g)c	Laboratory sample results for stockpile evaluated prior to shipment	• Analyze additional aliquot of composite sample; • Resample stockpile and re-evaluatea; • Blend with less contaminated material, resample stockpile and re-evaluate; • Ship material to alternate facility.
Unexpected Tc-99 results for concrete slab samples	>99th percentile of the dataset (1590 pCi/g)	Laboratory sample results for concrete slabs evaluated prior to shipment	• Analyze additional aliquot of sample; • Resample stockpile and re-evaluatea; • Blend with less contaminated material, resample stockpile and re-evaluate; • Ship material to alternate facility.

Table 2, Contingency Plan Table

Prior to shipment, the following conditions will be evaluated, combining results for this and the 20.2002 request approved in Amendment 58 to SNM-33:

Parameter	Action Level	How Monitored	Actions
Unexpected Tc-99 results for stockpile samples (piping internal debris / residue)	>99th percentile of the dataset (162 pCi/g)	Laboratory sample results for stockpile evaluated prior to shipment	• Analyze additional aliquot of composite sample; • Resample stockpile and re-evaluatea; • Blend with less contaminated material, resample stockpile and re-evaluate; • Ship material to alternate facility.
Unexpected Tc-99 results for stockpile samples (piping average concentration)	>99th percentile of the dataset (125 pCi/g)	Laboratory sample results for stockpile evaluated prior to shipment	• Analyze additional aliquot of composite sample; • Resample stockpile and re-evaluate[a]; • Blend with less contaminated material, resample stockpile and re-evaluate; • Ship material to alternate facility.
Maximum average concentration of Ra-226 and Th-232 within individual railcar	Ra-226 >13 pCi/g Th-232 >16 pCi/g	Laboratory sample results for each railcar evaluated prior to shipment	• Analyze additional aliquot of composite sample; • Resample stockpile and re-evaluate[a]; Blend with less contaminated material, resample stockpile and re-evaluate; • Ship material to alternate facility.

[a] Re-sampling of material will generally occur after down blending of stockpile material. When such sampling is performed, the new sample dataset will replace the initial data for the purpose of subsequent calculations. If re-sampling is performed without down blending (which would be the case if the material was sampled in-situ railcars) then, the additional samples will be used to augment the initial dataset.

[b] Based on analysis previously transmitted in HEM-10-46, 5/24/10.

[c] Value shown is the 99th percentile of the pooled site wide Tc-99 dataset with EP-08-00-SL and EP-10-00-SL excluded using spreadsheet software.

11 REFERENCES

1. Westinghouse (G. F. Couture) letter to NRC Document Control Desk HEM-09-52, dated May 21, 2009, "Request for Alternate Disposal Approval and Exemptions for Specific Hematite Decommissioning Project Waste" (ADAMS Accession No. ML091480071)
2. Westinghouse (E. K. Hackmann) letter to Document Control Desk (NRC), HEM-09-146, dated December 29, 2009, "Response to Request for Additional Information - Alternate Waste Disposal" (ADAMS Accession No. ML100320540)
3. Westinghouse (E. K. Hackmann) letter to NRC Document Control Desk, HEM-10-6, dated January 20, 2010, "Additional Information Concerning Alternate Waste Disposal" (ADAMS Accession No. ML100221416)
4. Westinghouse (E. K. Hackmann) letter to NRC Document Control Desk, HEM-10-38, dated March 31, 2010, "Additional Information for Alternate Waste Disposal Authorization and Exemption" (ADAMS Accession No. ML100950386)
5. Westinghouse (E. K. Hackmann) letter to Document Control Desk (NRC), HEM-10-46, dated May 24, 2010, "Additional Information and Clarifications Concerning 10 CFR 20.2002 Alternate Waste Disposal Authorization and Exemption for Specific Hematite Decommissioning Project Waste" (ADAMS Accession No. ML101450240)
6. Westinghouse (E. K. Hackmann) letter to Document Control Desk (NRC), HEM-11-16, dated February 18, 2011, "Revised Technical Basis for Characterization of Decommissioning Soils Waste That is Subject to the Alternate Disposal Request for U.S. Ecology Idaho, Inc" (ADAMS Accession No. ML110530155)
7. USNRC (Keith I. McConnell) letter to Westinghouse (E. K. Hackmann), dated October 27, 2011, Issuance of Hematite Amendment No. 58 Approving Westinghouse Hematite Request for Alternate Disposal of Soil and Debris and Granting Exemptions to 10 CFR 30.3 and 10 CFR 70.3, (ADAMS Accession No. ML112560105)
8. Humboldt Bay, Unit 3 – Request for 10 CFR 20.2002 Alternate Disposal Approval and 10 CFR 30.11 Exemption of Waste For Disposal at US Ecology Idaho (ADAMS Accession No. ML101170554)

APPENDIX R
Contingency Plan Table

Contingency Plan Table

Prior to shipment, the following conditions will be evaluated:

Parameter	Action Level	How Monitored	Actions
Total Quantity of Tc-99 shipped to USEI (mean)	>1.3 Ci	Running total activity (both shipped and pending shipment), based on laboratory sample results prior to shipment	• Reanalyze composite sample and/or analyze individual aliquots used to create the composite sample; • Resample stockpile and re-evaluate[a]; • Ship material to alternate facility.
95% Upper Confidence Level of the mean Tc-99 shipped to USEI (UCL(0.95)).	>2.05 Ci	Running confidence interval (both shipped and pending shipment) based on laboratory sample data prior to shipment	• Reanalyze composite sample and/or analyze individual aliquots used to create the composite sample; • Resample stockpile and re-evaluate[a]; • Ship material to alternate facility.
Total activity contribution from all radionuclides within individual railcar	>3000 pCi/g > 40 μR/hr[b]	Laboratory sample results for stockpile evaluated at 95% UCL prior to shipment Gamma radiation levels on railcars prior to shipment.	• Analyze additional aliquot of composite sample; • Unload railcar (at HDP) and re-load with material containing lower concentration (either blended or alternate material from onsite waste stream)[a]; • Ship material to alternate facility.
Unexpected Tc-99 results for stockpile samples (soil)	>99th percentile of the site wide dataset (573 pCi/g)[c]	Laboratory sample results for stockpile evaluated prior to shipment	• Analyze additional aliquot of composite sample; • Resample stockpile and re-evaluate[a]; • Blend with less contaminated material, resample stockpile and re-evaluate; • Ship material to alternate facility.
Unexpected Tc-99 results for stockpile samples (concrete)	>99th percentile of the site wide dataset (1590 pCi/g)	Laboratory sample results for stockpile evaluated prior to shipment	• Analyze additional aliquot of composite sample; • Resample stockpile and re-evaluate[a]; • Blend with less contaminated material, resample stockpile and re-evaluate; • Ship material to alternate facility.

APPENDIX R
Contingency Plan Table

Contingency Plan Table

Prior to shipment, the following conditions will be evaluated:

Parameter	Action Level	How Monitored	Actions
Unexpected Tc-99 results for stockpile samples (piping internal debris / residue)	>99th percentile of the dataset (162 pCi/g)	Laboratory sample results for stockpile evaluated prior to shipment	• Analyze additional aliquot of composite sample; • Resample stockpile and re-evaluate[a]; • Blend with less contaminated material, resample stockpile and re-evaluate; • Ship material to alternate facility.
Unexpected Tc-99 results for stockpile samples (piping average concentration)	>99th percentile of the dataset (125 pCi/g)	Laboratory sample results for stockpile evaluated prior to shipment	• Analyze additional aliquot of composite sample; • Resample stockpile and re-evaluate[a]; • Blend with less contaminated material, resample stockpile and re-evaluate; • Ship material to alternate facility.
Maximum average concentration of Ra-226 and Th-232 within individual railcar	Ra-226 >13 pCi/g Th-232 >16 pCi/g	Laboratory sample results for each railcar evaluated prior to shipment	• Analyze additional aliquot of composite sample; • Resample stockpile and re-evaluate[a]; Blend with less contaminated material, resample stockpile and re-evaluate; • Ship material to alternate facility.

[a] Re-sampling of material will generally occur after down blending of stockpile material. When such sampling is performed, the new sample dataset will replace the initial data for the purpose of subsequent calculations. If re-sampling is performed without down blending (which would be the case if the material was sampled in-situ railcars) then, the additional samples will be used to augment the initial dataset.

[b] Based on analysis previously transmitted in HEM-10-46, 5/24/10.

[c] Value shown is the 99th percentile of the pooled site wide Tc-99 dataset with EP-08-00-SL and EP-10-00-SL excluded using spreadsheet software.

NRC Comment:

CH-6, Section 5.2.1, Gamma Walkover is used to inform sampling for Tc-99 and RAI SA-4, Page 135 of 167.

NRC asked Westinghouse to provide the basis that no areas of Tc-99 have been overlooked given that sample locations were based on the gamma walkover survey results. Westinghouse committed to perform additional sampling on a systematic grid for Tc-99. Westinghouse stated it will verify the normal distribution assumption applied in determining the number of grid samples once the samples are retrieved. Does this mean that Westinghouse will wait for the sample results and verification of assumptions before performing excavation of this area?

NRC Comment:

It is noted several times in the VSP Sample Design report that a post collection assessment will be performed to validate that the sampling mean is normally distributed and that population values are not spatially or temporally correlated. What will happen if this data analysis indicates the sample mean is not normally distributed or that population values were spatially and temporally correlated? What would be the contingency?

Westinghouse Response:

New section 5.2.4 of HDP-TBD-WM-908 states that Westinghouse will wait for these sample results prior to shipment. The last sentence of section 6.5 of HDP-TBD-WM-906 has been revised to identify that additional sampling is planned.

New section 5.2.5 of HDP-TBD-WM-908 refers to sections 6.6 and 7.2 of HDP-TBD-WM-906 for requirements on the analysis of the sample results. New paragraphs have been added to section 6.6 of HDP-TBD-WM-906 to discuss how the concrete sample results will be evaluated. Note that since the 95th percentile of the inventory is calculated using nonparametric statistics, departure from normality does not necessarily disqualify the data.

New paragraphs have been added to section 7.2 of HDP-TBD-WM-906 to discuss how the piping sample results will be evaluated.

The end of section 7.2 was revised to reflect the changes in section 5.2.2 of HDP-TBD-WM-908 that are discussed elsewhere in this enclosure.

NRC Comment:

RAI SA-1, Page 129 of 167, and RAI GEN-1, Page 80 of 167.

Westinghouse [indicated] that no additional characterization for equipment in Table 8-1 of HDP-TBD-WM-906 will be performed. Does this contradict the statement in Section 8.1 that the scaling factors will be verified?

Westinghouse Response:

Westinghouse will perform additional sampling to verify the Tc-99 to uranium ratio. Text has been added to sections 8 and 8.1 to clarify that this verification is separate from the uranium characterization data.

uranium activity at locations 49, 50, and 51, which are away from any area of elevated activity. Sample locations with known subsurface activity were excluded, since these are accounted for in the samples within each elevated area.

Areas in which Tc-99 was present (based on historical information) were included in the targeted sampling within Buildings 240 and 260. Specifically, Tc-99 was present in materials handled in Areas 1, 2, and 6. The concentration of Tc-99 inside and outside these areas is presented below in Table 6-6. As indicated by this tabulation, the concentration of Tc-99 within the concrete material outside of the areas with a history of Tc-99 use is negligible in comparison to that within areas with such a history. Areas with a history of Tc-99 were targeted for sampling. Outside of these areas, the variation in the Tc-99 is low by comparison such that the remaining samples provide effective characterization without the need for use of a surrogate to identify Tc-99.

Table 6-6, Comparison of Tc-99 and Total Uranium Concentrations Inside and Outside Areas with History of Tc-99

Location	No. of Samples	Tc-99 (pCi/g)			U total (pCi/g)		
		Min	Max	Avg	Min	Max	Avg
Inside areas with history of Tc-99 (Bldg 240 and 260)	18	0.2	2,041	198	0.7	6,659	1,125
Outside areas with history of Tc-99	32	-0.3	12.6	2.4	0.3	3,226	455

Exclusion of portions of the concrete in Building 240 and 260 drastically reduces the variability of Tc-99 concentration within the remaining material. These two areas combined contain 88 percent of the Tc-99 inventory within the process building yet comprise only 3 percent of the material volume. The mean Tc-99 concentration at all sample locations is 73 ± 326 (at 1 sigma). Table 6-7, below, shows a summary of sample results divided into those that fall within the areas to be excluded and those that do not. Removing the two areas mentioned above reduces the mean Tc-99 concentration to 2.5 ± 3.2 (at 1 sigma).

Table 6-7, Comparison of Tc-99 and Total Uranium Concentrations Inside and Outside Areas That Will Be Excluded from Disposal at USEI

Location	No. of Samples	Tc-99, pCi/g			U total, pCi/g		
		Min	Max	Avg	Min	Max	Avg
Inside Areas that will be excluded from disposal	8	3.4	3,663	828	12	6,659	1,788
Outside Areas that will be excluded from disposal	46	-0.3	15.4	2.5	0.3	3,993	500

Based on nature and extent of characterization data available for this material, it is concluded that the data are of sufficient quality to be used as both an estimate of the total activity present in these materials, and to serve as the basis for determining the radionuclide concentration in materials shipped. However, additional sampling and analysis will be conducted as discussed in the next section.

6.6. Additional Characterization Data

Although the existing data are adequate to support this alternate disposal request, additional sampling on a systematic grid will be performed and used as a basis for determination of the activity in material prior to it being shipped. Data quality objectives specific to this sampling are provided in Appendix P. A process flow diagram outlining the characterization effort is shown in Appendix Q.

Appendix K contains the report generated by Visual Sampling Plan (VSP) software for determination of a confidence interval on a mean that is specific to HDP. The half-width of the confidence interval was set to ½ of the mean Tc-99 concentration outside the 5 identified elevated areas. The standard deviation of this same data set was also used. Additional design parameters are indicated on the attached sampling plan which indicates the nominal number of systematic samples to be 20 for each sampling area. Each building (240, 253, 254, 255, 256, 260) with the exception of 252 and 235 (which were combined) was considered a separate sampling area resulting in a total of about 140 samples for the entire process building slabs. The systematic samples will be taken from two depth intervals (0 – 0.75 inch and 0.75 inch to 1.5 inches. The 0.75 inch to 1.5 inch sample will be used in assessing the contamination within the remaining thickness of the concrete slab since the existing data set establishes that the radioactivity of concern is in the top 0.75 inch of the slab. The merging of the data sets will be 2 separate groups – results from the top 0.75 inches and results from the 0.75 inches to bottom of the slab.

Post data collection data analysis recommendations contained in the Appendix K section "Recommended Data Analysis Activities" are not tailored for this use of VSP. Post data collection data analysis will be implemented in the following manner to determine whether they are adequate in both quality and quantity to support the primary objective of sampling.

- A retrospective analysis will be performed using the data results to verify that a sufficient number of samples were collected to meet the data quality objectives. If an insufficient number of samples were collected, the data will be reviewed to determine the cause of the insufficiency (e.g., increased variability). Based on this analysis additional sampling may be performed or the dataset may be re-evaluated once material with localized areas of activity is excluded from the sample population (see items below regarding areas of elevated sample results).
- Data from each sampling area (building) will be reviewed to determine if it is normally distributed.
- Datasets which are not normally distributed will be reviewed to identify areas of elevated sample results. If such a condition is identified, additional samples will be collected as needed to bound the area of elevated activity. Once bounded, the original and bounding sample results will be used to determine the Tc-99 inventory for that individual area. Results located outside of the bounded area will be used to determine the Tc-99 activity within the balance of the material. The Tc-99 inventory for either of these areas will be divided by the mass of concrete in the area. These concentrations will be compared to the limits indicated in Appendix R. Contingency plans for instances where these limits are not met are contained in Appendix R.

- If the data is normally distributed or no areas of elevated activity are present, the data will be deemed usable as long as both the mean Tc-99 inventory and $UCL_{(0.95)}$ are within the limits indicated in Appendix R. The basis for this assertion is that the $UCL_{(0.95)}$ for inventory tracking purposes is calculated without an assumption of normality through the use of Chebyshev's Inequality. Contingency plans for instances where these limits are not met are contained in Appendix R.

Gamma walkover survey data indicates that, with the exception of the asphalt immediately south of Building 240/253, levels at the remaining concrete and asphalt areas are generally bounded by those associated with the process building general area. This is illustrated within Figure 6.6 where it can be seen that greater than 83% of the 1 meter average readings from the asphalt were less than 2,000 cpm while the percentage within the same grouping for the process building pad is only 78%. While the area immediately south of Buildings 240 and 253 appear to be more elevated, the maximum reading in this area is 60,000 cpm as compared to 69,000 cpm on the process building pad. A 100% scan of concrete pad outside Building 231 indicated that fixed alpha and beta/gamma levels did not exceed background levels.

The second sampling approach determined the number of samples to define the confidence interval on the mean activity where the half-width of the confidence interval was set to ½ the mean concentration. The required sample frequency based on the characteristics of the piping evaluated in the current application (mean of 33 pCi/g and standard deviation of 52 pCi/g) is 29 samples over 348 m^3 of piping (based on a 16.5 pCi/g confidence interval half-width and standard deviation of 52 pCi/g). This corresponds to one sample per 12 m^3 of piping. The more conservative sample density (1 sample per 7.1 m^3) will be applied to the sampling of piping. Details of this calculation and the method for sampling are contained in Appendix N.

Post data collection data analysis recommendations contained in the Appendix N section "Recommended Data Analysis Activities" are not tailored for this use of VSP. Post data collection data analysis will be implemented in the following manner to determine whether they are adequate in both quality and quantity to support the primary objective of sampling.

- The dataset will be reviewed to verify that the requisite sample frequency is met.
- The Tc-99 assay results will be compared against action levels presented in Appenix R and actions will be taken as stated in this same table.
- An assessment of the normality of dataset will not be performed and the data will be deemed usable as long as both the mean Tc-99 inventory and $UCL_{(0.95)}$ are within the limits indicated in Appendix R. The basis for this assertion is that the $UCL_{(0.95)}$ for inventory tracking purposes is calculated without an assumption of normality through the use of Chebyshev's Inequality. Contingency plans for instances where these limits are not met are contained in Appendix R.

Additional sampling will be performed on materials with are determined be screening measurements to exceed the nuclear criticality safety threshold values (i.e., > 0.1 g/L). This material will be sampled at a frequency of one sample per batch of material processed through an MAA/WEA.

8. VOLUME / WEIGHT / ACTIVITY ESTIMATES – MISCELLANEOUS EQUIPMENT

During the process building demolition, HEPA units and associated ducting were categorized as: 1) materials with sufficiently low specific activity to be disposed at Bulk Survey for Release (BSFR); 2) materials that exceed the BSFR criteria but which are suitable for disposal at USEI, and 3) materials that are unacceptable for disposal at USEI. Table 8-1 provides a summary of the uranium characterization data for each component.

The U-234, U-238 and Tc-99 activity (Table 8-2) as well as other trace radionuclides (Table 8-3) were determined using scaling factors contained in HDP-TBD-WM-901, *Scaling Factors for Radioactive Waste Associated with the Above Slab Portion of the Process Buildings* (Reference 3.1), and enrichment of 4.5 percent. Use of the scaling data is justified since the scaling factors were derived from equipment equivalent to that under consideration.

The HEPA units were installed and used during the period of commercial work at Hematite (post 1974) and as such were not exposed to uranium with an enrichment of greater than 4.5 percent.

Table 8-1, Summary of HEPA Unit and Associated Ducting Characterization Data – Total U-235 and Material Dimensions

Item	Item U-235 (grams)	Weight (lb)	volume (ft^3)
HEPA 1 240-12	8.03	2,580	6.45E+01
HEPA 2 240-12	7.08	2,580	6.45E+01
HEPA 3 253-26	7.08	2,580	6.45E+01
HEPA 7 254-35	13.88	2,580	6.45E+01
HEPA 18 255-51	9.25	2,580	6.45E+01
HEPA exhaust duct 240-12; y-duct at blower 240-12	1.68	450	1.13E+01
240-4 stack duct	1.68	134	3.35E+00
stack flange-240	1.33	450	1.13E+01
Total	**50**	**13,934**	**348**

package, and as such the average concentration of the package would be approximately 520 pCi/g, or 17 percent of the 3,000 pCi/g limit.

The overall amount of Tc-99 activity was determined based on waste scaling factors derived from the laboratory analytical data obtained during the initial characterization surveys and sampling performed in 2008, and subsequently published in HDP-TBD-WM-901, *Scaling Factors for Radioactive Waste Associated with the Above Slab Portion of the Process Buildings* (Reference 3.1). The waste scaling factors for Tc-99 to U-235 described in this document are appropriate since they were based on samples obtained from the surfaces that were exposed to the same radionuclide mixture. The Tc-99 concentrations within the individual items ranged from 1.4 to 28 pCi/g; and averaged 4 pCi/g (standard deviation was 8.6pCi/g). Consistent with process history that indicated that this equipment was not directly involved in processes that would have involved Tc-99, the concentration of Tc-99 contributed only a small fraction of the total activity in the source term. The Tc-99 scaling factor used in the above calculations will be verified through analysis of swipe samples from these items prior to shipment. The associated Tc-99 inventory will be adjusted as necessary based on the verified scaling factor and the existing uranium data. Scaling factor verification is not considered characterization since no additional uranium characterization of the equipment will be performed.

9. VOLUME / WEIGHT / ACTIVITY ESTIMATES - SUB-SLAB SOIL

Conceptual excavation contours for soils (including limestone backfill) beneath the former process buildings are shown on Figure H-1. These contours are based on soil sample results exceeding the DCGLs or exceeding the chemical Remediation Goals (RGs), and includes a projected average excavation depth of 2 feet within the footprint of the former Process Buildings.

The soils beneath the process building slabs were initially characterized during the site remedial investigation. Additional samples were collected during the 2010 and 2011 concrete slab characterization efforts. Finally, a series of core samples available from the earlier remedial investigation report were analyzed. Analysis of these samples provided data for soils down to the 16.5 ft below the surface. Sample locations are shown on Figure H-2. Note that different symbols are used to discern samples collected immediately under the building slab (e.g., initial 6 inches), versus samples collected subsurface, and the samples collected from archived cores (e.g., 4 foot composite samples down to 16.5 ft)

This combined data was used to develop an estimate of the radionuclide concentration within the sub-slab soil that is likely to be excavated. Analytical results for samples obtained from the areas within the excavation contours shown in Figure H-1 are presented in Tables H-1 through H-12 Data presented in Appendix H is summarized below in Table 9-1.

NRC Comment:

CH-9, Section 5.2, Inconsistencies in Table 6-2 thru Table 6-4 and Fig 1, RAI SA-3, Page 131 of 167, RAI SA-5, Page 136 of 167.

It is still not entirely clear how some of the values were determined in Table 6-5 from the sample data in the Appendix. The weights applied to the concentrations for each core segment are needed to reproduce the calculation.

Westinghouse Response:

Table 6-5 of HDP-TBD-WM-906 and associated text were revised to explain how the values were determined and add data that would allow reproduction of the calculation. In addition, the spreadsheet used to perform the calculation is provided as Enclosure 5 to Westinghouse letter HEM-12-121.

The waste mass of 5.35E9 g that is listed in Table 6-5 of HDP-TBD-WM-906 for concrete outside process buildings slabs is corrected from the mass listed on page 142 of 167 of Westinghouse letter HEM-12-67. The mass listed in HEM-12-67 should have been 1.18E7 lbs instead of 1.72E7 lbs. Editorial corrections were made in Table 6-5 of HDP-TBD-WM-906 to building numbers and to provide consistency among the location descriptions. Editorial correction was made to a reference to Table 6-4 that should have been 6-3.

Additional Westinghouse Information

Westinghouse noted that Figure G-1 to HDP-TBD-WM-906 was not revised as stated in Westinghouse letter HEM-12-67; page changes for Figure G-1 are included in this enclosure.

Table 6-4, Determination of Average Activity below ¾ inch in Elevated Area 3*

Station ID	Sample Mass (g)	Tc-99 (pCi/g)			U-234 (pCi/g)			U-235 (pCi/g)			U-238 (pCi/g)		
		Conc.	±2σ	MDC	Conc.	±2σ	MDC	Conc.	±2σ	MDC	Conc.	±2σ	MDC
2	1,366	0.46	0.86	2.1	4.7	-	-	0.2	0.2	0.1	0.3	3.0	1.8
3	1,301	2.8	1.1	2.2	4.6	-	-	0.2	0.2	0.1	3.8	3.4	1.7
5	1,620	0.45	0.85	1.9	12.0	-	-	0.6	0.3	0.2	4.5	4.0	2.1
7	1,250	0.041	0.79	2.1	4.7	-	-	0.3	0.1	0.1	0.9	2.8	1.6
8	1,090	1.8	0.93	2.2	10.0	-	-	0.3	0.2	0.1	-0.4	9.6	2.1
9	1,340	0.57	0.79	2.1	2.4	-	-	0.1	0.1	0.1	1.4	2.5	1.3
10	1,780	0.073	0.83	1.9	29.0	-	-	1.6	0.4	0.1	13.2	4.0	0.6
11	1,110	-0.40	0.78	2.0	39.0	-	-	2.1	0.4	0.1	13.8	4.1	0.9
12	2,050	0.31	0.33	1.2	0.5	-	-	0.0	0.1	0.1	0.3	2.7	1.6
15	1,190	1.6	0.39	1.2	15.0	-	-	0.8	0.2	0.1	2.9	3.0	1.5
19	3,040	0.32	0.36	0.90	8.9	-	-	0.5	0.2	0.1	4.8	3.9	1.8
	Maximum	**2.8**			**39**			**2.1**			**14**		
	Average	**0.64**			**11**			**0.59**			**4.2**		

* Sample Locations excluded since portion will not be shipped to USEI: 1, 4, 6, 13, 14, 16, 17, 18, 20, 21

Review of concentration data in Areas 1and 5 indicated concentrations of Tc-99 (Area 1) and Uranium (Area 5) such that a large fraction of the total radionuclide inventory would come from a small area. In each of these areas, it was determined that the 3,000 pCi/g limit on railcar radionuclide activity could be obtained from an area of such small size (less than 500 ft^3) as to require operational restrictions to ensure that such a contiguous area be prevented from being placed in a single railcar. Accordingly, the northeast portion of Area 1, which consists of the 3 inch over-poured floor surface, and Area 5 will be excluded from disposal at USEI. Based on this determination, the concentration in these areas presented in this document excludes samples from these areas.

The radionuclide activity for areas outside the process building and vaults was conservatively estimated using the data presented in Table 6-3, above. Use of this data is valid based on existing gamma survey data indicating an absence of areas of elevated contamination in these materials such as those present in the process building and vaults.

Table 6-5, below provides a summary of the activity assigned to the materials discussed. The radionuclide concentrations in Table 6-5 are calculated as the average of the listed sample station concentrations. Each sample station concentration is calculated using a weighted average. The weighting factor for stations 1 to 21 is the sample mass from Table 1 of Appendix D. The weighting factor for stations 31 to 59 is the thickness of the concrete that was sampled.

Table 6-5, Summary of Radionuclide Concentration in Building Slabs

Location	Sample Stations	Waste Volume (m^3)	Waste Mass (g)	Tc-99		U-234		U-235		U-238	
				pCi/g	Ci	pCi/g	Ci	pCi/g	Ci	pCi/g	Ci
Elevated Area 1 - Bldg 240, Red Room	2, 3, 35 (all >3"), & 4, 5	64	1.12E8	2	0.000	574	0.064	30	0.003	204	0.02
Elevated Area 2 - Bldg	6, 7, 8	56	9.80E7	6.1	0.001	459	0.045	23	0.002	126	0.01

Location	Sample Stations	Waste Volume (m^3)	Waste Mass (g)	Tc-99 pCi/g	Tc-99 Ci	U-234 pCi/g	U-234 Ci	U-235 pCi/g	U-235 Ci	U-238 pCi/g	U-238 Ci
240, Green Room											
Elevated Area 3 - Bldg 254	58, 59 (both <¾”), *	8.8	1.56E7	2.6	0.000	262	0.004	12	0.000	48	0.00
Elevated Area 4 -Bldg 255	14, 15, 16	21	3.74E7	4.9	0.000	295	0.011	12	0.000	51	0.00
Elevated Area 6 - Bldg 252	52, 53, 56 & 57 (<0.75”), *	40	6.99E7	4.2	0.000	156	0.011	7.1	0.000	15	0.00
Bldg 235	54, 55	12	2.03E7	1.9	0.000	22	0.000	1.9	0.000	2.7	0.00
Total - Elevated Areas	**-**	**200**	3.53E8	**3.9**	**0.0014**	**385**	**0.14**	**19**	**0.007**	**110**	**0.039**
Balance of Process Buildings Slabs Excluding: Areas (1-4), area 1 cap, area 5 and Vaults	**, ***	1,152	2.03E9	2.7	0.0055	233	0.47	10	0.021	45	0.09
Building Total	-	**1,353**	**2.38E9**	**2.9**	**0.0069**	**256**	**0.610**	**11.5**	**0.028**	**55**	**0.13**
Concrete outside process buildings slabs	Avg. from Table 6-3	3,035	5.35E9	2.7	0.014	48	0.26	1.94	0.010	8.3	0.04
Asphalt		1,112	1.96E9	2.7	0.005	48	0.095	1.94	0.004	8.3	0.016
Total for Site	-	**5,499**	**1.21E10**	**2.7**	**0.026**	**99**	**0.96**	**4.3**	**0.042**	**19.8**	**0.19**

* Maximum Concentration for each isotope from >0.75" core samples (excluding samples at expansion joints, cracks, seams, and/or near walls) from Table 6-4.

** Average concentration inside areas where GWS exceeded 4,400 cpm or where there are higher Tc-99 samples. Averages are from Table 6-2. This average represents 18 percent of the total area and volume.

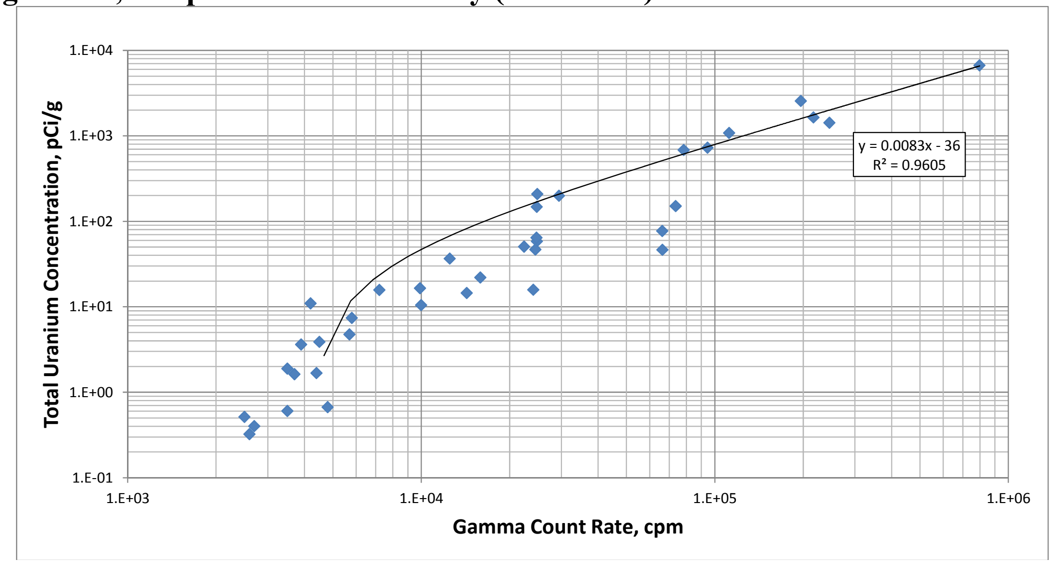
*** Average concentration outside elevated areas where GWS exceeded 4,400 cpm or where there are higher Tc-99 samples. Averages are from Table 6-3. This average represents 82 percent of the total area and volume.

6.5. Evaluation of Characterization Data

Data from 50 sample locations has been obtained during sampling efforts. Of these 50 samples, 33 were targeted in and around areas of elevated activity. The remaining 17 locations were dispersed throughout the remainder of the building. A GPS logged gamma walkover survey was conducted. This survey demonstrates that areas with elevated activity were sampled. This fact is clearly evident upon inspection of Figure 6-3 and Appendix D, Figure 1.

The suitability of the GPS walkover data to identifying elevated uranium activity can be seen in Figure 6-5, below, in which the gamma count rate and total uranium activity at each sample location is plotted.

Figure 6-5, Graph of Surface Activity (count rate) Versus Total Uranium Activity

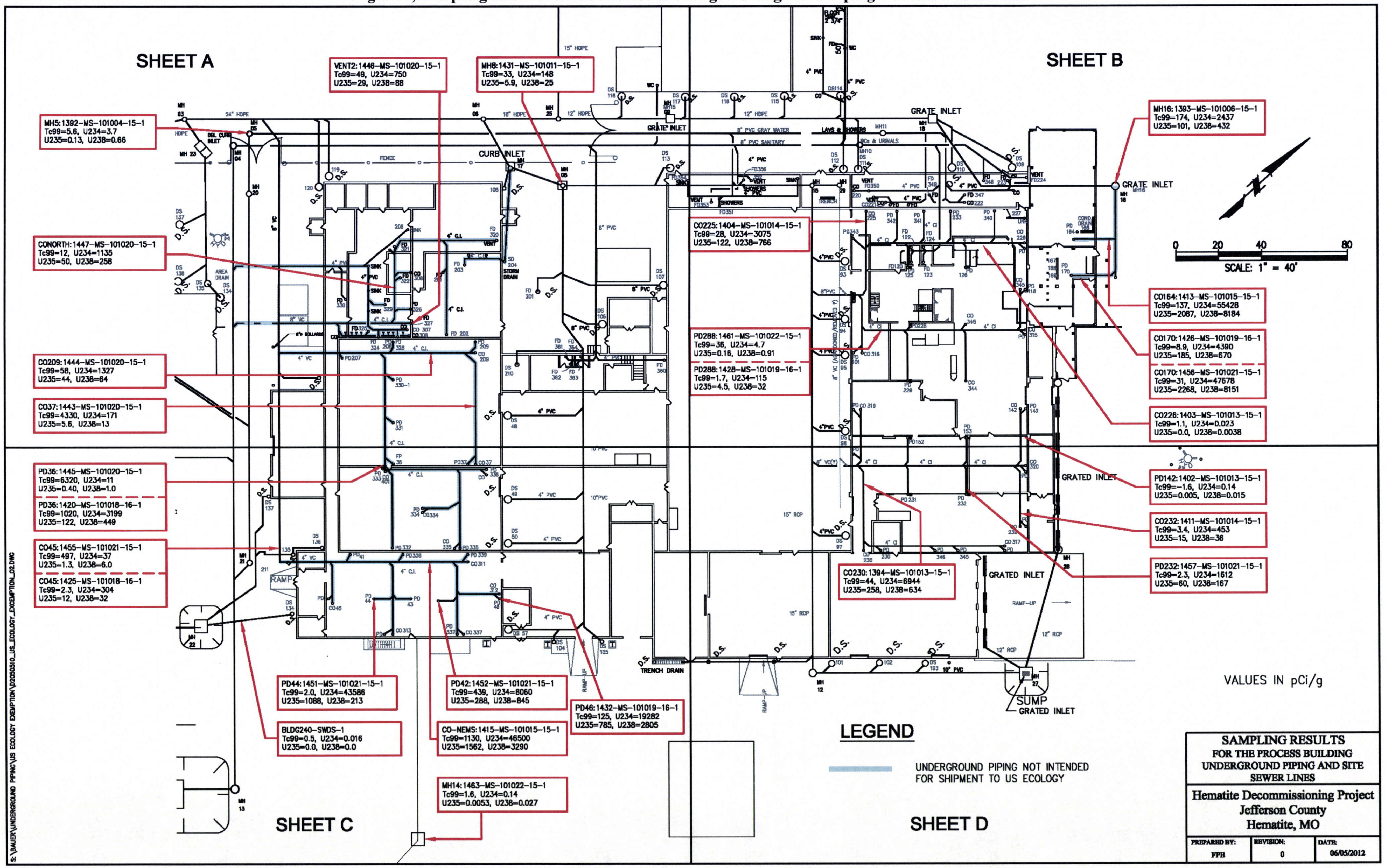


The axis for the plot in Figure 6-5 was selected to indicate 0.4 pCi/g total uranium at a gamma count rate of 4400 cpm. These values were selected to represent ambient conditions based on the baseline gamma response within the building and on the total

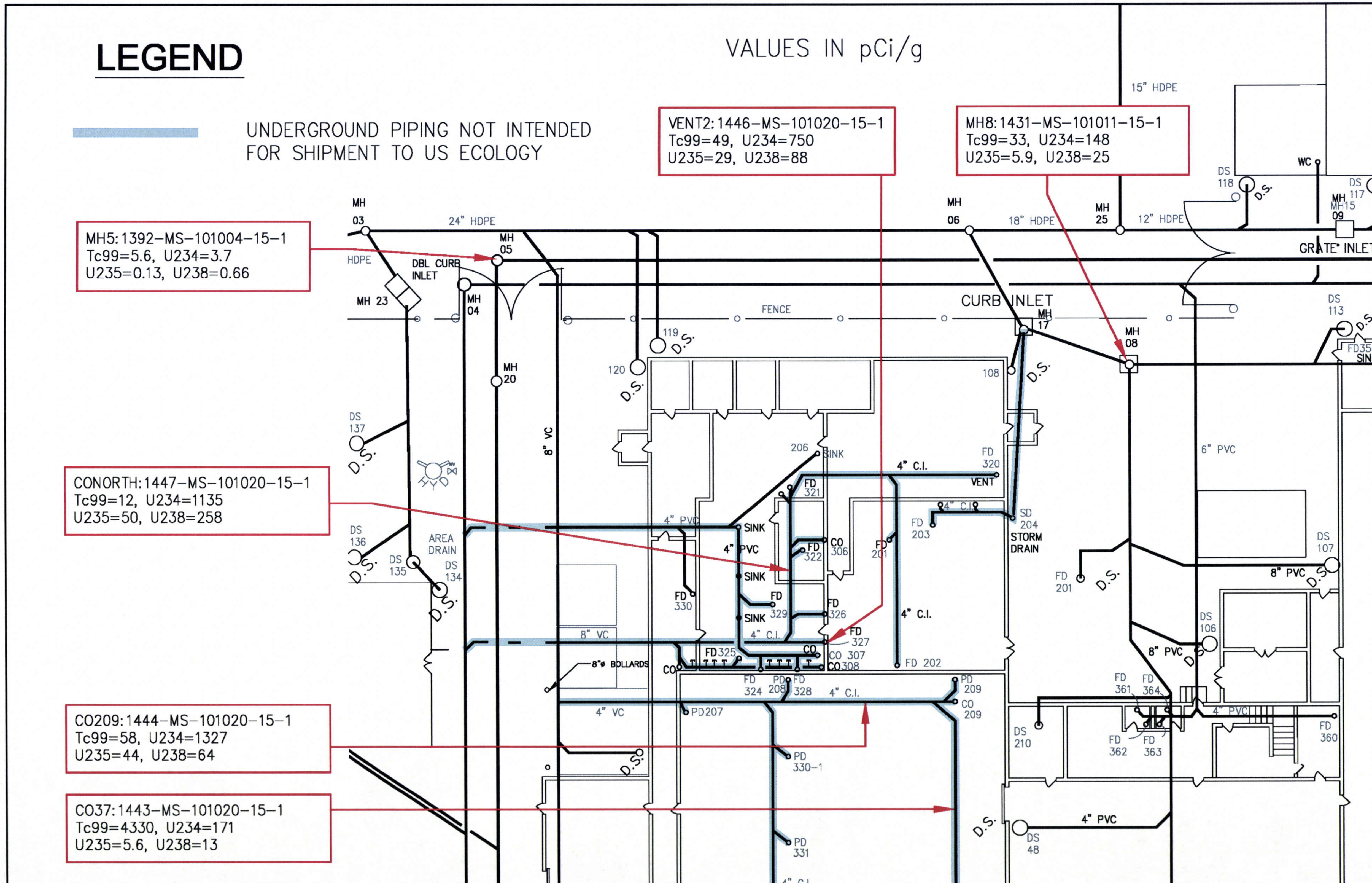
Appendix G

Radiological Sampling Results – Underground Piping

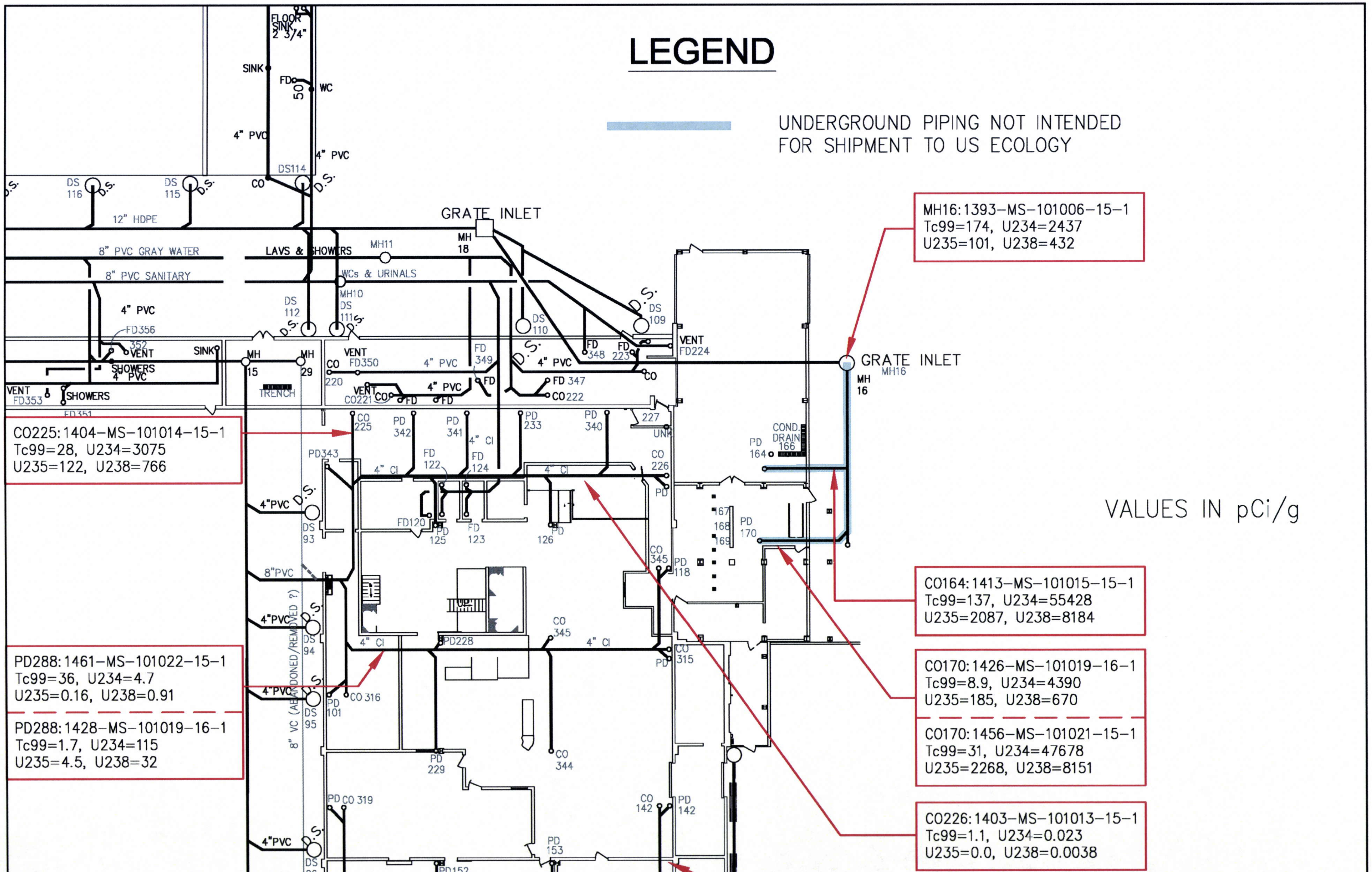
Figure 1, Sampling Results for the Process Buildings Underground Piping and Site Sewer Lines



Appendix G
Radiological Sampling Results – Underground Piping
Sheet A to Figure 1



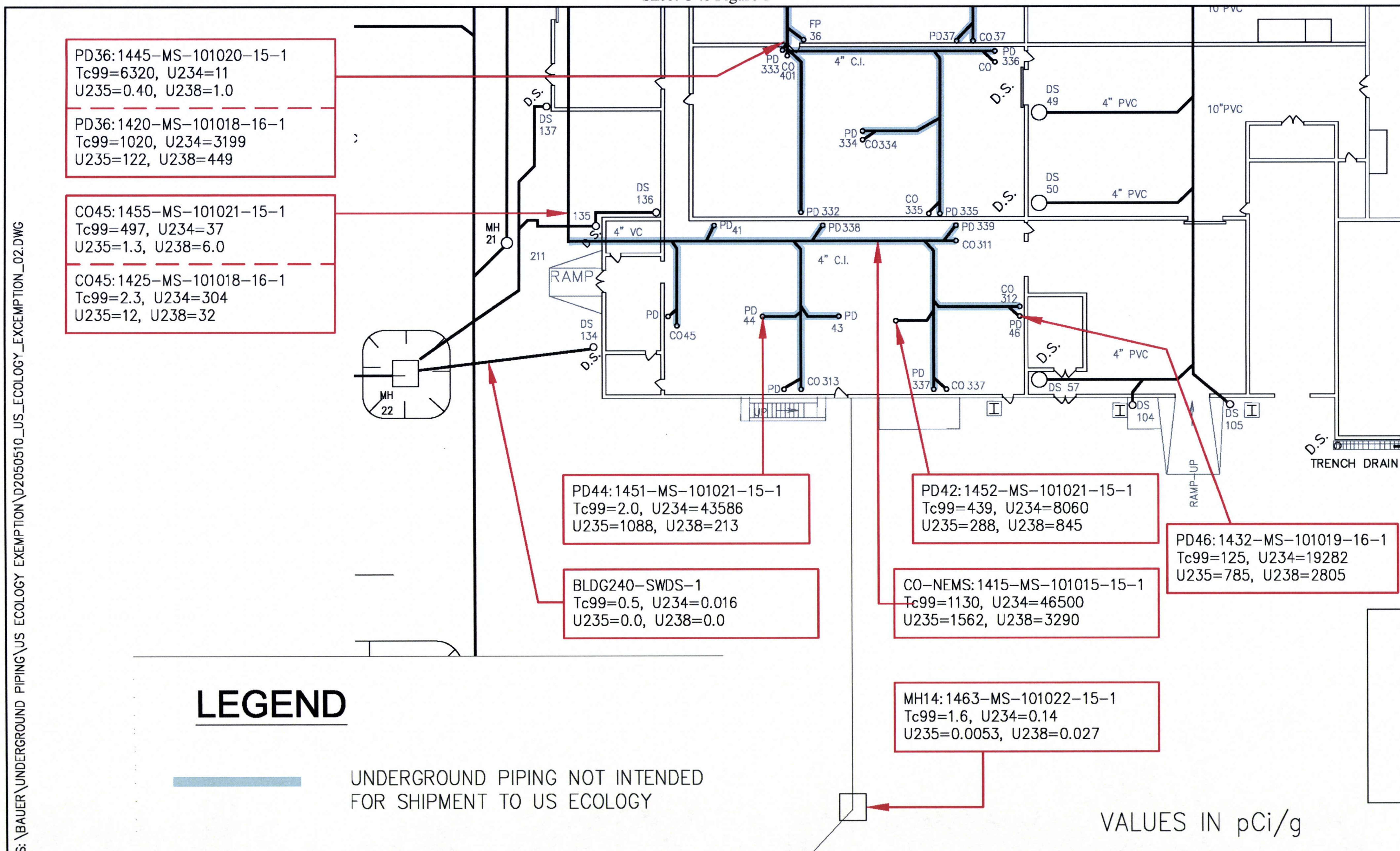
Appendix G
Radiological Sampling Results – Underground Piping
Sheet B to Figure 1



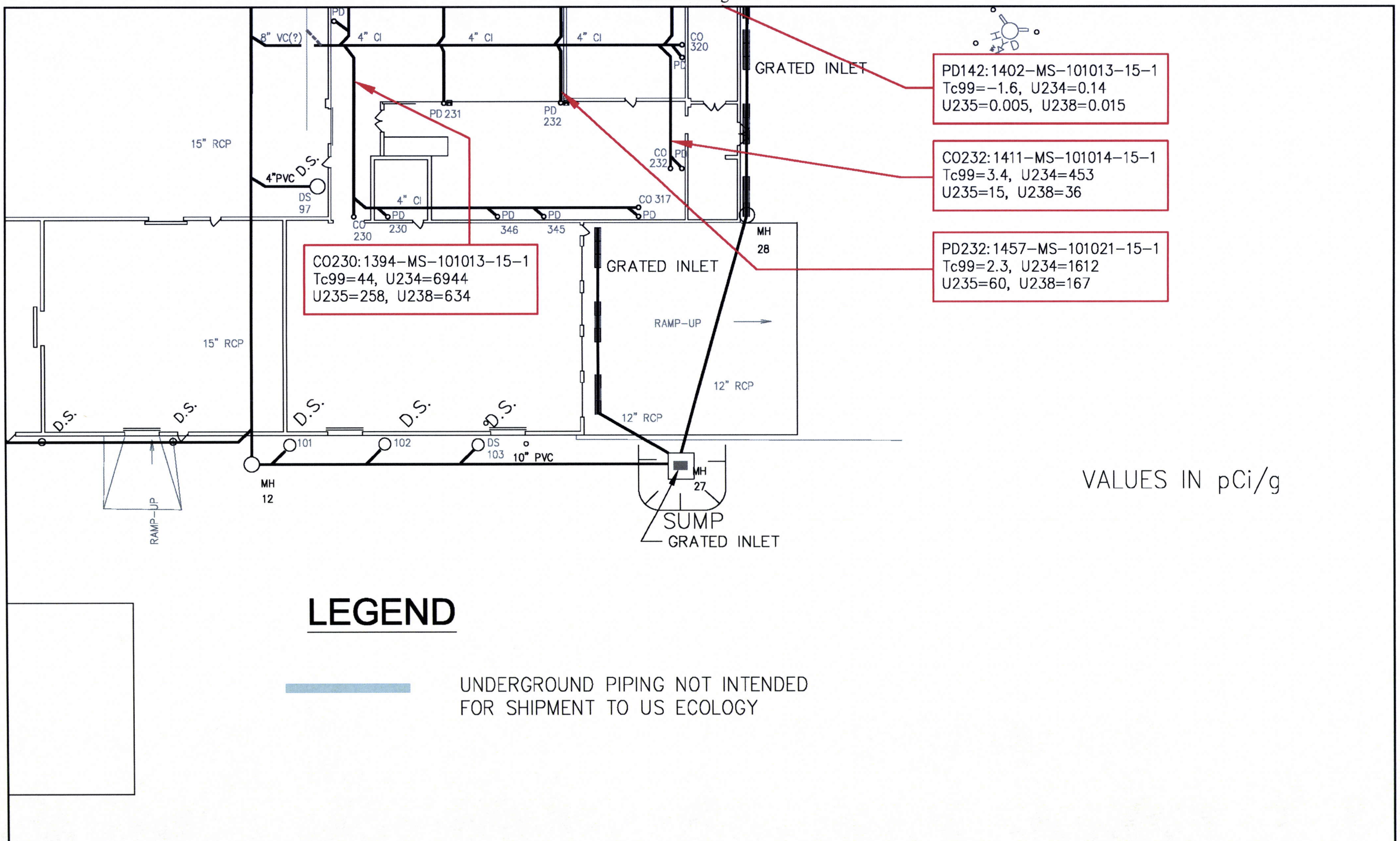
Appendix G

Radiological Sampling Results – Underground Piping

Sheet C to Figure 1



Appendix G
Radiological Sampling Results – Underground Piping
Sheet D to Figure 1



Enclosure 2 to HEM-12-121

Spreadsheet, "99th Percentile Piping.xlsx"

(For the NRC docket, the electronic spreadsheet file with the above filename is submitted in its native file format as an EIE attachment)

Westinghouse Electric Company LLC
US Ecology Idaho, Inc.

Westinghouse Electric Company LLC, Hematite Decommissioning Project

Docket No. 070-00036

Enclosure 3 to HEM-12-121

Spreadsheet, "99th Percentile Soil.xlsx"

(For the NRC docket, the electronic spreadsheet file with the above filename is submitted in its native file format as an EIE attachment)

Westinghouse Electric Company LLC
US Ecology Idaho, Inc.

Westinghouse Electric Company LLC, Hematite Decommissioning Project

Docket No. 070-00036

Enclosure 4 to HEM-12-121

Spreadsheet, "Core Sample Data.xlsx"

(For the NRC docket, the electronic spreadsheet file with the above filename is submitted in its native file format as an EIE attachment)

Westinghouse Electric Company LLC
US Ecology Idaho, Inc.

Westinghouse Electric Company LLC, Hematite Decommissioning Project

Docket No. 070-00036

Enclosure 5 to HEM-12-121

Nuclear Criticality Safety Assessment of Sub-Surface Structure Decommissioning at the Hematite Site

Revision 1
November 2011

Westinghouse Electric Company LLC
US Ecology Idaho, Inc.

Westinghouse Electric Company LLC, Hematite Decommissioning Project

Docket No. 070-00036

Nuclear Criticality Safety Assessment of Sub-Surface Structure Decommissioning at the Hematite Site

Revision 1

November 2011

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This document prepared by Nuclear Safety Associates, Inc., for Westinghouse Electric Company, under contract.

NuclearSafety Associates

Revision History

Rev. #	By	Significant Changes
0	D. Vaughn	▪ Original issue.
1	B. Matthews & D. Mann	▪ To maintain consistency with Reference 8, the definition of the *Fissile Material Exhumation Limit* is redefined. ▪ Results of the radiological survey performed on the concrete slabs of the former process and auxiliary building are incorporated into this assessment. These radiological survey results coupled with results of cored-concrete sample analysis, which are also incorporated in this assessment, were sufficient to demonstrate that a criticality accident from concrete slab excavations is not credible. CSCs are nonetheless implemented that protects *Bounding Assumptions* of downstream operations. Furthermore, because the assessment concludes that concrete debris generated from concrete slabs removal operations meets *NCS Exempt Material* criteria, requirements to collect concrete debris into a *Field Container* has been removed. ▪ Excavation of the soil/ground regions beneath the concrete slabs (once the slabs are removed) that do not cover subterranean structures is only required if : (1) The soil/ground regions are beneath the concrete slabs of Building 240 and Building 260 (former processing buildings that handled solution forms of ^{235}U) AND (2) The independent surface measurements of the soil/ground regions beneath the concrete slabs of Building 240 and Building 260 indicate presence of *Fissile Material*. Requirements to excavate all soil regions beneath the concrete slabs have been removed. ▪ Requirements pertaining to handling of *Field Containers* filled with soil that does not meet *NCS Exempt Material* criteria have been explicitly removed from this assessment. These requirements are replaced with referrals to Reference 8 to maintain consistency. ▪ Results of the in-pipe probe radiological surveys performed on subterranean piping are incorporated into this assessment. These results allowed the following changes to subterranean pipe exhumation activities: ✓ Requirements to fill the subterranean pipe sections with grout or expanding foam fixative prior to extracting the section from the ground has been replaced with capping or bagging all open ends of the pipe sections to be extracted. ✓ In-pipe assay is no longer the only approved measurement method for the subterranean piping. Surface assays of the exposed subterranean piping are also allowed as supplemental measurements to the subterranean pipes. ✓ Use of *Secured-Isolated Storage Areas* (SISAs) has been authorized which are used exclusively to securely stage and

Rev. #	By	Significant Changes
		store capped (or bagged), intact (uncrushed), extracted pipe sections that have been demonstrated or suspected to contain *Fissile Material* (or that have not been demonstrated to meet *NCS Exempt Material* criteria). A ^{235}U mass limit of 700 grams is currently established for each SISA provided a 12’ separation is maintained between individual SISAs. ▪ In order to maintain consistency with established limits for CDs, a ^{235}U mass limit of 350 grams is established for extracted piping placed inside CDs. Consequently, the restriction that only one pipe segment may be deposited per CD has been replaced with the mass limitation. Furthermore, the pipe volume restriction that can be placed inside the CD has also been replaced with the mass limit (as compared to the previous 10 liter segment requirement). ▪ It has been identified by operations that placing an extracted intact pipe section on the ground adjacent to the extracted location is more efficient and relieves other potential job-related hazards compared with the current process of placing the intact pipe section on an inspection stand. Since this process detail is not driven by criticality safety, it has been removed from the process discussion and related safety controls. ▪ The *Extracted Piping Fissile Material Limit* is increased from 75 g^{235}U to 350 g^{235}U. ▪ Other minor changes.

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GLOSSARY OF ACRONYMS, ABBREVIATIONS, AND TERMS

Acronym/Term	Definition
AEC	Atomic Energy Commission
ALARA	As Low As Reasonably Achievable
CD	Collared Drums (CDs) are used (as relevant to this NCSA) for *Field Container* and for extracted pipe segments transit between the excavation site and a WEA. Each CD has a cylindrical geometry, possessing a minimum internal diameter of 57 cm. Each CD, irrespective of dimension, is fitted with a collar that extends 18" beyond the external radial surface of the CD. The CD collar is designed to ensure that any un-stacked arrangement of CDs would guarantee a minimum 36" separation distance between the outer surfaces of the CDs. The affixed collar is permanently secured to the CD and is not removed at any time the CD is being used, except when secured in a FMSA or CDRA. Each CD is limited to a total 235U mass of no more than 350 g^{235}U.
CDRA	Collared Drum Repack Area
CFR	Code of Federal Regulations
cm	Centimeter
CSC	Criticality Safety Control
cut depth	Term used to define the appropriate exhumation depth that can be excavated before needing to assay exposed debris. The calibration document for the particular assay equipment used on a particular type of debris determines this maximum thickness of debris than can be exhumed before needing to perform additional assays.
D&D	Decontamination and Decommissioning
Double Contingency Principle	Safety principle interpreted by ANSI/ANS-8.1 as "Process designs should incorporate sufficient factors of safety to require at least two *unlikely*, independent, and concurrent changes in process conditions before a criticality accident is possible."
Extracted Piping Fissile Material Limit	Upper threshold of 350 g^{235}U within a section of intact subterranean piping. Uranium content within a contiguous pipe section higher than this value cannot be extracted intact.
Field Container	Container used to collect suspected *Fissile Material* discovered during decommissioning activities (limited in volume to 20 liters)
Fissile Material	Material that contains a significant quantity of ^{235}U such that criticality safety controls are required when handling this material.
Fissile Material Exhumation Limit	Fissile materials with a fissile nuclide mass content that exceed the *NCS Exempt Material* criteria but with an upper threshold of 700 ^{235}U.
FMSA	Fissile Material Storage Area – area used to interim store containerized *Fissile Materials* that have an ascribed ^{235}U mass content. The containerized *Fissile Material* are sealed within CDs.
g	Gram
GM	Geiger-Muller
g/cm^3	gram per cubic centimeter
highly improbable	Probability of occurrence not expected during the anticipated decommissioning duration and involves concurrent fruition of at least two independent and *unlikely* occurrences.
HPGe	High purity germanium detector
Kg	Kilogram
L	Liter
lbs	Lbs
HRGS	High Resolution Gamma Spectrometer
likely	Probability of occurrence anticipated to occur frequently
MCNP	Monte Carlo n-particle transport code
mg	Milligram
MLD	minimum level of detection

Acronym/Term	Definition
MO	Missouri
NaI	sodium iodide
NCS Exempt Material	Material not requiring NCS oversight..
NCS	Nuclear Criticality Safety
NCSA	Nuclear Criticality Safety Assessment
NCSC	Nuclear Criticality Safety Calculation
PPE	Personal Protective Equipment
SNM	Special Nuclear Material (synonymous with '*Fissile Material*' used in this document)
SISA	Secured Isolated Storage Area – an isolated, secured area that is used (as relevant to this NCSA) to securely stage and store capped (or bagged), intact (uncrushed), extracted pipe sections that have been demonstrated or suspected to contain Fissile Material (or that have not been demonstrated to meet the NCS Exempt Material criteria). Each SISA is authorized to store up to 700 g^{235}U.
Soil	A natural body comprised of solids (minerals and organic matter), liquid, and gases that occur naturally on land surfaces. Stones, gravels and other back-fill type materials are also defined as *soil* in this document.
SSC	System, structure, or component
U	Uranium
UF_6	uranium hexafluoride
unlikely	Probability of occurrence no greater than one time during the anticipated decommissioning duration
WEA	Waste Evaluation Area – area used to evaluate solid wastes generated from site remediation activities that are believed to have the potential to contain SNM in a quantity/concentration sufficient to require NCS controls/oversight.
WHA	Waste Holding Area – area used to stage solid wastes generated from site remediation activities that have been categorized as *NCS Exempt Material*.
wt. %	Percentage by weight

1.0 INTRODUCTION

This Nuclear Criticality Safety Assessment (NCSA) is provided in support of final decommissioning of the Hematite site. The activities assessed in this NCSA encompass excavation of subterranean structures, which include concrete slabs and foundations, piping, surrounding soil, and septic and sewage treatment systems that are to be unearthed at the Hematite site and eventually packaged for disposal at an accepting off-site facility.

This NCSA is organized as follows:

- **Section 1** introduces the NCSA of Sub-Surface Structure Decommissioning at the Hematite site.
- **Section 2** provides the risk assessment of Sub-Surface Structure Decommissioning, as outlined in Section 1.
- **Section 3** summarizes any important engineered and administrative requirements identified in the criticality safety risk assessment provided in Section 2.
- **Section 4** details the conclusions of the NCSA of Sub-Surface Structure Decommissioning at the Hematite site.

1.1 DESCRIPTION OF THE HEMATITE SITE

The Westinghouse Hematite site, located near Festus, MO, is a former nuclear fuel cycle facility that is currently undergoing decommissioning. The Hematite site consists of approximately 228 acres, although operations at the site were confined to the "central tract" area which spans approximately 19 acres. The remaining 209 acres, which is not believed to be radiologically contaminated, is predominantly pasture or woodland.

The central tract area is bounded by State Road P to the north, the northeast site creek to the east, the union-pacific railroad tracks to the south, and the site creek/pond to the west. The central tract area currently includes former process buildings, facility administrative buildings, a documented 10 CFR 20.304 burial area, two evaporation ponds, a site pond, storm drains, sewage lines with a corresponding drain field, and several locations comprising contaminated limestone fill.

1.2 HEMATITE SITE HISTORY

Throughout its history, operations at the Hematite facility have included the manufacturing of uranium metal and compounds from natural and ^{235}U for use as nuclear fuel. Specifically, operations have included the conversion of uranium hexafluoride (UF_6) gas of various ^{235}U enrichments to uranium oxide, uranium carbide, uranium dioxide pellets, and uranium metal. These products were manufactured for use by the federal government and government contractors and by commercial and research reactors approved by the Atomic Energy Commission (AEC). Research and Development was also conducted at the facility, as were uranium scrap recovery processes.

The Hematite facility was used for the manufacture of low-enriched (≤ 5.0 wt.% ^{235}U), intermediate-enriched (5 wt.% < ^{235}U ≤ 20 wt.% ^{235}U) and high-enriched (> 20 wt.% ^{235}U) materials during the period 1956 through 1974. In 1974 production of intermediate and high-enriched material was discontinued and all associated materials and equipment were removed from the facility. From 1974 to cessation of manufacturing operations in 2001, the Hematite facility produced nuclear fuel assemblies for commercial nuclear power plants. In 2001, fuel manufacturing operations were terminated and the facility license was amended to reflect a decommissioning scope. Accountable uranium inventory was removed and Decontamination and Decommissioning (D&D) of equipment and surfaces within the process buildings was undertaken. This effort resulted in the removal of the majority of process piping (above ground piping) and equipment from the buildings. At the conclusion of that project phase, the accessible surfaces of the remaining equipment and surfaces of the buildings were sprayed with fixative in preparation for building demolition.

1.3 SUBTERRANEAN STRUCTURES

Several former process buildings and facility administration buildings are situated on the Hematite Site. Each of the former process buildings required a combination of storm water drains and lines, sanitation lines, gray water lines, and process drains and lines. Two different sewage treatment tanks and one septic tank have been used at the Hematite Facility. The first septic tank was commissioned at the start of operations in 1956 and was taken out of service between 1977 and 1978, at which time the sewage treatment tank, which employed an aerated system, was placed in service and remained in service until mid 1991. These two treatment tanks filtered into a sand and gravel drain field. In 1991, a larger aeration system was placed in service, which bypasses the sand and gravel drain fields.

This evaluation assumes that the former process buildings and other structures will have been demolished and reduced to grade level prior to decommissioning concrete slabs, foundations, subterranean process piping, and other subterranean structures.

There are several building drawings and site plans that depict the location and dimensions of the subterranean structures. However, these are used only as a guide for this NCSA. Specifically, no reliance is placed on the content depicted on the existing drawings and plans.

1.4 EXCAVATION OPERATIONS

In order to excavate the subterranean structures such as piping, surrounding soil, and the septic tank and sewage treatment tanks, it is necessary to first remove any concrete slabs that are located on the surface of the ground above the piping. Concrete slabs of the Hematite facility former process and auxiliary buildings are crushed, broken, cut, or hammered and the concrete debris is subsequently excavated and transferred to an appropriate stockpile in a Waste Holding Area (WHA). Once concrete slabs are removed, surface assays of the underlying regions are performed to identify any contaminated ground regions. Excavation of contaminated ground regions identified by the surface assay (if any) will then be carried out. Further excavation of the ground material beneath the concrete slabs would only be necessary if the *NCS Exempt Materia*l limit is not met and/or subsurface structures (e.g., piping and septic system) is present and requires exhumation. Exposed piping, drainage systems (e.g., manholes) and the septic tank and sewage treatment tanks are either crushed in place, cut-up into sections or lifted as one piece (intact), dependent upon the appropriate excavation method.

If the selected excavation method is to extract the pipes intact or in sections, the affected section must be below the *Fissile Material Exhumation Limit* or be classified as *NCS Exempt Material*. If the content of the affected section exceeds the *NCS Exempt Material* criteria,[1] then the length (or volume) of the subterranean structure that can be excavated must be less than or equal to the *Extracted Piping Fissile Material Limit*, which is set at 350 $g^{235}U$. The *Extracted Piping Fissile Material Limit* is determined using results of the in-pipe probe measurements, which are described in Section 1.4.3, or performing surface survey measurements of the associated structure using calibrated *Fissile Material* assay equipment. Inlets and outlets of the segmented pipe are capped (or bagged) to mitigate spillage of uranium-contaminated debris that may be present within the subsurface structure for pipe sections that have not been demonstrated to be *NCS Exempt Material*.

The *non-NCS Exempt* capped (enclosed) pipe segments are removed from the ground and either subjected to additional measurement(s)[2] to confirm that they do exceed the *NCS Exempt Material* criteria before containerization as *non-NCS Exempt Material*, or are directly containerized as *non-NCS Exempt Material.* The packaging limits for non-*NCS Exempt* pipe sections are 700 $g^{235}U$ per *Secured Isolated Storage Area* (SISA), or 350 $g^{235}U$ per *Collared Drum* (CD).

If the content of the affected pipe or other subterranean section meets the *NCS Exempt Material* criteria, the associated section is transferred to an appropriate stockpile in a WHA and not subject to further NCS controls.

If excavated as crushed debris, the excavated material is bulked into a large conveyance by excavating the crushed debris and any comingled soil/stones/gravel in layers. Each excavation is limited to an appropriate *cut depth*. The following subsections provide further detail for the aforementioned operations.

1.4.1 Concrete Slab Removal

Typically concrete structures such as foundations and slabs are exempt from NCS controls during decommissioning operations due to the small potential to contain significant quantities of *Fissile Material*. However, spills of process materials during manufacturing operations at the Hematite site have been documented, and it is possible that these incidents, especially those involving solutions, may have involved significant quantities of *Fissile Material*. Moreover, because of cracks, expansion joints, and seams in the concrete surfaces, it is possible that non-

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1 *NCS Exempt Material* is defined as material requiring NCS oversight. Limits are established in Section 2.

2 It is expected that the background levels above ground are significantly less than in the excavation location. The reduced background levels and use of other *Fissile Detection Equipment* may conclude that the extracted pipe section (or portions thereof) is below the *NCS Exempt Material* criteria. If these subsequent measurements demonstrate that the pipe section is below the *NCS Exempt Material* criteria, the affected pipe section can then be transferred to an appropriate stockpile in a WHA.

trivial quantities of *Fissile Material* could have collected in pockets within portions of concrete subject to contamination.

It has been reported that the concrete slabs subject to non-trivial contamination from spillages during manufacturing operations, were either scrubbed clean or scabbled and then re-surfaced by overlaying the contaminated concrete with an additional layer of concrete. These remedial actions were performed during the manufacturing era and were likely necessary at the time to ensure that the subject areas could be safely occupied for manufacturing operations. The remaining portions of concrete not known to have been subject to significant contamination incidents during manufacturing operations were cleaned and sprayed with fixative to immobilize any surface contamination.

To address the potential for encountering significant quantities of *Fissile Material* associated with contaminated concrete during decommissioning operations, an extensive radiological surface survey (non-destructive surface assay) was undertaken during 2009 for the purpose of providing radiological data to assist in quantifying the residual mass of ^{235}U associated with concrete surfaces [1-3].[3] The radiological survey was then complemented by destructive analysis of cored-concrete and underlying soil/gravel samples [4]. Results of the destructive analysis and non-destructive assays performed on the concrete slabs are presented in Sections 1.4.1.1 and 1.4.1.2, respectively.

Results of the destructive analysis and non-destructive assays performed on the concrete slabs and the evaluation presented herein demonstrate that the concrete slabs meet the NCS exempt material criteria. Therefore, equipment can be used to crush, break, cut, scabble, or hammer the concrete slab regions of the former process and auxiliary building of the Hematite facility. The concrete debris can subsequently be excavated and transferred to an appropriate stockpile in a WHA.

1.4.1.1 <u>Concrete Core Sampling</u>

Core sampling provides an effective method of establishing the distribution of uranium contamination within a portion of a concrete slab. Twenty-one samples from concrete floors of the former process buildings slabs were cored and collected, and the collected samples were then destructively analyzed [4]. The collected samples also included gravel and soil that was present under the concrete slabs. Figure 1.1 provides a schematic of the locations of the concrete slab samples. Note that the schematic of Figure 1.1 depicts a total of 28 samples, however, only samples #01 through #21 are floors samples and samples #22 through #28 are wall samples. Selection of the core sample locations was based on the following criteria:

- Concrete regions that are known, or are suspected, to have been resurfaced because of contamination during manufacturing operations, which was the basis for selecting the locations for samples #02 and #03.

[3] Numbers appearing inside square brackets herein represent cited reference numbers that are listed in Section 5.0.

- For portions of concrete that yielded relatively high count rates (hotspots) from the radiological surveys, such as core samples #02 and #21.
- For portions of concrete associated with cracks, expansion joints, or seams. An example is sample #13, which was cored from an expansion joint, a picture of this location is presented in Figure 1.2.
- Representative core samples not meeting the above criteria.

The analysis consisted of dividing each concrete sample into three axial sections: top ¼", middle ½", and the remainder of the concrete sample. Gravel or soil collected from underlying regions of the affected concrete sections is also analyzed. Results of the destructive analysis performed on the collected samples [4] are used to generate the data presented in Table 1.1 through Table 1.4. In generating the data of Table 1.1 through Table 1.4, a 3" diameter for the cored-samples and a density of 2.3 g/cm^3 for concrete are used. The data listed in Table 1.1 through Table 1.4 consist of the following:

- Table 1.1 describes the location and selection basis for each of the cored samples.
- Table 1.2 lists the ^{235}U enrichment and weights of the analyzed sample sections.
- Table 1.3 : ^{235}U Concentration Levels in Each Sample Segment and ^{235}U Concentration Levels Averaged Over Axial Height of Concrete Cored Sample.
- : ^{235}U Distribution within the Concrete Core Sample Sections^{235}U Distribution within the Concrete Core Sample Sections.

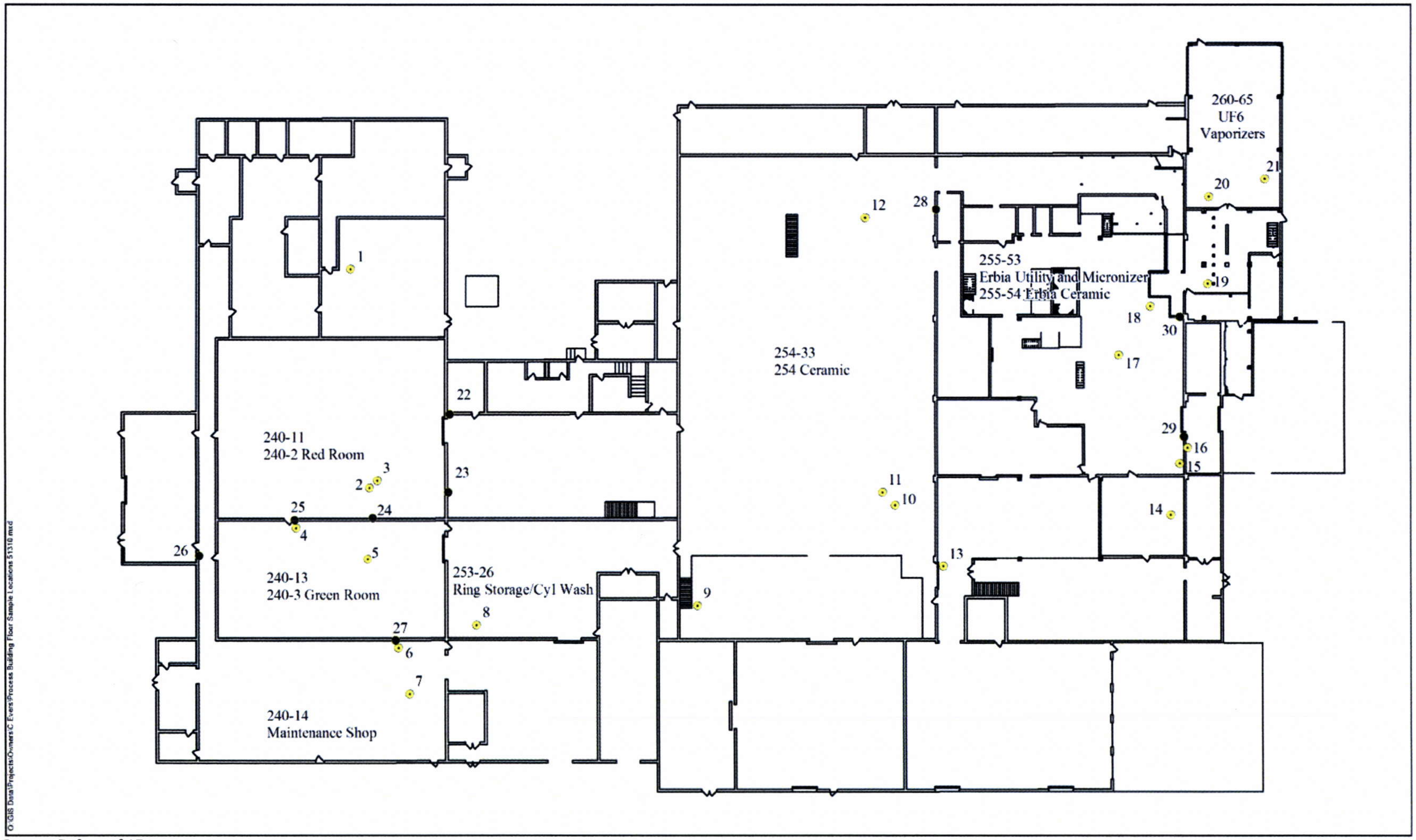

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Figure 1.1: Delineation of Concrete Samples Cored from the Hematite Site Process Buildings

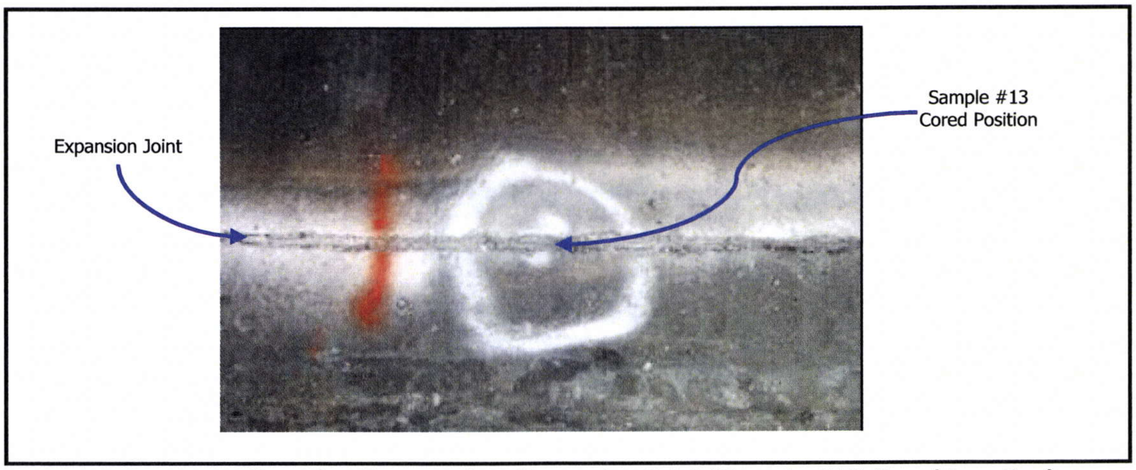

Figure 1.2: Overview Image of an Expansion Joint (Sample #13 Cored Location)

Table 1.1: Delineation of the Cored-Concrete Samples

Sample ID/Location	Resurfaced Concrete Regions	Expansion Joint, Crack, Seams, and/or Near Walls	Identified as a Hot Spot Location	Comments, if Any
#01		✓		
#02A	✓		✓	*Samples ID's ending with "A" indicate samples obtained from the newer (resurfaced) concrete region and those ending with "B" are from the older concrete regions.*
#02B				
#03A	✓	✓		
#03B				
#04		✓		
#05			✓	
#06		✓		
#07			✓	
#08			✓	
#09		✓		Representative sample of the general area
#10			✓	
#11				Representative sample of the general area.
#12				Representative sample of the general area
#13		✓		
#14		✓		
#15				Representative sample of the general area
#16		✓	✓	
#17		✓	✓	
#18		✓		
#19				Representative sample of the general area
#20		✓		
#21			✓	

Table 1.2: Mass of the Cored Samples and Measured Average ^{235}U Enrichment

Sample Location	Average ^{235}U Enrichment	Top ¼" of the Concrete Sample	Middle ½" of the Concrete Sample	Remainder of the Concrete Sample	Underlying Soil/Gravel
#01	8.2%	62 g	125 g	1,160 g	650 g
#02A	3.8%	60 g	106 g	634 g	N/A
#02B	18.7%	85 g	136 g	579 g	960 g
#03A	3.5%	59 g	119 g	622 g	N/A
#03B	2.2%	75 g	113 g	612 g	1,930 g
#04	2.5%	113 g	122 g	1,290 g	1,280 g
#05	2.5%	96 g	187 g	1,620 g	1,010 g
#06	2.8%	66 g	120 g	1,080 g	1,000 g
#07	2.1%	61 g	118 g	1,250 g	1,420 g
#08	3.6%	85 g	125 g	1,090 g	980 g
#09	3.8%	75 g	114 g	1,340 g	1,490 g
#10	3.4%	73 g	120 g	1,780 g	N/A
#11	3.6%	73 g	118 g	1,110 g	1,590 g
#12	3.8%	63 g	120 g	2,050 g	1,430 g
#13	9.4%	102 g	137 g	870 g	1,350 g
#14	15.6%	53 g	138 g	2,530 g	880 g
#15	3.1%	70 g	125 g	1,190 g	960 g
#16	2.4%	70 g	133 g	1,750 g	1,060 g
#17	2.9%	147 g	230 g	1,290 g	1,280 g
#18	1.7%	90 g	138 g	1,100 g	1,120 g
#19	2.6%	73 g	124 g	3,040 g	1,190 g
#20	3.3%	82 g	120 g	2,450 g	1,060 g
#21	3.5%	74 g	124 g	2,400 g	1,270 g

Table 1.3: ^{235}U Concentration Levels in Each Sample Segment and ^{235}U Concentration Levels Averaged Over Axial Height of Concrete Cored Sample

Sample Location	Top ¼" of the Concrete Sample	Middle ½" of the Concrete Sample	Remainder of the Concrete Sample	Average ^{235}U Concentration Over Axial Height of Concrete Core	Underlying Soil/Gravel
#01	6.7 mg/L	7.9 mg/L	4.5 mg/L	4.87 mg/L	2.1 mg/L
#02A	1,629.2 mg/L	0.5 mg/L	0.5 mg/L	122.7 mg/l	N/A
#02B	4.5 mg/L	0.2 mg/L	0.5 mg/L	0.9 mg/L	0.1 mg/L
#03A	770.0 mg/L	297.5 mg/L	72.2 mg/L	157.2 mg/L	N/A
#03B	5.1 mg/L	0.3 mg/L	0.5 mg/L	0.87 mg/L	117.3 mg/L
#04	72.4 mg/L	232.6 mg/L	182.8 mg/L	178.6 mg/L	27.1 mg/L
#05	2,415.7 mg/L	4.1 mg/L	1.0 mg/L	123.1 mg/L	31.4 mg/L
#06	1,499.7 mg/L	0.2 mg/L	0.3 mg/L	78.5mg/L	0.6 mg/L
#07	198.6 mg/L	0.2 mg/L	0.4 mg/L	8.9 mg/L	0.2 mg/L
#08	113.0 mg/L	0.1 mg/L	0.6 mg/L	7.9 mg/L	1.2 mg/L
#09	537.3 mg/L	0.2 mg/L	0.2 mg/L	26.6 mg/L	0.7 mg/L
#10	1,712.0 mg/L	0.1 mg/L	2.1 mg/L	65.2 mg/L	N/A
#11	63.6 mg/L	0.6 mg/L	2.7 mg/L	5.9 mg/L	0.2 mg/L
#12	215.6 mg/L	0.1 mg/L	0.2 mg/L	6.3 mg/L	0.3 mg/L
#13	94.6 mg/L	18.5 mg/L	10.6 mg/L	19.3 mg/L	20.9 mg/L
#14	20.6 mg/L	16.1 mg/L	15.2 mg/L	15.4 mg/L	23.7 mg/L
#15	23.4 mg/L	0.1 mg/L	1.1 mg/L	2.2 mg/L	5.3 mg/L
#16	605.0 mg/L	0.3 mg/L	0.4 mg/L	22.1 mg/L	6.7 mg/L
#17	50.7 mg/L	228.2 mg/L	2.5 mg/L	37.9 mg/L	0.4 mg/L
#18	30.5 mg/L	55.0 mg/L	12.8 mg/L	18.4 mg/L	5.0 mg/L
#19	187.5 mg/L	137.9mg/L	0.7 mg/L	10.2 mg/L	1.9 mg/L
#20	101.2 mg/L	0.3 mg/L	0.2 mg/L	3.4 mg/L	15.3 mg/L
#21	7,620.8 mg/L	3.3 mg/L	51.5 mg/L	264.8 mg/L	5.7 mg/L
Averaged of All Samples	781.7 mg/l	43.7 mg/L	15.8 mg/L	51.5 mg/L	12.7 mg/L

Table 1.4: ^{235}U Distribution within the Concrete Core Sample Sections

Sample Location	Top ¼" of the Concrete Sample	Middle ½" of the Concrete Sample	Remainder of the Concrete Sample
#01	35.11%	41.42%	23.47%
#02A	99.94%	0.03%	0.03%
#02B	86.68%	3.43%	9.89%
#03A	67.56%	26.10%	6.34%
#03B	87.44%	4.63%	7.93%
#04	14.85%	47.68%	37.47%
#05	99.79%	0.17%	0.04%
#06	99.96%	0.01%	0.02%
#07	99.66%	0.12%	0.21%
#08	99.43%	0.08%	0.49%
#09	99.92%	0.04%	0.05%
#10	99.87%	0.01%	0.12%
#11	95.09%	0.87%	4.04%
#12	99.87%	0.05%	0.08%
#13	76.50%	14.92%	8.57%
#14	39.68%	31.06%	29.26%
#15	94.85%	0.50%	4.65%
#16	99.87%	0.06%	0.07%
#17	18.01%	81.10%	0.89%
#18	31.02%	55.94%	13.05%
#19	57.49%	42.28%	0.23%
#20	99.46%	0.30%	0.24%
#21	99.29%	0.04%	0.67%

The data presented in Table 1.1 through Table 1.4indicate the following:

- ✓ Table 1.2 indicates that the majority of the samples exhibited low-enriched ^{235}U levels ($\leq$ 5 wt.% ^{235}U), with only four samples exhibiting intermediate-enriched ^{235}U levels (5 wt.% < ^{235}U/U $\leq$ 20 wt.%). There were no samples that measured enrichments above intermediate-enriched ^{235}U levels.

- ✓ Although Table 1.3 indicates a number of samples yielded relatively high ^{235}U content levels[4] in their upper ¼" thickness (highest sample is #21 with 7,621 mg-^{235}U/L followed by sample #05 with 2,416 mg-^{235}U/L), the following are also noted:
  - o Table 1.3 indicates that when the ^{235}U contamination is averaged over the entire lengths of samples #21 and #05, the result is 264.8 and 123.1 mg-^{235}U/L, respectively.
  - o Table 1.3 indicates that the ^{235}U contamination confined to the top ¼" of the samples when averaged over all samples is 781.7 mg-^{235}U/L, and that the ^{235}U contamination averaged over the entire length of all samples is only 51.5 mg-^{235}U/L.

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4 These sample locations have been selected based on identification as localized hotspots from the radiological surveys and do not represent ^{235}U concentration levels that are characteristic of general areas of the former process buildings.

- ✓ Table 1.3 indicates that previously scabbled concrete regions (samples #02B and #03B) have relatively low ^{235}U contamination levels, which further indicates that the scabbling effort previously performed was successful in reducing the amounts of ^{235}U contamination to insignificant levels (≤ 6 mg-^{235}U/L in the upper ¼" surface). The ^{235}U concentration averaged over the entire lengths of samples #02B and #03B is found to be 0.9 mg-^{235}U/L for both samples (from Table 1.3), which is more than a factor of 110 below the *NCS Exempt Material* criteria of 0.1 g^{235}U/L.

- ✓ Table 1.4indicates the following:
  - o Samples collected from areas that are not identified as having cracks, expansion joints, seams, or have not been identified as previously resurfaced have the majority of their ^{235}U contamination (> 95%) confined to the upper ¼" surface of the concrete with insignificant ^{235}U contamination residing within their underlying regions.
  - o The eleven samples that have been collected from areas near seams, cracks, expansion joints, or walls, exhibit greater vertical ^{235}U migration than areas not identified as having cracks, expansion joints, or seams. Samples #06, #09, #16, and #20 have ≥ 99.5% of their ^{235}U contamination confined to the upper ¼" surface of the concrete, samples #03(A and B), #13, and #17 have > 91% of their ^{235}U contamination confined to the upper ½" surface of the concrete, and samples #01, #04, #14, and #18 have > 60% of their ^{235}U contamination confined to the upper ½" surface of the concrete.
  - o Sample #02A, which was collected from a resurfaced concrete section (and not near cracks, expansion joints, or seams), also has its ^{235}U contamination (> 99.9%) confined to the upper ¼" surface of the concrete.

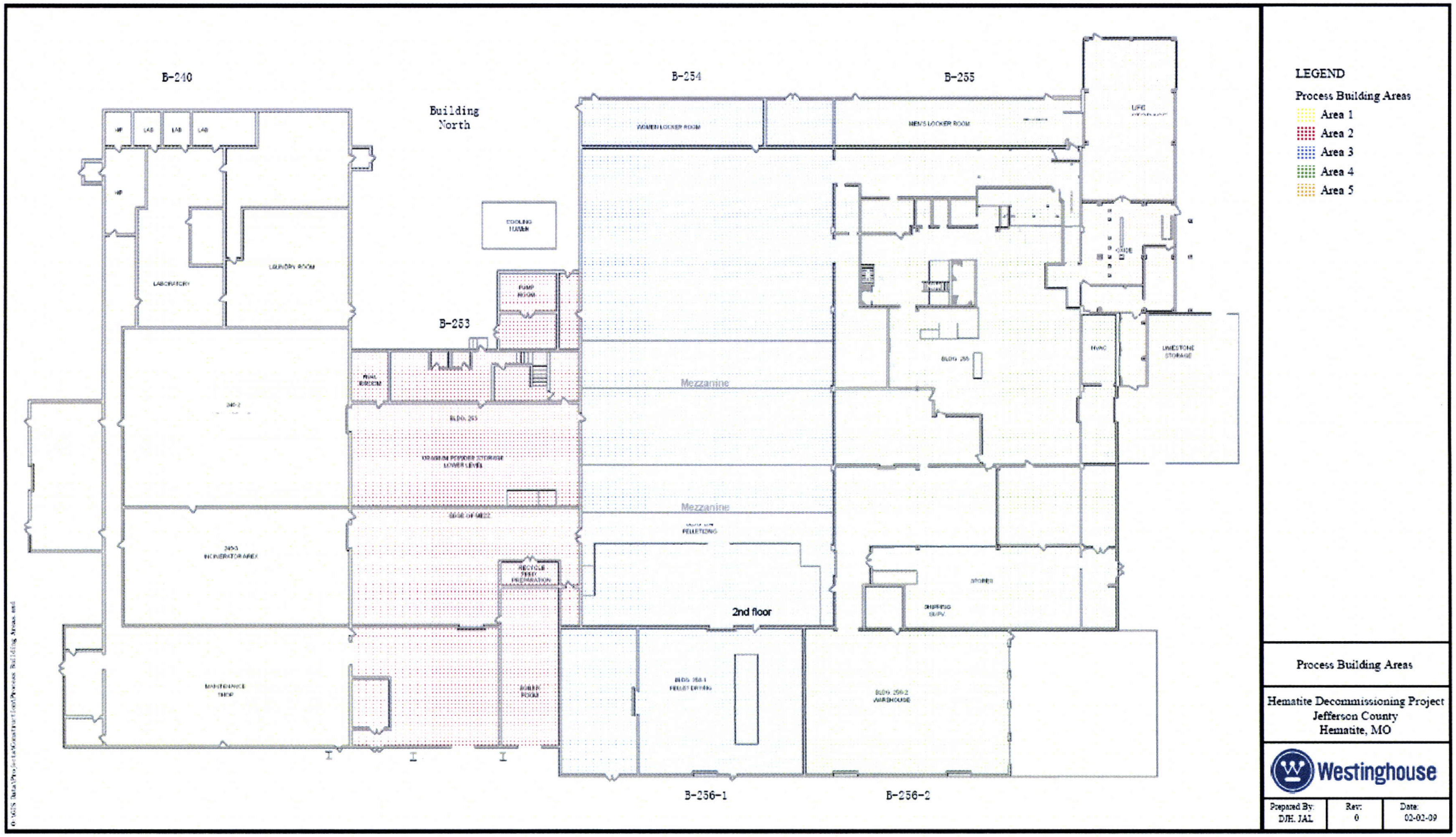
- ✓ Table 1.3 indicates that the largest level of ^{235}U contamination in the underlying soil/gravel region is beneath sample #03B and is found to be at a concentration level of 117 mg-^{235}U/L. Recall sample #03B is a resurfaced concrete region that has been previously scabbled and is a sample identified as being cored from near an expansion joint, crack or seam. All other gravel/soil samples have ^{235}U contamination levels that are well below the *NCS Exempt Material* criteria of 0.1 g^{235}U/L (≤100 mg-^{235}U/L).

1.4.1.2 Non-Destructive Surface Survey

As indicated previously, a comprehensive radiological survey program was undertaken during 2009 to provide radiological data to assist in quantifying the residual mass of ^{235}U associated with building surfaces (floors, walls, ceilings, and roof) of the Hematite Facility former process and auxiliary buildings. Results of the radiological survey were used to evaluate and to provide estimates for the mass and areal density of ^{235}U associated with the building surfaces [2-3]. The analytical method used involved correlating the observed count rate in a sodium iodide (NaI) detector used in close-proximity scans of building surfaces, to a ^{235}U areal density. A calibration between the mass per unit area (i.e., areal density) of ^{235}U contamination and observed count rate was determined based on independent measurements of selected contaminated surfaces using a high-purity germanium (HPGe) detector. The analyses documented in References 2 and 3 utilized the MCNP code and involved the use of extensive radiological survey data obtained for the building surfaces. Of interest herein are the results pertaining to the concrete floor slabs. Results of these studies, which are the ^{235}U area densities and total ^{235}U that would be present on the concrete floor surfaces of the former Hematite facility process and auxiliary buildings, are presented in Table 1.5. The corresponding area delineations for the Hematite facility former process buildings listed in Table 1.5 are outlined in Figure 1.3.

Table 1.5: Assayed ^{235}U Areal Densities and Total ^{235}U on the Concrete Floors of the Hematite Facility Former Process and Auxiliary Buildings

Location	Area Description	Average Area Density, g-$^{235}U/ft^2$	Area, ft^2	^{235}U, g
Former Process Buildings [2]	1	0.036	17,056	614
	2	0.018	8,444	152
	3	0.022	30,273	666
	4	0.02	21,950	439
	5	0.073	6,397	467
Former Auxiliary Buildings [3]	Bldg-115	0.016	450	7.2
	Bldg-245	0.016	31	0.5
	SWTP	0.001	2,100	2.1
	Bldg-101, Tile Barn – Floor 1	0.021	2,962	62.2
	Bldg-101, Tile Barn – Floor 2	0.019	3,126	59.4
	Bldg-120, Red Barn – Floor 1	0.019	1,905	36.2
	Bldg-120, Red Barn – Floor 2	0.016	1,938	31
	Bldg-235	0.063	379	23.9
	Bldg-252	0.119	1,049	124.8
Total		0.027	98,060	2,685



Source: Reference 2

Figure 1.3: Hematite Site Process Buildings and Delineation of Facility Areas

It should be noted that the radiological surveys conducted for building floors did not employ a collimator on the NaI detector, and hence the gross count rates observed in the detector include contributions from the background. The corresponding analysis utilizing the radiological survey data conservatively ignored background contributions and treated all observed counts as originating from localized ^{235}U contamination. Therefore, the ^{235}U areal densities and mass estimates listed in Table 1.5 are overstated.

Note further that the ^{235}U areal densities and mass estimates listed in Table 1.5 represent the ^{235}U that would be present on the concrete slabs upper surfaces only and not in their substrate. Attenuation of the ^{235}U gammas through the substrate must therefore be accounted for in order to reliably establish bounding ^{235}U mass estimates.

Reference 6 documents results of an assessment of scaling factors that would be appropriate for converting surface based mass estimates into volumetric based mass estimates for concrete with various contamination depth profiles. Although analysis for the cored concrete samples presented in Section 1.4.1.1 indicate that the bulk of ^{235}U contamination is confined within the upper ¼" of the concrete slabs, a contamination penetration depth of ½" is conservatively selected.[5] Reference 5 has determined that a scaling factor of 1.7 is appropriate for ^{235}U contamination that is uniformly distributed[6] throughout a ½" concrete substrate. This scaling factor is applied to the ^{235}U mass estimates listed in Table 1.5, results of which are presented in Table 1.6.

Table 1.6: Adjusted Total ^{235}U due to a Penetration Depth of ½" in the Concrete Substrate of the Hematite Facility Former Process and Auxiliary Buildings

Location	Area Description	Area, ft²	^{235}U, g	^{235}U Concentration per Concrete Cut-Depth, g/L				
				½"	1"	1½"	2"	3"
Former Process Buildings [2]	1	17,056	1043.8	0.052	0.026	0.017	0.013	0.009
	2	8,444	258.4	0.026	0.013	0.009	0.006	0.004
	3	30,273	1132.2	0.032	0.016	0.011	0.008	0.005
	4	21,950	746.3	0.029	0.014	0.010	0.007	0.005
	5	6,397	793.9	**0.105**	0.053	0.035	0.026	0.018
	Total of All Process Buildings	84,120	3974.6	0.040	0.020	0.013	0.010	0.007
Former Auxiliary Buildings [3]	Bldg-115	450	12.2	0.023	0.012	0.008	0.006	0.004
	Bldg-245	31	0.9	0.023	0.012	0.008	0.006	0.004
	SWTP	2,100	3.6	0.001	0.001	0.000	0.000	0.000
	Bldg-101, Tile Barn – Floor 1	2,962	105.7	0.030	0.015	0.010	0.008	0.005
	Bldg-101, Tile Barn – Floor 2	3,126	101.0	0.027	0.014	0.009	0.007	0.005
	Bldg-120, Red Barn – Floor 1	1,905	61.5	0.027	0.014	0.009	0.007	0.005
	Bldg-120, Red Barn – Floor 2	1,938	52.7	0.023	0.012	0.008	0.006	0.004
	Bldg-235, West Vault	379	40.6	0.091	0.045	0.030	0.023	0.015
	Bldg-252, South Vault	1,049	212.2	**0.171**	0.086	0.057	0.043	0.029
	Total of All Auxiliary Buildings	13,940	590.4	0.036	0.018	0.012	0.009	0.006
Total of All Process and Auxiliary Buildings		98,060	4565.0	0.039	0.020	0.013	0.010	0.007

[5] Results presented in Section 1.4.1.1 that indicate a penetration depth of greater than ¼" are only observed for cored samples collected from expansion joints, cracks, or seams. Gammas emitted from these regions do not experience the extent of attenuation as gammas emitted from the concrete substrate, and therefore applying a penetration depth of ½" is also bounding for concrete regions that have expansion joints, cracks, or seams.

[6] It is noted that a uniform contamination distribution assumption is conservative because the ^{235}U contamination would be expected to be peaked toward the surface of the concrete.

Table 1.6 indicates the following:

- ✓ Bldg-252, South Vault, an auxiliary building, has the highest ^{235}U concentration in its concrete floors than all other buildings. However, because of its relatively small area (~1,000 ft^2), the total amount of ^{235}U contained within its concrete floor is ~200 g^{235}U.
- ✓ The total amount of ^{235}U present in the floor regions of all auxiliary building is less than 590 g^{235}U.
- ✓ Area 3 of the former process buildings has the highest amount of ^{235}U, at ~1,150 g^{235}U. However, because of its large area (~30,000 ft^2), the concentration of ^{235}U that is trapped within the upper ½" of its floor regions is well below the *NCS Exempt Material* criteria of 0.1 g^{235}U/L.
- ✓ The total amount of ^{235}U present in the floor regions of all Hematite facility buildings is less than 4,565 g^{235}U. However, Table 1.6 also indicates that the average ^{235}U concentration confined in only the upper ½" of all floor regions is well below the *NCS Exempt Material* criteria of 0.1 g^{235}U/L.

1.4.2 Soil Exhumation Surrounding Substructures

As indicated previously, in order to excavate the subterranean structures such as piping and the septic tank and sewage treatment tanks, it is necessary to first remove any concrete slabs that are located on the surface of the ground above the piping. Once concrete slabs are removed, soil and any gravel and stones that cover subterranean structures and/or have been subjected to ^{235}U contamination can then be exhumed.

Soil is carefully exhumed when the soil is determined to be contaminated or in close proximity to potentially heavily contaminated substructures such as the septic tank and sewage treatment tanks and piping. Prior to exhuming soil, concrete slabs that overlay the soil must first be removed. Once the concrete slabs are removed, two independent assay measurements are performed of the now exposed soil under Building 240 and Building 260. The surface assays are performed with calibrated equipment and can be used to quantify *Fissile Material* within the soil. Note that because the only credible contamination pathways[7] to the soil beneath former concrete slabs is spills that have occurred during manufacturing operations that seeped through seams, expansion joints, and cracks of the concrete floors, the surface assay measurements are capable of detecting and identifying soil regions that must be exhumed.

Once the surface assay measurements have been performed, excavation of areas that are found to be below the *NCS Exempt Material* criteria and do not contain subterranean structures targeted for extraction can be performed without any NCS control.[8]

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7 Soil that lies beneath or next to subterranean structures may have experienced contamination through leaks from the subterranean structures. Soil regions addressed above refer to soil that is beneath the concrete slabs.

8 Note that remediation operations will continue until the excavation areas are found to be below the *NCS Exempt Material* Limit.

However, if an area of soil is found to be contaminated but meets the *NCS Exempt Material* criteria, the soil is carefully exhumed as a layer not exceeding the maximum *cut depth.*[9] The exhumed soil is transferred to an appropriate stockpile in a WHA. If a portion of the soil is determined to exceed *NCS Exempt Material* criteria, but does not exceed the *Fissile Material Exhumation Limit*, then the associated portion is removed and packaged in a *Field Container*. The *Field Container* is handled pursuant to the guidance, procedural requirements, and criticality controls outlined in Reference 8. Once the contaminated soil layer/portion is exhumed, two independent surface assays are once again performed over the uncovered soil regions. The sequence of operations that involve exhumation of contaminated soil up to the maximum *cut depth* and subsequent independent surface assays are performed until soil is determined to be below the NCS Exempt Material limit. Note that if subterranean structures are encountered or exposed during exhumation of contaminated soil, the subterranean structures exhumation procedures and processes are then invoked, as described in Sections 1.4.3 and 1.4.4.

For soil regions that overlay subterranean structures but have been determined to not exceed the *NCS Exempt Material* criteria, the soil covering the subterranean structures is carefully removed until these structures are encountered, at which time, subterranean structures exhumation procedures and processes are then invoked.[10]

1.4.3 Subterranean Piping Removal

There are potentially several thousand feet of subterranean piping located within the Hematite Facility. Operations related to excavation of the subterranean piping are handled pursuant to the results obtained from the in-pipe probe measurements, which are summarized in this section. Alternately, results of surface survey measurements performed during excavation operations can be used to justify exhuming pipe sections greater than that determined from the in-pipe probe measurements, provided the length (or volume) of the subterranean piping that can be excavated must be less than or equal to the *Extracted Piping Fissile Material Limit*.

As alluded to earlier, in preparation for excavation of the subsurface piping, an extensive in-pipe survey effort was conducted in 2010 for the purpose of providing radiological data to assist in quantifying the residual mass of ^{235}U in subsurface piping that reside mainly beneath the former process buildings at the Hematite site. More than one thousand feet of subsurface piping was surveyed. Results of the in-pipe radiological survey was used to provide bounding estimates of the mass of ^{235}U present as holdup in the subsurface piping associated with the Hematite facility former process buildings [6]. The analytical method involved correlating the observed dose rates inside the subterranean pipes from a calibrated Geiger-Muller (GM) probe to the mass of ^{235}U present as holdup. The GM probe and its associated electronic (rate meter) were calibrated and their calibration was verified throughout their use. The analyses documented in Reference 6 utilized the MCNP code and involved the use of the in-pipe probe survey data.

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9 The maximum thickness of soil that can be adequately characterized by in-situ assay equipment is established in the calibration basis document associated with the type of assay equipment.

10 Note that, not only do subterranean excavations on non-NCS Exempt pipe require two independent surface assays using calibrated equipment of the subterranean structures, but also of the surrounding soil.

Results obtained from these analyses, which include ^{235}U mass estimates, are reproduced in Appendix A. The data in Appendix A indicates that only four pipe sections totaling 190' did not meet the *NCS Exempt Material* limit for piping based on *NCS Exempt Material* criteria (a) in Appendix A (which is a fissile concentration based limit). Note that the actual amount of ^{235}U present in the referenced 190' of piping is expected to be significantly less than that reported in Appendix A, because the calculations reported in [6] utilized conservative assumptions, such as modeling the source term of the emitted gammas as originating from uranium that is a 100% enriched with ^{235}U that is mixed with conservative quantities of attenuating debris.

Much of the subterranean piping comprises the site storm water system, gray water lines, and sanitation lines. Typically, storm water piping gray water lines and sanitation lines are not decommissioning debris that necessitates concern regarding criticality safety. However, the legacy processing plant was designed such that the process piping used for evaporator overflows, process water runoff, and laboratory sinks were directly conjoined with this underground system. Consequently, in-pipe probe measurements of the storm water system, gray water lines, and sanitation lines have been performed

The remaining portion of the subterranean piping consists of the processing lines used for evaporator overflows, process water runoff, and laboratory sinks that were formerly used during fuel manufacturing operations. In practice, the design of the equipment used in various former production operations that were connected to these lines would have ensured that release of significant quantities of *Fissile Material* into these drain lines was not a frequent occurrence.

Because the assayed pipe length represents a significantly large sample, and the assayed pipes represent pipes with drains that were in the vicinity of the fuel manufacturing operations, results of the in-pipe radiological surveys are also expected to be a bounding representation of the ^{235}U activity in all other subterranean piping.

However, a second set of independent measurements can be performed once a section or region of the subterranean piping has been exposed during soil exhumation activities (described in Section 1.4.2) to allow exhumation of pipe sections that are determined to potentially be of NCS concern as a result of the data collected during the in-pipe radiological surveys. The results of the pipe assays can then be used as follows:

- ⇨ To determine if the pipe section, or portions thereof, meets *NCS Exempt Material* criteria.
- ⇨ To determine the maximum pipe length that contains less than or equal to the *Extracted Piping Fissile Material Limit*.

Results of the in-pipe probe measurements can also be used to determine whether the pipe section must be extracted in-tact from the ground or whether it can be crushed in place and exhumed as debris.[11] This operational flexibility is necessary because significant portions of the

[11] Based on results obtained from the in-pipe probe measurements (Appendix A), it is expected that the majority of pipes can be crushed in place and extracted as ^{235}U contaminated debris.

piping system are believed to be composed of concrete or vitrified clay. As typical with most storm water and sewer systems, these materials are prone to fracture and breakage during excavation.

If the decision is made to excavate *non-NCS Exempt* piping in-tact, then the length of piping that contains less than or equal to the *Extracted Piping Fissile Material Limit* must first be determined, which is, as indicated previously, is accomplished by using results of the in-pipe probe measurements or based on results of supplemental measurements that can be performed using calibrated *Fissile Material* assay equipment once the pipe section is exposed. In either case, the *Extracted Piping Exhumation Length Limit* is limited to no more than 350 g ^{235}U. Inlets and outlets of the segmented pipe are capped[12] (or bagged) to mitigate spillage of uranium-contaminated debris that may be present within the subsurface structure of pipe sections that are determined to be or suspected to be *non-NCS Exempt Material.* The capped (enclosed) pipe segment is then removed from the ground and is either subjected to another measurement(s)[13] to confirm if it exceeds the *NCS Exempt Material* criteria; placed inside an SISA, provided the total amount of ^{235}U inside the SISA will be less than the SISA *Fissile Material Loading Limit*; or subdivided into appropriate segments and placed inside a CD, provided the total amount of ^{235}U inside the SISC will be less than the CD *Fissile Material Loading Limit*.

As described previously, capping off the pipe section ends is not required if the pipe section is determined to meet *NCS Exempt Material* criteria. Pipe sections that meet the *NCS Exempt Material* criteria can be bulked in a waste transfer vehicle and transferred to an appropriate stockpile in a WHA.

If the decision is made to excavate piping using the "crush and exhume" method, then it must first be confirmed that the material within the intact piping to be crushed and the surrounding soil, as determined by the *Fissile Material* detection equipment will not result in a uranium concentration that exceeds the *Fissile Material Exhumation Limit*. If this criterion is met, then the pipe is crushed in place. Prior to exhuming the debris (i.e., mixture of pipe contents, piping material, and any soil/stones/gravel), a surface assay is performed on the debris. The post crushing assay is identical in function and method to soil surveys. Provided that the surface assay establishes that the crushed debris meets *NCS Exempt Material* criteria, the debris is carefully exhumed as a layer not exceeding the maximum permitted *cut depth*.[14] The exhumed debris is then transferred to an appropriate stockpile in a WHA. If a portion of the debris is determined to exceed *NCS Exempt Material* criteria, but does not exceed the *Fissile Material Exhumation Limit*, then the associated portion is removed and packaged in a *Field Container*. The *Field Container* is then handled pursuant to the guidance, procedural requirements, and criticality controls outlined in Reference 8.

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[12] Inlets and outlets of pipe segments that are determined to be *NCS Exempt Material* are not required to be capped or bagged.

[13] It is expected that the background levels above ground are significantly less than in the excavation location. The reduced background levels and use of other *Fissile Detection Equipment* may conclude that the extracted pipe section (or portions thereof) is below the *NCS Exempt Material* criteria. If these subsequent measurements demonstrate that the pipe section is below the *NCS Exempt Material* criteria, the affected pipe section can then be transferred to an appropriate stockpile in a WHA.

[14] The maximum thickness of piping material and/or soil/stones/gravel that can be adequately characterized by in-situ assay equipment is established in the calibration basis document associated with the type of assay equipment.

1.4.4 Septic and Sewage Treatment Tank and Drain Field Extraction

The Hematite site contains two sewage treatment systems and a concrete septic tank, all of which were connected to the lavatories within the former process buildings. Note that only a single sewage treatment system and the associated sanitation lines and drain lines remain in service. The older sewage treatment tank and concrete septic tank were previously abandoned in place, filled with gravel, and are embedded in the ground near the current sewage treatment tank. The two decommissioned systems' tanks filtered into a common sand and gravel drain field, i.e., separate from the drain line used for the current sewage treatment system.

Prior to exhuming the content of the current sewage treatment tank, sanitation lines leading to the treatment tank will be exhumed and disposed of in the manner outlined in Section **Error! Reference source not found.**, "*Subterranean Piping Removal*." If the sanitation lines leading to the current sewage treatment tank were found to meet the *NCS Exempt Material* criteria, and the linear ^{235}U activity decreases as the sanitation lines approach the current sewage treatment tank, then it is reasonable to assume that the sewage treatment tank will also meet *NCS Exempt Material* criteria. This is because if any uranium was discarded into the sanitation lines, the bulk of the discharged uranium will be deposited in the elbow and trap sections of the sanitation lines that are closest to their source drains. This assumption is supported by results of the in-pipe radiological surveys of the subsurface piping that reside mainly beneath the former process buildings at the Hematite site. The in-pipe radiological survey concluded that, when measurable dose rates (dose rates above background levels) were encountered, the highest observed dose rates were measured at the elbow section of the surveyed pipes. As measurements were taken downstream from the elbow sections, the measured dose rates decreased. However, if the sanitation lines are demonstrated to contain material exceeding the *NCS Exempt* criteria, or exhibited non-declining linear ^{235}U activity as the sanitation lines approach the current sewage treatment tank, the subject treatment tank will then be assumed to contain *Fissile Material*.

Prior to exhumation of the sewage treatment tanks and septic tank, the overlying soil must be removed. This soil is not anticipated to contain ^{235}U concentrations that exceed the *NCS Exempt Material* criteria. This is because all treatment tanks associated with the Hematite facility were located outside fuel manufacturing operations; and hence there is no credible pathway for ^{235}U to contaminate or seep into soil regions that overlay treatment tanks.

However, soil surrounding the sewage treatment tanks and septic tank are conservatively treated as soil that potentially contains ^{235}U concentrations above the *NCS Exempt Material* criteria, but is not anticipated to exceed the *Fissile Material Exhumation Limit*. Surface areas of soil surrounding the sewage treatment tanks and septic tank are independently assayed using *Fissile Material* detection equipment. If an area of soil is found to be contaminated but meets the *NCS Exempt Material* criteria, the soil is carefully exhumed as a layer not exceeding the maximum *cut depth*. If the soil that surrounds the sewage treatment tanks and septic tank has been determined to not exceed the *NCS Exempt Material* limit, the soil is carefully exhumed and set aside the excavation site, which can be used later as backfill ground material. However, if a portion of the soil is determined to exceed *NCS Exempt Material* criteria, but does not exceed the *Fissile Material Exhumation Limit*, then the associated portion is removed and packaged in a *Field*

Container. The *Field Container* is handled pursuant to the guidance, procedural requirements, and criticality controls outlined in Reference 8.

If the soil in the vicinity of the sewage treatment tanks and septic tank is found to meet *NCS Exempt Material* criteria, then it is very reasonable to assume that either no leaks from the sewage treatment tanks and septic tank have occurred, or if leaks have occurred, then the sewage treatment tanks and septic tank should also meet the *NCS Exempt Material* criteria. Conversely, if the soil in the vicinity of the sewage treatment tanks and septic tank is demonstrated to contain *Fissile Material*, then the tank must be assumed to contain *Fissile Material*.

Based on the above discussion, it is considered acceptable to assume the current sewage treatment tank will meet the *NCS Exempt Material* criteria if:

- The sanitation lines leading to the current sewage treatment tank is found to meet the *NCS Exempt Material* criteria, and decrease in the linear ^{235}U activity as the sanitation lines approach the current sewage treatment tank;

  AND
- The soil in the vicinity of the current sewage treatment tank is found to meet the *NCS Exempt Material* criteria.

However, by design, treatment tanks collect organic material allowing solids or solutions denser than water to settle or layer in the bottom of the tank, therefore, any uranium (solids or solutions) discarded into sanitation lines during fuel manufacturing operations that have reached the current sewage treatment tank would be expected to have settled to the bottom. Based on this premise it is considered prudent to require two independent surface assay measurements of the sewage treatment tanks and septic tank targeted for exhumation.

Based on these considerations, excavation of the drain line tied to the current sewage treatment system can be initiated after excavation of the treatment tank. If the content of the current sewage treatment tank is determined to meet *NCS Exempt Material* criteria, then it is very reasonable to assume that the associated drain line will also meet *NCS Exempt Material* criteria. Conversely, if any portion of the current sewage treatment tank contents are determined to contain *non- NCS Exempt Material* then the associated drain line and the sewage treatment tank structure are assumed to contain *non- NCS Exempt Material*.
Following determination that the content of the current sewage treatment tank meets *NCS Exempt Material* criteria, material is carefully exhumed as a layer not exceeding the maximum *cut depth*.[15] The exhumed material is bulked in a waste transfer vehicle and transferred to an appropriate stockpile in a WHA. If the entire content of the current sewage treatment tank is found to not contain any material with a uranium concentration exceeding the *NCS Exempt Material* criteria, then the sewage treatment tank structure and associated drain field may be exhumed without Criticality Safety Controls (CSCs).

[15] The maximum thickness treatment tank content material that can be adequately characterized by in-situ assay equipment is established in the calibration basis document associated with the type of assay equipment.

If a portion of current sewage treatment tank content is determined to exceed *NCS Exempt Material* criteria, but does not exceed the *Fissile Material Exhumation Limit*, then the associated portion is removed and packaged in a *Field Container*. The *Field Container* is handled pursuant to the guidance, procedural requirements, and criticality controls outlined in Reference 8.

Note that once all the contents of the current sewage treatment tank is extracted, and any portion of the content was determined to exceed *NCS Exempt Material* criteria, then two independent assays using qualified and calibrated *Fissile Material* detection equipment of the current sewage treatment tank must be performed. If the subject sewage treatment tank is found to meet the *NCS Exempt Material* criteria, a fixative is applied to the tank structure and then the treatment tank can be exhumed. The subject exhumed sewage treatment tank is transferred to an appropriate stockpile in a WHA. Excavation of the drain line must then be performed in accordance with the subterranean piping removal for the perforated tubes (Section 1.4.3) and per the contaminated soil exhumation procedures (Section 1.4.2).

The above assumptions cannot be made for the previous sewage treatment tank or the previous septic treatment tank. Based on the premise that both of the aforementioned treatment tanks have been decommissioned the material residing within the treatment tanks cannot be interpreted as representative of the material in the associated common drain field[16], the common drain field will be disposed of in accordance with the soil exhumation procedure and subterranean piping removal procedure.

If the current in use tank structure is found to exceed the *NCS Exempt Material* criteria, the tank structure and the associated drain line is not approved for excavation until further evaluation is performed and approval is obtained from the NCS Organization.

1.5 Overview of Equipment used for Sub-Surface Structure Decommissioning

This section provides an overview of safety significant equipment employed for sub-surface structure decommissioning activities, as relevant to this NCSA.

1.5.1 Field Containers

Field Containers are readily identifiable and are used to containerize loose *Fissile Material* and suspect *Fissile Material* identified during excavation operations. Each *Field Container* possesses a maximum volumetric capacity of 20 liters (equivalent to the volume of a nominal 5 gallon container). This limited volume minimizes the potential to accommodate an unsafe mass of *fissile material*.

Only one *Field Container* is allowed at any given time for a particular operation in a given area. Up to 350 g ^{235}U is allowed in a *Field Container*. Once the *Field Container* is lidded, it is

[16] Note that only the perforated tubes and soil/rock/sand/gravel beneath the tubes are considered to constitute the drain field (i.e., not the soil above the tubes).

handled pursuant to the guidance, procedural requirements, and criticality controls outlined in Reference 8.

1.5.2 Collared Drums

CDs are used to stage, store, and transfer items demonstrated or suspected to be *Fissile Material* or items that have not been demonstrated to meet *NCS Exempt Material* criteria. In respect to the operations evaluated in this NCSA, items to be placed within CDs include:

- *Field Containers*.
- Bulked, capped/bagged, intact pipe sections up to 3' in length.

Each CD has a cylindrical geometry, possessing a minimum internal diameter of 57 cm. This geometry and dimension ensure that unlimited quantities of CDs, each loaded with up to 350 $g^{235}U$, will remain safely subcritical in any unstacked configuration [9].

Each CD, irrespective of dimension, is fitted with a collar that extends 18" beyond the external radial surface of the CD. The CD collar is designed to ensure that any un-stacked arrangement of CDs would guarantee a minimum 36" separation distance between the outer surfaces of the CDs. The affixed collar is permanently secured to the CD and is not removed at any time the CD is being used, except when secured in a Fissile Material Storage Area (FMSA) or Collared Drum Repack Area (CDRA).

1.5.3 Secured Isolated Storage Area

SISAs are used to securely stage and store long,[17] capped (or bagged), intact (uncrushed), extracted pipe sections that have been demonstrated to or suspected to be non *NCS Exempt Material* (or that have not been demonstrated to meet *NCS Exempt Material* criteria).

An SISA consists of the following:

- Only authorized for storage of long[17] intact pipe sections that have their ends capped or bagged.
- Limited to a total of 700 $g^{235}U$ per SISA.
- Only one SISA is accessed at any given time.
- Separated by ≥ 12' from other SISAs, CDs.
- Controlled access.

[17] The term long pipes is used herein to refer to pipes that cannot be accommodated within a CD without cutting.

1.5.4 Fissile Material Monitoring Equipment

Fissile Material detection equipment employed for sub-surface structure decommissioning activities comprise a variety of assay equipment. The assay equipment that may be used includes, but is not limited to, NaI scintillator probes for surface surveys, hand-held gamma survey instruments for surface surveys, in-pipe probes for in-pipe surveys, and High Resolution Gamma Spectrometers (HRGS). Other assay equipment may be used provided the equipment satisfies the functional requirements credited in this NCSA.

The used assay equipment are suitable for the detection of gamma radiation from uranium sources at the full range of enrichment. When calibrated and used in accordance with applicable procedures, this equipment provides confidence in the avoidance of unrevealed or underestimated potential ^{235}U content of suitable surveyed items. The assay equipment is maintained under a measurement control program, which include as a minimum, daily verification of its calibration when used.

The HRGS equipment is used to obtain nuclide specific abundance, and in particular, ^{235}U assay. The HRGS equipment includes software and routines that analyze the assay data to produce an estimate of the ^{235}U content of the item presented for assay. When calibrated and used in accordance with applicable procedures, this equipment provides confidence in the avoidance of unrevealed or underestimated ^{235}U content of any suitable surveyed items.

1.6 SCOPE OF ASSESSMENT

Activities addressed in this NCSA are limited to actions associated with the excavation and initial handling/packaging of subterranean piping, concrete slabs, the septic tank and sewage treatment tanks, and soil in the vicinity of the aforementioned subsurface structures. Activities associated with subsequent handling of packaged debris classified as *non-NCS Exempt Material* is outside the scope of this assessment (e.g., on site transfer of exhumed decommissioning debris).

1.7 METHODOLOGY

This NCSA uses a risk-informed approach. Risk insights, gained from the findings of the risk assessment, are used to establish aspects of the design and process susceptible to faults important to nuclear criticality safety.

The risk-informed approach is complemented with an *As Low As Reasonably Achievable* (ALARA) assessment that is focused on identifying practicable measures that can be reasonably implemented to further reduce the risk of criticality to a level as low as reasonably achievable. The ALARA assessment also serves to provide an additional degree of confidence that a criticality incident resulting from the activities assessed is not credible.

In summary, the approach used in this NCSA is as follows:

1) Establish the margin of safety between normal (i.e., expected) conditions and foreseen credible abnormal conditions.

2) Determine whether the inherent margin of safety is sufficient to safely accommodate the credible deviations from normal conditions, and if not, identify feature(s) of the process[18] that are important to ensuring criticality safety under all credible conditions.
3) Establish what additional practicable measures, if any, can reasonably be implemented to ensure that the risks from criticality are as low as reasonably achievable.

[18] In the selection of safety controls, preference is placed on use of engineered controls over procedural controls.

2.0 CRITICALITY SAFETY ASSESSMENT

The criticality safety assessment is organized as follows:

- **Section 2.1** describes the hazard identification method employed in the criticality safety assessment of Sub-Surface Structure Decommissioning and provides a summary of the hazard identification results.
- **Section 2.2** outlines the generic assumptions used in the criticality safety assessment.
- **Section 2.3** contains the criticality safety assessment of Sub-Surface Structure Decommissioning under normal (i.e., expected) conditions.
- **Section 2.4** contains the criticality safety assessment of Sub-Surface Structure Decommissioning under abnormal (i.e., unexpected) conditions.

2.1 CRITICALITY HAZARD IDENTIFICATION

This section outlines the method used to identify criticality hazards associated with Sub-Surface Structure Decommissioning. A summary of the hazards identified is also provided, together with a brief description of their disposition in the NCSA.

2.1.1 Hazard Identification Method

The hazard identification method employed in the criticality safety assessment of Sub-Surface Structure Decommissioning is based on the *What-If/Checklist* analysis method. The *What-If/Checklist* analysis technique is a combination of two hazard evaluation methods: *What-If* analysis and *Checklist* analysis. This evaluation technique is a brainstorming approach in which a group or team familiar with the facility equipment and processes ask questions or voice concerns about possible undesirable events. The checklist adds a systematic nature to the process by ensuring all applicable hazards are addressed. The *What-If/Checklist* method identifies hazards, hazardous situations, and specific events that could produce undesirable consequences. Consequences and existing controls are listed and suggestions are made for further risk reduction.

As part of the *What-If/Checklist* analysis, the eleven (11) criticality safety controlled parameters are examined to determine the extent of their importance to criticality safety.

The eleven (11) criticality safety controlled parameters examined include:

- ✓ *Geometry*
- ✓ *Interaction*
- ✓ *Mass*
- ✓ *Isotopic/Enrichment*
- ✓ *Moderation*
- ✓ *Density*
- ✓ *Heterogeneity*
- ✓ *Neutron Absorbers*
- ✓ *Reflection*
- ✓ *Concentration*
- ✓ *Volume*

The eleven (11) parameters listed above are traditionally considered in criticality safety assessments of processes at operating facilities possessing Special Nuclear Material (SNM).

Typically, the non-process based nature of decommissioning operations limits the ability to control many parameters, resulting in the need to use bounding values for parameters in this NCSA in many instances.

2.1.2 Hazard Identification Results

A summary of the criticality hazards identified from the *What-If/Checklist* analysis is presented in Table 2.1 and are based on Reference 7. Hazards that result in events with similar consequences and safeguards are grouped in single criticality accident event sequences, and then analyzed in Section 2.4.

Table 2.1: Criticality Hazards Identified from the Sub-Surface Structure Decommissioning *What-if/Checklist* Analysis

What-if	Causes	Consequences	Accident Sequence in NCSA
Mass and Concentration			
What if an unexpected quantity/concentration of *Fissile Material* is accumulated as a result of concrete slab extraction?	• Segregation of heavily contaminated surfaces into a localized volume	Potential for credible criticality accident if proper excavation techniques are not employed	**Section 2.4.1**
What if soil contains an unexpected quantity/concentration of *Fissile Material*?	• *Fissile Material* discarded into an undocumented ground area during past production operations • Unrecognized pipe crack or breach in the vicinity • *Fissile Material* penetrated through concrete slabs and saturated soil below	Potential for credible criticality accident if proper excavation techniques are not employed	**Section 2.4.2**
What if an unexpected quantity/concentration of *Fissile Material* accumulates when subterranean pipe sections are excavated?	• *Fissile Material* having been poured into non-fissile drains and pipes during past production operations • Crushing of pipe sections in the ground leads to significant concentration of *Fissile Material* in a localized volume • Tilting or breakage of pipe section when exhumed leads to significant concentration of *Fissile Material* in a localized volume	Potential for credible criticality accident if proper excavation techniques are not employed	**Section 2.4.3**
What if an unexpected quantity/concentration of *Fissile Material* is accumulated as a result of septic/sewage treatment tank or drain field excavation?	• *Fissile Material* discarded into lab sinks during past production operations • *Fissile Material* removed during cleansing of (personal protective equipment) PPE	Potential for credible criticality accident if proper excavation techniques are not employed	**Section 2.4.4**
Volume and Interaction			
✓ A limited volume *Field Container* is used to collect exhumed debris detected to contain *Fissile Material* not exceeding the *Fissile Material Exhumation Limit.* The controls associated with preventing use of larger containers are discussed in Sections 2.4.1 through 2.4.4. ✓ CDs are used for confinement and transport of *Fissile Material* between different areas of the site. The CD design ensures safe interaction between *Fissile Materials* in transit. ✓ SISAs are used to securely stage and store long, capped (or bagged), intact (uncrushed), extracted pipe sections that have been demonstrated to or suspected to be non NCS Exempt Material (or that have not been demonstrated to meet NCS Exempt Material criteria). SISAs are staged with a minimum separation distance of 12' from other SISAs and *Fissile Containers* and are defined by physical barriers. The employed physical barriers ensure separation is maintained, which ensures safe interaction among *Fissile Materials* in storage.			

<table>
<tr><th>What-if</th><th>Causes</th><th>Consequences</th><th>Accident Sequence in NCSA</th></tr>
<tr><td colspan="4">Geometry</td></tr>
<tr><td colspan="4">✓ There are no geometrical dimensions credited to ensure criticality safety during Sub-Surface Structure Decommissioning.</td></tr>
<tr><td colspan="4">Density</td></tr>
<tr><td colspan="4">✓ There are no identified causes that could create a density more onerous than that assumed as a normal condition (i.e., theoretical density of uranium as metal).</td></tr>
<tr><td colspan="4">Heterogeneity</td></tr>
<tr><td colspan="4">✓ There are no identified causes that could create a material configuration more onerous than that assumed as a normal condition (i.e., homogeneous 100 wt. % ^{235}U).</td></tr>
<tr><td colspan="4">Neutron Absorbers</td></tr>
<tr><td colspan="4">✓ There are no neutron absorbers credited to ensure criticality safety during Sub-Surface Structure Decommissioning.</td></tr>
<tr><td colspan="4">Reflection</td></tr>
<tr><td colspan="4">✓ The close fitting full water reflection used in establishing the ^{235}U subcritical limit bounds any other credible reflection condition that may be encountered by the sample material, e.g., three-sided concrete reflection (Sample Receptacles or Sample Container staged in a concrete corner).</td></tr>
<tr><td colspan="4">Isotopic/Enrichment</td></tr>
<tr><td colspan="4">✓ There are no identified causes that could create an isotopic/enrichment condition more onerous than that assumed as a normal condition (i.e., 100 wt.% $^{235}U/U$).</td></tr>
<tr><td colspan="4">MODERATION</td></tr>
<tr><td>What if hydrogenous solutions other than water are commingled with sample materials</td><td>✓ Hydrogenous fluids have been spilled (e.g., oils and hydraulic fluids) into the piping system, on concrete pads, and onto land areas covering subterranean structures.</td><td>Potential to attain a more onerous moderating condition than the moderating condition on which the maximum subcritical limits for ^{235}U are based, which may result in a criticality accident</td><td>Section 2.4.5</td></tr>
</table>

Source: Original

2.2 GENERIC SAFETY CASE ASSUMPTIONS

This section outlines the generic assumptions on which this criticality safety assessment is based.

The pertinent underlying assumptions of this NCSA related to the assessed Sub-Surface Structure Decommissioning are as follows:

- This assessment does not consider fissile nuclides other than ^{235}U. Based on the history of the site and site documentation (refer to Section 1), there is no expectation that fissile nuclides other than ^{235}U could exist within the site boundary.
- *Fissile Material* mass limits have been derived assuming homogeneous,[19] optimally-moderated aqueous mixtures of 100% ^{235}U with close fitting full water reflection, i.e., 760 g^{235}U. This approach is applicable due to the following:
    - The decommissioning debris to be exhumed is expected to be intermixed with water from ground sources and precipitation. The septic tank and sewage treatment tanks, subterranean piping, soil, and concrete debris are not anticipated to contain significant quantities of more adverse moderators (such as hydrocarbons typically found in solid process wastes). For example, *Fissile Material* mass limits for soil are significantly larger than the 760 g^{235}U mass limit used as the basis for this assessment. The introduction of credible levels of hydrocarbons to the soil mixture is not expected to cause the mass limit to decrease below the derived 760 g^{235}U limit.
    - Decommissioning debris may encounter reflectors that potentially have superior reflection qualities than water, e.g., soil surrounding the subterranean structures or the concrete (or paved) pads on which the decommissioning debris may reside. The one sided (floor) or three sided (corner) reflection that the *Sample Container* is expected to encounter does not provide for an overall superior reflector condition that close fitting infinite water reflection used in establishing the 760 g^{235}U subcritical mass limit. Furthermore, because the presence of structural material/media between the decommissioning debris and any reflectors is essentially guaranteed (e.g., PVC or steel), and would result in parasitic neutron absorption, and consequently, an increase in the maximum subcritical mass limit of 760 g^{235}U.
- *Fissile Material* concentration limits in soil have been derived assuming an unrealistic infinite sea of ^{235}U and soil. This is conservative with respect to infinite aqueous systems due to the small neutron absorption provided by soil in an infinite sea, relative to water. Therefore, rather than using the ANSI/ANS-8.1 maximum subcritical ^{235}U concentration of 11.6 g^{235}U/L [10], this analysis uses a far more

[19] Homogenous systems involving uranium enriched 100% with ^{235}U isotope are always more reactive than heterogeneous systems due to lack of the ^{238}U isotope self-shielding and resonance effects present in low enriched systems.

conservative lower threshold of 4 g^{235}U/L based on soil matrices (see Reference 8 for additional discussion).

- The Hematite former process and auxiliary buildings are assumed to have been demolished prior to implementing this NCSA for decommissioning operations involving excavation of concrete slabs and foundations.

2.3 NORMAL CONDITIONS

This section contains the criticality safety assessment of Sub-Surface Structure Decommissioning assuming anticipated (normal) conditions.

As detailed in Section 1.4, Sub-Surface Structure Decommissioning includes the following operations:

- Removal of concrete slabs (i.e., the floor of the decommissioned buildings and associated walkways);
- Exhumation of soil that covers and surrounds subterranean piping and contaminated soil that is beneath concrete slabs;
- Extraction of subterranean piping; and
- Extraction of the septic tank and sewage treatment tanks(s) and associated drain fields.

2.3.1 Concrete Slab Anticipated Conditions

Under normal conditions, former processing building concrete slabs that are free of cracks, expansion joints, and seams are anticipated to have only contamination that is confined within upper surface regions of the slabs. This expectation is based on prior decommissioning activities and on operational practices during the manufacturing era, which would have required floor surfaces to be periodically cleaned. Furthermore, this expectation is validated in Reference 4, where analyses of core concrete samples indicate that nearly all of the ^{235}U contamination is confined to the upper ¼" of the concrete surface (results obtained from Reference 4 that support this expectation are summarized in Table 1.4). In addition, the surface contamination of the concrete is anticipated to be fixed based on prior decommissioning activities in the former process buildings. The concrete walkways and pathways on-site are not anticipated to be contaminated. Furthermore, Section 1.4.1.2 indicates that if only the ^{235}U is confined to the top ½" of the concrete slabs and if only the top ½" of the concrete slabs is removed, the effective ^{235}U concentration is expected be less than the applicable non-*NCS Exempt Material* lower threshold of 0.1 g^{235}U/L.

Former processing building concrete slabs comprising cracks, expansion joints, and seams along are anticipated to have elevated levels of contamination. However, the magnitude of the contamination is expected to be well below limits that would be of concern to criticality safety. Based on the analysis outlined above, *NCS Exempt Material* criteria is anticipated to be met for all concrete regions, including concrete portions that were, historically, in the vicinity of uranium processing equipment, and which contain cracks, expansion joints, and seams, as discussed in Section 2.4.1.

2.3.2 Soil Anticipated Conditions

Soil that is not in the vicinity of subterranean structures and the soil that is not near concrete slabs that were used as floors or foundations of the Hematite facility former process and auxiliary buildings[20] are all expected to meet *NCS Exempt Material* criteria. This is because regions that cover soil in these areas would have not been subjected to ^{235}U contamination and these soils were protected against contamination by "non-production use" concrete slabs. Furthermore, there is no credible pathway for ^{235}U to seep to this soil.

Soil surrounding subterranean piping that is not in the vicinity of pipe breaches or cracks is also anticipated to meet *NCS Exempt Material* criteria, because the piping would have provided a barrier against entrainment of uranium into the surrounding soils.

Under normal conditions, the soil surrounding subterranean piping that is in the vicinity of pipe breaches or cracks and the soil that is near concrete slabs that were used as a floor for fuel manufacturing operations in the former process buildings are conservatively anticipated to exceed *NCS Exempt Material* criteria, but are not anticipated to contain a ^{235}U concentration in excess of the *Fissile Material Exhumation Limit.* With regard to soil near concrete slabs that are free of cracks, expansion joins, and seams and were in the vicinity of fuel manufacturing operations in the former process buildings, this assumption is judged to be conservative based on sample analysis of underlying gravel and soil cored from beneath the former process building concrete slabs, which include samples of soil/gravel cored through concrete slab regions that were determined from the radiological survey to constitute hotspots [2,4]. Results of the sample analysis, reproduced herein in Table 1.3, indicate that the highest observed ^{235}U concentration in the sampled gravel/soil is ≤ 30 mg-^{235}U/L (≤ 0.03 g^{235}U/L), which is significantly below the *NCS Exempt Material* criteria of 0.1 g^{235}U/L.

However, cored-sample analysis of the underlying soil/gravel regions collected from beneath concrete sections that exhibited cracks, expansion joints, and seams indicate that the highest ^{235}U concentration in the sampled gravel/soil is 117 mg-^{235}U/L (0.117 g^{235}U/L), which is slightly above the *NCS Exempt Material* criteria of 0.1 g^{235}U/L, but a factor of 34 less than the maximum subcritical limits of ^{235}U in soil (4 g^{235}U/L) [8]. The underlying soil/gravel sample with this measured ^{235}U concentration was obtained through a crack from a resurfaced concrete region, which indicates the referenced concrete section was subjected to significant contamination levels. Hence, it is not expected that the 0.117 g^{235}U/L represents ^{235}U concentration levels in the general underlying ground regions; albeit the 0.117 g^{235}U/L does not pose a criticality risk.

With regard to soil near cracked or breached subterranean piping, this assumption is also judged to be conservative based on results of the in-pipe probe radiological surveys [6], where well over one thousand feet of subterranean pipes was surveyed. Results of the in-pipe radiological survey did not reveal excessive dose rate levels in the assayed subterranean pipes. Lack of excessive dose rates in the assayed pipes provides assurance that any ^{235}U that may have escaped through cracks of said pipes is not of significant quantities.

[20] These are none-production concrete slabs, such as sidewalks and concrete slabs outside former process and auxiliary buildings.

2.3.3 Subterranean Piping Anticipated Conditions

Under normal conditions, a small amount of *Fissile Material* is expected to have been introduced into the subterranean process piping. Consequently, under normal conditions any ^{235}U that was inadvertently introduced within subterranean process piping is attached to the interior of piping structure. This is due to the fact that over 50 years of water running through the subterranean process piping and storm water system would have ensured that any loose ^{235}U would have been flushed out. Based on the 50 years of water running through the subterranean piping and the assumption that loose ^{235}U would have been flushed out of the system the majority of subterranean piping is expected to contain only trace amounts of *Fissile Material*. This assumption is supported by the results of the in-probe radiological surveys that examined over one thousand feet of subterranean piping, and concluded that all but four individual segments totaling ≈ 190' exhibited an average concentration in excess of the *NCS Exempt Material* concentration limit (criteria (a) of Appendix A) of 1.4 g^{235}U/L.

Under expected conditions, the vast majority of subterranean piping will only contain trivial amounts of contamination that is residual in nature. Based on the in-probe radiological surveys, sanitary and gray water lines residing within the confines of process buildings, i.e., subterranean sanitation piping, laboratory sinks, and drains connected to personal protective equipment (PPE) washing machines, were found to be insignificantly contaminated with *Fissile Material,* such that under normal conditions the receiving systems would only contain trace quantities of *Fissile Material.*

Because the in-probe radiological surveys represent a significantly large sample, and the assayed pipes represent pipes with drains that were in the vicinity of the fuel manufacturing operations, results of the in-pipe radiological surveys are also expected to represent a bounding estimate of the ^{235}U activity in all other subterranean piping. Thus, based on the assumed normal condition that the vast majority of subterranean piping will only contain trivial fissile loading dispersed over several thousand liner feet the exhumed subsurface piping will remain safely subcritical.

2.3.4 Septic and Sewage Treatment Tank(s) and Associated Drain Field Anticipated Conditions

Under normal conditions, the current sewage treatment tank is anticipated to contain only small (insignificant) quantities of ^{235}U. This is due to the fact that the subterranean piping connected to the treatment tank originates primarily from the lavatories (i.e., non-fissile material handling locations). Under normal (anticipated) conditions, any *Fissile Material* associated with the treatment tank content will have a low mass/concentration, well below safe subcritical limits, such that, it is considered unlikely to have a ^{235}U average concentration in excess of the *NCS Exempt Material* criteria of 0.1 g^{235}U/L.

Under anticipated conditions the drain line associated with current sewage treatment system is of no concern provided the current treatment tank meets the *NCS Exempt Material* criteria. Therefore, the drain line is anticipated to meet *NCS Exempt Material* criteria even without verification by assay, provided the current sewage treatment tank is demonstrated to meet *NCS*

Exempt Material criteria. However, if the current sewage treatment tank is classified as *non-NCS Exempt Material* then the drain line associated with the *non-NCS Exempt* subject tank must be excavated in accordance with the subterranean piping removal process and soil exhumation procedures (presented in Sections **Error! Reference source not found.** and **Error! Reference source not found.**).

Note because the older sewage treatment tank and concrete septic tanks have been decommissioned and the material residing within the tanks cannot be interpreted as representative of the associated drain field, the drain field in conservatively anticipated to comprise *non-NCS Exempt material* and will be excavated in accordance with the subterranean piping removal process and soil exhumation procedures.

2.4 ABNORMAL CONDITIONS

This section provides an assessment of the criticality hazards identified from the *What-if* analysis of Sub-Surface Structure Decommissioning. The *What-If/Checklist* analysis, which is summarized in Section 2.1, identified potential criticality hazards requiring further evaluation. The postulated hazards are grouped and assessed in the following event sequences:

- Section 2.4.1: Unexpected *Fissile Material* Quantities/Concentration in Concrete
- Section 2.4.2: Unexpected *Fissile Material* Quantities/Concentration in Soil
- Section 2.4.3: Unexpected Fissile Material Quantities/Concentration during Subterranean Pipe Section Excavation
- Section 2.4.4: Unexpected *Fissile Material* Quantities/Concentration in Septic Tank and/or Sewage Treatment Tanks and Drain Fields
- Section 2.4.5: Hydrogenous Solutions other than Water are Commingled with Exhumed Subterranean Structures and Debris

2.4.1 Unexpected *Fissile Material* Quantities/Concentration in Concrete

2.4.1.1 Discussion

To alleviate a concern of bulking significant quantities of *Fissile Material* associated with concrete excavation, an extensive radiological surface survey (nondestructive surface surveys) was undertaken during 2009 for the purpose of providing radiological data to assist in quantifying the residual mass of ^{235}U associated with concrete surfaces [1-3]. The radiological survey was then complemented by coring data [4].

Results of the destructive assays and nondestructive performed on concrete surfaces, which have been summarized in Sections 1.4.1.1 and 1.4.1.2, respectively, include the following:

2.4.1.1.1 Results from the Cored-Concrete Sample Analysis

Results summarized in this section are based on the data presented in Table 1.1 through Table 1.4 in Section 1.4.1.1 of this document.

- ✓ The majority of the samples exhibited low-enriched ^{235}U levels (i.e., ≤ 5 wt.% ^{235}U), with only four samples exhibiting intermediate-enriched ^{235}U levels (i.e., 5 wt.% < $^{235}U/U$ ≤ 20 wt.%). There were no samples that measured enrichments above the intermediate-enrichment limit.
- ✓ Samples collected from concrete regions that are not identified as having cracks, expansion joints, seams, or have not being identified as previously resurfaced have the majority of their ^{235}U contamination (> 95%) confined to the upper ¼" surface of the concrete with insignificant ^{235}U contamination residing within their underlying regions.
- ✓ Samples collected from previously scabbled regions[21] exhibited relatively low ^{235}U contamination levels, which further indicate that the scabbling effort previously performed was successful in reducing the amounts of ^{235}U contamination to insignificant levels. Analysis of the cored-concrete sample demonstrated that ≤ 6 mg^{235}U/L is constrained in the samples' upper ¼" segment, and when averaged over the entire lengths of samples, the ^{235}U concentration is found to be ~0.9 mg^{235}U/L, which is more than a factor of 110 below the *NCS Exempt Material* criteria of 0.1 g^{235}U/L.

2.4.1.1.2 Results from the Radiological Surface Survey

Results summarized in this section are based on the data presented in Table 1.6 in Section 1.4.1.2 of this document.

[21] The referenced "scabbled" concrete regions were resurfaced with ≥ 3" thick layer of concrete during manufacturing operations.

- ✓ Bldg-252, South Vault, an auxiliary building, has the highest ^{235}U concentration in its concrete floors than all other buildings. However, because of its relatively small area (~1,000 ft^2), the total amount of ^{235}U contained within its concrete floor is ~200 $g^{235}U$.
- ✓ The total amount of ^{235}U present in the floor regions of all auxiliary building is less than 590 $g^{235}U$.
- ✓ Area 3 of the former process buildings has the highest amount of ^{235}U, at ~1,150 $g^{235}U$. However, because of its large area (~30,000 ft^2), the concentration of ^{235}U that is contained within its upper ½" regions is 0.032 $g^{235}U/L$, i.e., below the *NCS Exempt Material* criteria of 0.1 $g^{235}U/L$.
- ✓ The total amount of ^{235}U present in the floor regions of all Hematite facility buildings is less than 4,565 $g^{235}U$. However, the results also indicate, when averaged over all floor regions, that the ^{235}U concentration confined in only the upper ½" (the concentration is conservatively derived by applying a scaling factor of 1.7) is well below the *NCS Exempt Material* criteria of 0.1 $g^{235}U/L$.

2.4.1.2 Risk Assessment

A criticality accident cannot be realized when exhuming portions of concrete as long as one of the two following criteria is met:

- The total mass of ^{235}U associated with the exhumed concrete does not exceed its maximum subcritical mass limit.

OR

- The macroscopic concentration of ^{235}U associated with the exhumed concrete does not exceed its maximum subcritical concentration limit.

Results of the radiological survey (presented in Section 1.4.1.2) indicate that the total mass of ^{235}U contained within all concrete slabs is less than 4,650 $g^{235}U$, which is a factor of ~6 greater than the ^{235}U subcritical mass limits derived in Reference 8. Since the ^{235}U contained in the concrete slab regions is spread over a large area (~98,000 ft^2), the radiological survey results can therefore be used to limit the slab removal operations to only allow removal of concrete slab regions with less than 760 $g^{235}U$ at any given time,[22] thereby eliminating the potential for a criticality accident. However, it is not reasonable to postulate that such idealized conditions could be achieved or even approximated for the very large volume of concrete (~230,000 L, if the concrete slabs were only 1" thick, and well over 1,000,000 L for nominally thick concrete slabs)[23] containing only 4.65kg ^{235}U.

[22] The 760 $g^{235}U$ is selected as the subcritical mass limit for ^{235}U despite the fact that ^{235}U is embedded in a concrete mixture that exhibits inferior moderating capabilities than water.

[23] Thicknesses of the concrete slab regions in the Hematite former process and auxiliary buildings range from 4" to 12".

Maximum subcritical concentration limits for ^{235}U have also been derived for a vast number of materials. Reference 10 derives a concentration of 11.6 $g^{235}U/L$ for an infinite aqueous solution containing 100 wt.% enriched ^{235}U. Reference 8 establishes a maximum subcritical mass concentration of 4.0 $g^{235}U/L$ for an infinite system comprising only ^{235}U and soil, in addition, a concentration limit is derived from the fictitious minimum critical concentration of 1.4 $g^{235}U/L$ for bounding soil consisting of only SiO_2 per NUREG/CR-6505 (Ref 13)

For this assessment, the smallest subcritical concentration limit is selected, i.e., 1.4 $g^{235}U/L$, to be the subcritical concentration limit of ^{235}U in concrete. Note that this selected concentration limit is also significantly smaller than the actual limit that would apply for ^{235}U contained within the concrete slabs. This is recognized when considering that the selected subcritical limit of 1.4 $g^{235}U/L$ is based on a fictitious infinite medium comprising only ^{235}U and SiO_2, which is far removed from any system comprising predominantly surface contaminated concrete.

Table 1.6 indicates that if the entire observed inventory of ^{235}U is contained in ½" thick concrete, the resultant bulk concentration would be 0.039 $g^{235}U/L$, which is below the *NCS Exempt Material* screening criteria established for the majority of remediation activities at the Hematite facility of 0.1 $g^{235}U/L$ [8] (Note that this 0.1 $g^{235}U/L$ screening criteria established for remediation activities is only intended to serve as an insurance for waste to be accepted at an alternate disposal facility rather than representing an actual safety limit for site operations). The thicknesses of concrete slabs are significantly greater than ½", which imply that the bulk ^{235}U concentration is significantly less than 0.039 $g^{235}U/L$. The concrete slab floors of the Hematite facility former process and auxiliary buildings range from 4" to 12". Assuming the concrete slabs are only 4" thick results in a ^{235}U concentration of less than 0.005 $g^{235}U/L$, which is a factor of twenty (20) less than the *NCS Exempt Material* screening criteria of 0.1 $g^{235}U/L$ for soil.
Note further that ^{235}U in the concrete slab regions is expected to be significantly less than that shown in Table 1.6, primarily for the following two reasons:

- ✓ In performing the radiological surveys of the concrete floor regions, a collimator was not employed on the NaI detector. Collimators are generally used to reduce the extent of background counts, and hence the gross count rates observed in the detector include contributions from the background. The corresponding analysis utilizing the radiological survey data conservatively ignored background contributions and treated all observed counts as originating from localized ^{235}U contamination. Ignoring the effects of background counts has the potential to significantly exaggerate the levels of ^{235}U contamination.
- ✓ A ^{235}U uniform penetration depth of ½" was imposed on the radiological survey data to account for attenuation of uranium emitted gammas through the concrete substrate. Doing so resulted in scaling the radiological survey data upward by a factor of 1.7.

Despite the very conservative amount of ^{235}U assigned to the concrete floors and despite the fact that the ^{235}U enrichment is well below 100 wt. %, the resultant low concentration level of the

^{235}U in concrete of < 0.005 g^{235}U/L is a factor of twenty less than the *NCS Exempt Material* screening criteria of 0.1 g^{235}U/L for soil. Therefore, it is concluded to be not credible for a criticality to occur from piling up the extracted concrete debris.

Furthermore, it is considered at least *unlikely* that excavation of concrete slabs could result in release of sufficient quantities of fissile material from broken, hammered, or cut concrete sections, and it is also considered to be *unlikely* for the released fissile material to be bulked into a configuration leading to a critical configuration, especially when the relatively large area in which concrete excavation will occur is considered. This is due to the fact that any *Fissile Material* that has embedded itself into the concrete would be essentially fixed in place. Excavation operations would not be expected to result in the release of significant of uranium from the concrete matrix. In order for a criticality safety concern to be significant, large quantities of *Fissile Material* associated with the surface of the concrete or within pockets of the concrete must be mobilized and accumulated in a localized region. This potential is extremely small, especially given the large area of concrete considered in the excavation activity (~98,000ft^2). It is reasonable to assume that the concrete surfaces experienced routine foot traffic during the fuel manufacturing era and that housekeeping policies at that time would have ensured that significant quantities of ^{235}U would not have been discarded into the recesses of the concrete floor or left lying on its surface. Furthermore, decommissioning operations conducted since then have further reduced the potential for significant contamination levels, and especially the potential for loose *Fissile Materials* on the concrete surfaces. Additionally, the concrete floors of the former process and auxiliary buildings were sprayed with fixative to further ensure the uranium contamination is immobile. Based on these considerations, loose *Fissile Material* is not expected to be found on the surface or within open or porous regions of the concrete slabs. As such, it is judged as not credible for concrete excavation operations to lead to significant release of *Fissile Material* in a localized region and then result in a criticality accident.

It is anticipated that concrete excavation operations will result in lifting part of the underlying ground region that may be stuck to the lower surfaces of the concrete slabs. However, it is considered *unlikely* that ground regions will contain ^{235}U concentrations to be of significant quantities. This is because concrete regions that are free of cracks, expansion joins, and seams will act as a barrier against ^{235}U that was spilled during the manufacturing era from seeping to the underlying ground regions. The only credible contamination pathway to the soil beneath former concrete slabs is from spills of liquid forms of uranium that have occurred during manufacturing operations that occurred near seams, expansion joints, and cracks of concrete slabs and seeped through the underlying regions. Cored-sample analysis of the underlying soil/gravel regions collected from beneath concrete sections that exhibited cracks, expansion joints, and seams indicate that the highest ^{235}U concentration in the sampled gravel/soil is 117 mg-^{235}U/L (0.117 g^{235}U/L), which is slightly above the *NCS Exempt Material* criteria of 0.1 g^{235}U/L for soil, but a factor of thirty-six less than the maximum subcritical limits of ^{235}U in soil (4 g^{235}U/L) [8]. The underlying soil/gravel sample with this measured ^{235}U concentration was obtained through a crack from a resurfaced concrete region, which indicates the referenced concrete section was subjected to significant contamination levels. Hence, it is not expected that the 0.117 g^{235}U/L represents ^{235}U concentration levels in the general underlying ground regions, albeit the 0.117 g^{235}U/L does not pose a criticality risk. This expectation is further supported by the cored-sample analysis results, which also indicate that the average observed ^{235}U concentration in all the sampled gravel/soil is 12.7 mg-^{235}U/L (≤ 0.013 g^{235}U/L), which is more than a factor of seven (7) below the *NCS Exempt Material* criteria of 0.1 g^{235}U/L and a factor of more than 300 less than the maximum subcritical limits of ^{235}U in soil (4 g^{235}U/L).

Notwithstanding the above, sporadic small-sized pockets of ground regions underlying the concrete slabs are conservatively assumed to exhibit elevated ^{235}U concentration levels that exceed *NCS Exempt Material* criteria of 0.1 g^{235}U/L. However, it is considered *unlikely* that these regions will exhibit ^{235}U concentration levels that exceed the *Fissile Material Exhumation Limit*, and it is also considered *unlikely* that ground regions attached to concrete debris will contain ^{235}U in significant quantities that would result in a criticality accident.

Even though the risk of a criticality accident during unmitigated concrete excavation is judged to be incredible as explained above, CSCs are nonetheless implemented to ensure downstream operations *Bounding Assumptions* are maintained (i.e., all materials transferred to WHA meet *NCS Exempt Material* criteria of 0.1 g^{235}U/L). The controls consist of the following:

- ⇨ The upper surface of all concrete floor regions of the former manufacturing facilities and auxiliary buildings that were involved in manufacturing and storage of ^{235}U SHALL be ensured to have a fixative[24] applied to immobilize the entrained ^{235}U contamination prior to any excavation of the concrete slabs.
- ⇨ Visible quantities of ground material (soil/gravel) attached to the bottom of hammered, broken, or cut concrete section removed from floor sections of Hematite facility buildings that were involved with handling liquid forms of uranium (i.e., Building 240 and Building 260) SHALL be handled in accordance with exhumation procedures for suspected contaminated soil, as outlined in Section 1.4.2. Therefore, independent assay of ground material attached to concrete sections excavated from Building 240 and Building 260 SHALL be performed using qualified, calibrated *Fissile Material* detection equipment to ensure that *non-NCS Exempt Material* is not bulked with the concrete debris.

2.4.1.3 <u>Summary of Risk Assessment</u>

Based on the risk assessment provided in Section 2.4.1.2, concrete excavation operations cannot credibly result in an unsafe condition because the ^{235}U mass quantity associated with the concrete debris is too low considering its form and relative abundance (very low concentration levels). However, because the excavated concrete debris will be bulked and transferred to an appropriate stockpile in a WHA, controls are established that ensure containment of the ^{235}U within the concrete debris during excavation operations and to prevent exhumation of potentially contaminated underlying ground material with the concrete debris, i.e., to prevent transfer of underlying soil that may potentially exceed the *NCS Exempt Material* criteria of 0.1 g^{235}U/L to the WHA.

[24] Concrete surfaces that have been treated with a fixative do not need to be replaced or retreated unless the fixative has been removed or is no longer present.

2.4.1.4 Safety Controls

The following procedural requirements (recognized as a Defense-in-Depth (DinD) controls) are considered a practicable measure for further reducing criticality risk. It is considered that their implementation will ensure that the risks from criticality are as low as is reasonably achievable.

Administrative DinD Control 01: *The upper surface of the concrete slabs residing in the following former facilities SHALL be ensured to have been coated with a fixative prior to exhumation:*

- ⇨ *Building 235*
- ⇨ *Building 240*
- ⇨ *Building 252*
- ⇨ *Building 253*
- ⇨ *Building 254*
- ⇨ *Building 255*
- ⇨ *Building 256*
- ⇨ *Building 260*

Administrative DinD Control 02: *Following excavation of concrete debris, the underside of the excavated concrete SHALL be inspected for any attached sub-surface debris (e.g., mounds of soil, embedded piping, etc.). Any identified attached debris SHALL be radiologically surveyed for* ^{235}U *content, or removed and later radiologically surveyed for* ^{235}U *content during survey of the surrounding exposed soils. Any identified non-NCS Exempt debris SHALL be handled and containerized as non-NCS Exempt Material.*

Note: *This CSC only applies to concrete surfaces within the environs of Building 240 and Building 260.*

2.4.2 Unexpected *Fissile Material* Quantities/Concentration in Soil

2.4.2.1 Discussion

As discussed in Section 2.3.2, it is deemed as not credible for the soil that is not in the vicinity of subterranean structures and the soil that is not near concrete slabs[25] that were used as floors or foundations of the Hematite facility former process and auxiliary buildings to exceed *NCS Exempt Material* criteria. This is because this soil in these areas would have not been subjected to ^{235}U contamination. This is also true for the soil and underlying ground regions beneath slabs associated with manufacturing operations that were restricted to dry forms of uranium.

However, the soil surrounding subterranean piping and the soil that is near concrete slabs that were used as a floor for fuel manufacturing operations in the former process buildings that employed liquid forms of uranium (i.e., solutions) is conservatively anticipated to exceed *NCS Exempt Material* criteria, but is not anticipated to contain a ^{235}U concentration in excess of the *Fissile Material Exhumation Limit.*

With regard to soil beneath concrete slabs that are free of cracks, expansion joints, and seams and (in the vicinity of fuel manufacturing operations in the former process and auxiliary buildings), this assumption is judged to be very conservative based on sample analysis of underlying gravel and soil cored from beneath the former process building concrete slabs, which include samples of soil/gravel cored through concrete slab regions that were determined from the radiological survey to constitute hotspots [2,4]. Results of the sample analysis, presented herein in Table 1.3, indicate that the highest observed ^{235}U concentration in the sampled gravel/soil is ≤ 30 mg-^{235}U/L (≤ 0.03 g^{235}U/L), which was measured by means of destructive assay that was performed on sample #05. Sample #05 originated from a concrete region that was identified as one of the hotspots during radiological survey analysis of the concrete slabs, and the sample analysis performed on the top ¼" concrete surface of the sample indicates a relatively high activity of 2,416 mg/L. So despite the fact that the concrete region above the sampled underlying ground material exhibited relatively high levels of ^{235}U contamination, the amount of ^{235}U that seeped into the ground region was sufficiently small such that the resultant ^{235}U concentration is substantially below the maximum safe fissile concentration of 4.0 g^{235}U/L consisting of ^{235}U and soil [8].. Furthermore, the cored sample analysis of underlying soil/gravel regions indicates that the average ^{235}U concentration observed in the twenty-one cored gravel/soil samples is ≤ 13 mg-^{235}U/L (≤ 0.013 g^{235}U/L), which is more than a factor of seven (7) smaller than the *NCS Exempt Material* threshold.

However, cored-sample analysis of the underlying soil/gravel regions collected from beneath concrete sections that exhibited cracks, expansion joints, and seams indicate that the highest ^{235}U concentration in the sampled gravel/soil is 117 mg-^{235}U/L (0.117 g^{235}U/L), which is slightly above the *NCS Exempt Material* criteria of 0.1 g^{235}U/L for soil, but a factor of thirty-four (34) less than the maximum subcritical limits of ^{235}U in soil (4 g^{235}U/L) [8]. The underlying soil/gravel sample with this measured ^{235}U concentration was obtained through a crack from a resurfaced concrete region (sample #03B), which indicates the referenced concrete section was subjected to significant contamination levels. Hence, it is not expected that the 0.117 g^{235}U/L

25 These are none-productive concrete slabs, such as sidewalks and concrete slabs outside former process and auxiliary buildings.

represents ^{235}U concentration levels that is characteristic of the general underlying ground regions, albeit the 0.117 g^{235}U/L does not pose a criticality risk.

With regard to soil near cracked or breached subterranean piping, this assumption is also judged to be conservative based on results of the in-pipe probe radiological surveys [6], where well over a thousand feet of subterranean pipes was surveyed. Results of the in-pipe radiological survey did not reveal excessive dose rate levels in the assayed subterranean pipes. Lack of excessive dose rates in the assayed pipes provides assurance that ^{235}U that may have escaped through cracks of said pipes is not of significant quantities.

However, to ensure soil that exceeds the *NCS Exempt Material* criteria is not inadvertently un-exhumed and treated as *NCS Exempt Material*, the surface of underlying soil beneath the concrete slab regions of the former process and auxiliary buildings that were involved in the handling of liquid forms of uranium (specifically, Building 240 and Building 260) are thoroughly assayed independently using diverse or redundant methods once the overlaying concrete slabs are removed. Redundant methods would include surface assay performed by two different operators using the same type (but different) of equipment. Surface assay is a very conservative method when used to quantify *Fissile Material*. The surface assay is performed with calibrated equipment that is effective for *Fissile Material* identification and quantification within the soil. Surface assays of the underlying soil and ground regions beneath nonproduction use concrete slabs and other surfaces (pavement) and surface assays of the underlying soil and ground regions beneath former concrete slab buildings that were restricted to dry forms of uranium are not required because there is no credible pathway for dry forms of uranium to seep through the concrete slabs, which was indicated previously in this section.

Areas that are found to be below the *NCS Exempt Material* criteria of 0.1 g^{235}U/L and do not contain subterranean structures targeted for extraction can be left untouched without further exhumation activities.

However, if an area of soil is found to be contaminated but meets the *NCS Exempt Material* criteria, the soil is carefully exhumed as a layer not exceeding the maximum *cut depth.*[26] The exhumed soil is bulked and transferred to an appropriate stockpile in a WHA. If a portion of the soil is determined to exceed *NCS Exempt Material* criteria, but does not exceed the *Fissile Material Exhumation Limit* of 700 g^{235}U,[27] then the associated portion is removed and packaged in a *Field Container*. The *Field Container* is handled pursuant to the guidance, procedural requirements, and criticality controls outlined in Reference 8. Once the layer of contaminated soil is exhumed, two independent surface assays are then performed over the uncovered soil regions. The sequence of operations that involve exhumation of contaminated soil up to the maximum *cut depth* and subsequent independent surface assays are performed until soil is determined to be below the *NCS Exempt Material* Limit. Note that if subterranean structures are encountered or exposed during exhumation of contaminated soil, the subterranean structures exhumation procedures and processes can then be invoked.

26 The maximum thickness of soil that can be adequately characterized by in-situ assay equipment is established in the calibration basis document associated with the type of assay equipment.

27 Remediation operations in the affected area will cease and the NCS Organization will be notified in the event of discovery of portions of soil containing a *Fissile Material* concentration exceeding the *Fissile Material Exhumation Limit*.

For soil regions that overlay subterranean structures but have been determined to not exceed the *NCS Exempt Material* Limit, the soil covering the subterranean structures is carefully exhumed until these structures are encountered, at which time, subterranean structures exhumation procedures and processes are then invoked.[28] Note that any exhumed soil classified as NCS Exempt Material, and which also does not exceed the *NCS Exempt Material* Limit, may be set aside the excavation area and used as back-fill material.

In the event soil is determined to contain *Fissile Material* greater than the *Fissile Material Exhumation Limit,* affected operations will cease and will not resume without instruction and approval of the NCS Organization.

2.4.2.2 Risk Assessment

A criticality accident cannot be realized when exhuming portions of soil as long as one of the two following criteria is met:

- The total mass of ^{235}U associated with the exhumed soil does not exceed its maximum subcritical mass limit.

OR

- The macroscopic concentration of ^{235}U associated with the exhumed soil does not exceed its maximum subcritical concentration limit.

Subcritical mass limits for ^{235}U have been derived for a vast number of materials. Reference 8 establishes a maximum subcritical mass limit of 760 g^{235}U, which is based on full water-reflection of optimally-moderated, spherical aqueous solutions containing 100 wt.% enriched ^{235}U. For conservatism, this assessment will utilize 760 g^{235}U as the subcritical mass limit for ^{235}U.

It is important to note that the soil areas that are of particular concern to criticality safety involve portions of soil that are in the vicinity of subterranean piping or soil beneath heavily contaminated concrete slabs associated with fuel manufacturing operations in the former process buildings that handled uranium solutions. The subterranean piping has the potential to contain a crack or breach, which could have allowed solutions laden with *Fissile Material* to seep into surrounding pockets of soil. The heavily contaminated concrete slabs also had the potential to allow seepage of *Fissile Material* to collect within the soil through cracks, expansion joints, or seams adjacent to walls.

The two different surface assays utilize calibrated equipment that is effective for *Fissile Material* identification and quantification within soil. The operators that are responsible for the detector's response and function are knowledgeable, skilled and trained to perform the task.

[28] Note that, not only do subterranean excavations of non-NCS Exempt Material require two independent surface assays using calibrated equipment of the subterranean structures, but also of the surrounding soil.

Once the assay results confirm that the soil meets *NCS Exempt Material* criteria, then the soil portions are excavated to a depth justified by the calibration document for the assay equipment and then bulked. This criterion is defined as a concentration no greater 0.1 $g^{235}U/L$ of decommissioning debris.[29] By assuring that the macroscopic homogenous concentration of the debris is ≤ 0.1 $g^{235}U/L$, a significant margin of safety (≥ 40) is utilized. Even accounting for a conservative factor of two reduction in this large safety margin to account for credible non-homogeneity, a large factor of safety (20) still exists. Based on the low ^{235}U concentration limit of 0.1 $g^{235}U/L$, and the large safety margin outlined above, criticality safety is assured for bulked soil.

If the assay results do not confirm that the soil meets *NCS Exempt Material* criteria and instead concludes that the soil is non-*NCS Exempt Material*, then the associated soil portion is carefully extracted into a *Field Container* as long as the *Fissile Material* content was determined to be lower than the *Fissile Material Extraction Limit*. The *Fissile Material Extraction Limit* is an upper threshold set at 350 grams of ^{235}U which ensures a substantial margin of safety for each individual container.

In the event soil is determined to contain *Fissile Material* that exceeds the *Fissile Material Extraction Limit,* affected operations will cease and will not resume without instruction from the NCS Organization.

The potential risks in the above procedural requirements which could lead to a condition favorable for criticality include:

- misinterpreting the assay results
- improperly calibrating the assay equipment
- excavating portions of soil that have not been assayed
- using containers other than *Field Container*s for soil classified as *Fissile Material*

Each of these scenarios is discussed in turn in the subsections that follow.

2.4.2.2.1 <u>*Misinterpreting the Assay Results*</u>

It is considered *highly improbable* that multiple personnel would inadvertently misinterpret multiple assay results by more than a factor of 25 (minimum margin of error required to reach a potentially unfavorable condition). This is due to the qualification and training required of the operators, the fact that more than one person is responsible for interpretation of the results, multiple assay results being involved, and the large safety margin taken into account in the thresholds. If the multiple assay results for a particular soil region were mistakenly interpreted as meeting *NCS Exempt Material* criteria when in fact the soil contained ≤ 0.1 $g^{235}U/L$, then significant quantities of *Fissile Material* could potentially be bulked together. However, for

[29] The surface assay response and function used for converting radiation counts to ^{235}U concentration is described in the detector calibration basis document for the given material.

conditions favorable for criticality to exist, the actual ^{235}U concentration in the soil must be at least 25 times higher than the misinterpreted result.

Training is essential for any nuclear facility decommissioning activity and this excavation activity is treated no differently. The operators are knowledgeable, trained and qualified to perform their assigned tasks, and fully recognize the importance in performing their tasks independently and according to procedure. Converting a reading displayed on surface assay equipment into quantification of *Fissile Material* for a given volume is a simple task. Since a decision to excavate with a bulking method requires concurrence from multiple operators performing the same simple task, unknowingly exhuming an unsafe concentration of *Fissile Material* due to misinterpretation of multiple assay results is considered *highly improbable* to occur during the decommissioning activities. If the multiple assay results for a particular soil portion were mistakenly interpreted as meeting *Fissile Material* classification but was actually above the *Fissile Material Extraction Limit* of 350 grams of ^{235}U, then significant quantities of *Fissile Material* could potentially be loaded into a *Field Container*. The *Field Container* is limited in maximum usable volume to only 20 liters and *Fissile Material Extraction Limit* of 350 grams of ^{235}U, which ensures a substantial margin of safety for each individual container.

2.4.2.2.2 *Improperly Calibrating the Assay Equipment*

It is considered *highly improbable* that multiple assay equipment would be inadvertently used without proper calibration that could lead to underestimated *Fissile Material* content in a portion of soil by more than a factor of 25 (minimum margin of error required to reach a potentially unfavorable condition). This is due to the knowledge, qualification and training required of the operators, the fact that more than one person is responsible for ensuring calibration of the assay equipment, multiple assay equipment being used, the reliability of the assay equipment even without frequent calibration, and the large safety margin taken into account in the thresholds.

If multiple improperly calibrated assay equipment was used on a particular soil region resulting in a reading that confirmed the soil as meeting *NCS Exempt Material* criteria when in fact the soil contained ≤ 0.1 g^{235}U/L, then significant quantities of *Fissile Material* could potentially be bulked. However, for conditions favorable for criticality to exist, the actual ^{235}U concentration in the soil must be at least 25 times higher than the misinterpreted result.

Training is essential for any nuclear facility decommissioning activity and this excavation activity is treated no differently. The operators are knowledgeable, trained and qualified to perform their assigned tasks, and fully recognize the importance in performing their tasks independently and according to procedure. Ensuring proper calibration of assay equipment prior to its use is a simple task. Since a decision to excavate with a bulking method requires concurrence from multiple operators performing the same simple task, unrecognizably unknowingly exhuming an unsafe concentration of *Fissile Material* due to using improperly calibrated assay equipment is considered *highly improbable* to occur during the decommissioning activities.

If multiple improperly calibrated assay equipment were used on a particular soil region resulting in a reading that confirmed the soil as meeting *Fissile Material* classification but was actually above the *Fissile Material Extraction Limit* of 350 grams of ^{235}U per *Field Container*, then significant quantities of *Fissile Material* could potentially be loaded into a *Field Container*. The *Field Container* is limited in maximum usable volume to only 20 liters and *Fissile Material Extraction Limit* of 350 grams of ^{235}U, which ensures a substantial margin of safety for each individual container. Based on this safety margin, the simplicity of the procedures, the requirement for multiple persons to follow the procedures, and the human reliability arguments presented, this gross failure is also considered *highly improbable* to occur during the decommissioning activities.

2.4.2.2.3 *Excavating Regions of Soil that have not been Assayed*

It is considered *highly improbable* that multiple personnel would inadvertently excavate regions of soil that have not been thoroughly assayed leading to an accidental criticality. This is due to the knowledge, qualification and training required of the operators, the fact that more than one person is responsible for ensuring only soil with an acceptable assay value is excavated, and the inherently *unlikely* probability of exhuming large quantities of highly concentrated *Fissile Material* that surround confirmed insignificant ^{235}U concentrations in soil. Two independent, *unlikely* conditions must first concurrently exist prior to reaching favorable conditions for a criticality accident regarding this hazard scenario.

The first *unlikely* condition is the inadvertent failure of the excavation crew to recognize lifting soil at a greater thickness than the *cut depth* limit and subsequently bulking with other soil. Excavating deeper than the *cut depth* limit is not a criticality concern until the excavated soil is exhumed and bulked with other soil that is also contaminated with ^{235}U. It is reasonable to assume that the excavating crew will recognize that the *cut depth* has been exceeded and will return the soil to its excavated area and perform multiple surface assays again prior to bulking with other exhumed soil. It should be recognized that exhuming soil in this method (i.e., bulk lifting of soil) implies that the anticipated soil layer was confirmed to meet *NCS Exempt Material* criteria and that any soil beneath or surrounding this layer would undoubtedly be mixed together forming a potentially highly ^{235}U concentrated soil matrix.

This leads to the second *unlikely* condition that would need to occur which is the extremely high ^{235}U concentration required to exist in the unassayed soil. The ^{235}U concentration required in the unassayed soil would have to be as high as 40 grams of ^{235}U in a 5 liter volume. This high concentration conservatively assumes that a layer of unassayed soil has been excavated that has a thickness just as great as the *cut depth*. For example, if the *cut depth* required by the assay equipment calibration document is

1 foot for soil, the excavator is assumed to have actually lifted 2 feet of soil (i.e., 1 foot of *NCS Exempt Material* comprising a negligible ^{235}U mass content and 1 foot of unassayed soil beneath that contains as high as 40 grams of ^{235}U in each 5 liter volume). By assuming a mixture of the two layers upon excavation (which is more than *likely* to occur), the resulting matrix yields an average concentration of ~40 grams ^{235}U per 10 liter volume which is the threshold between safe and potentially unsafe conditions for a criticality accident.

Consequently, due to the two *unlikely* conditions required to reach favorable criticality accident conditions (i.e., the first being inadvertent failure of the multiple responsible personnel to recognize unacceptable *cut depth* and the second being an extraordinarily high ^{235}U concentration in the unassayed layer of exhumed soil), it is considered *highly improbable* that a criticality accident could occur during soil exhumation if a large portion of soil is exhumed that does not have an assay value.

2.4.2.2.4 *Using Containers other than Field Containers for Soil Classified as Fissile Material*

It is considered highly improbable that multiple personnel would inadvertently allow repeated excavation of soil portions classified as *Fissile Material* debris to be collected into a container larger than a *Field Container*. Ensuring that a *Field Container* is used to collect debris classified as *Fissile Material* is a simple task. Even if a container as large as a CD were mistakenly used to collect debris classified as *Fissile Material*, the largest *Fissile Material* content that could be collected is 350 g^{235}U which is the *Fissile Material Extraction Limit* and is still safely subcritical (assuming no other concurrent unlikely procedural failures). Since *Field Container* loading operations involve multiple operators performing simple tasks, inadvertently loading an unsafe mass of *Fissile Material* into a non-approved container is considered highly improbable to occur during the decommissioning activities.

2.4.2.3 Summary of Risk Assessment

Based on the risk assessment provided in Section 2.4.2.2, the following conditions must exist before a criticality accident due to soil exhumation would be possible:

Criticality due to bulking soil supposedly meeting *NCS Exempt Material* criteria:

- Subterranean piping must be cracked or breached resulting in surrounding soil to contain greater than 4 g^{235}U/L **or** soil is located underneath cracked concrete or seams in concrete associated with former uranium solution operations resulting in surrounding soil to contain greater than 4 g^{235}U/L; and
- Bulking of soil containing *Fissile Material* from a pipe leak **or** seepage from concrete above
- Multiple soil assays inaccurately report *NCS Exempt Material* criteria is met.

Criticality due to exhuming soil with *Field Container*s:

- Subterranean piping must be cracked or breached resulting in surrounding soil to contain greater than 4 $g^{235}U/L$ **or** soil is located underneath cracked concrete or seams in concrete resulting in surrounding soil to contain greater than 4 $g^{235}U/L$; **and**
- Multiple soil assays inaccurately report *Fissile Material Exhumation Limit* is not met; **and**
- *Field Container* assay inaccurately reports *Fissile Material Exhumation Limit* is not met; **and**
- Containers other than *Field Container*s are used to collect soil classified as *Fissile Material* **or** multiple *Field Containers* are situated together in a single excavation location.

2.4.2.4 Safety Controls

The explicit CSCs relied on to provide the criticality safety barriers identified above (and thus relied on to preclude a criticality accident as a result of improper container movement/handling) are listed below. These controls, coupled with the control reliability arguments presented above, and combined with the use of multiple persons, ensures that this event sequence satisfies the DCP, because two unlikely concurrent failures would be required before a criticality accident could be possible.

> **Safety Related Equipment 01:** *Assay equipment used to classify soil debris as NCS Exempt Material (i.e., ≤ 0.1 $g^{235}U/L$) or non-NCS Exempt Material (i.e., > 0.1 $g^{235}U/L$) (when used in support of a CSC).*
>
> **Administrative CSC 01:** *Each assayed layer of soil debris SHALL be exhumed cognizant of the maximum permitted cut depth established in the assay equipment calibration basis document. At least two qualified individuals SHALL ensure that the exhumed soil debris is deposited in the excavation area and re-assayed if its exhumation results in the removal of a layer of material exceeding the maximum permitted cut depth.*
>
> **Administrative CSC 02:** *All reasonably practicable measures SHALL be taken to minimize the potential to exhume a layer of soil debris exceeding the maximum permitted cut depth. Consideration should be given to:*
>
> - ⇨ *Controlling the excavation depth to a value smaller than the maximum permitted cut depth to provide margin;*
> - ⇨ *Employing excavation techniques and equipment that allow for an optimally controlled depth excavation; and*
> - ⇨ *Use of markers or other tools to provide indication when exceeding the maximum permitted cut depth.*

Administrative CSC 03: *Soil in the vicinity of subterranean structures (e.g., subterranean piping, septic tanks, etc.) and underlying soil and ground regions beneath concrete slabs within the environs of buildings 240 and 260 SHALL be independently assayed prior to exhumation using independent assay instruments. The average ^{235}U concentration of the soil debris SHALL be demonstrated to not exceed 0.1 $g^{235}U/L$ prior to treating as NCS Exempt Material.*

NOTE:

1. *Soil in the vicinity of subterranean structures SHALL encompass all regions within 12" of the surface of the affected subterranean structure. Assay of the soil region extending beyond 12" from the surface of the subterranean structure SHALL continue until the soil in the vicinity of the affected subterranean structures is determined to be below the NCS Exempt Material criteria.*
2. *This CSC does not apply to underground utilities such as electrical conduit or gas lines.*

Administrative CSC 04: *Only Field Containers SHALL be used for collection of soil debris classified as non-NCS Exempt Material (i.e., soil debris comprising > 0.1 $g^{235}U/L$).*

Administrative CSC 05: *The fissile mass content of Field Containers SHALL be limited to a maximum 350 $g^{235}U$. In the event that the exhumation of surveyed debris could result in loading a single Field Container with greater than 350 $g^{235}U$ then the subject operation SHALL not proceed without approval from the NCS Organization.*

In support of the above Administrative CSCs, *Field Containers* are designated as a Safety Feature, the Safety Functional Requirement being to possess a maximum volumetric capacity of 20 liters (equivalent to the volume of a nominal 5 gallon container).

Safety Feature 01: *Field Containers (when used in support of a CSC) possess a maximum internal volume of 20 liters (equivalent to the volume of a nominal 5 gallon container).*

The following additional CSCs are recognized in accordance with the generic criticality controls established in Reference 8, and are adapted from the CSCs defined therein. These CSC ensures that excavation and downstream operations involving the movement, evaluation, and storage of the *non-NCS Exempt Material* evaluated herein remains safely subcritical.

Administrative CSC 06: *In the event that the fissile nuclide mass content of any surveyed debris is estimated (i.e., not confirmed) to exceed 700 g^{235}U, the debris exhumation activities in the associated remediation area SHALL cease and the NCS Organization informed as soon as is practicable and at least before excavation operations in the subject area resume.*

NOTE: *Remediation areas separated by an edge-to-edge distance of at least 12 ft may be considered neutronically isolated and thus separate.*

Administrative CSC 07: *All Field Containers loaded with non-NCS Exempt Material SHALL be over-packed with a CD prior to removal from the respective remediation area, and prior to loading an additional Field Container within the respective remediation area.*

NOTE: *Remediation areas separated by an edge-to-edge distance of at least 12 ft may be considered neutronically isolated and thus separate.*

Administrative CSC 08: *CDs SHALL be closed/lidded after completion of loading activities. Closing/Lidding of a CD in use SHALL occur prior to loading an additional CD within the respective remediation area, and prior to exporting the CD to an approved downstream area.*

In support of the above Administrative CSC, *CDs* are designated as a Safety Feature, the Safety Functional Requirement being to possess a maximum volumetric capacity of ~208 liters (equivalent to the volume of a nominal 55 gallon drum).

Safety Feature 02: *CDs (when used in support of a CSC) possess a maximum volumetric capacity of ~208 liters (equivalent to the volume of a nominal 55 gallon drum).*

2.4.3 Unexpected Fissile Material Quantities/Concentration during Subterranean Pipe Section Excavation

2.4.3.1 Discussion

As discussed previously, in-pipe probe measurements and visual surveys were conducted on over 1,600' of subterranean piping. Results of these in-pipe probe measurements concluded that all but four individual segments totaling ≈190' exhibited an average concentration in excess of the *NCS Exempt Material* concentration limit defined in criteria (a) of Appendix A. Because the assayed pipe length represents a significantly large sample, and the assayed pipes represent pipes with drains that were in the vicinity of fuel manufacturing operations, results of the in-pipe radiological surveys are deemed to be a bounding representation of the ^{235}U activity in all other subterranean piping. Furthermore, it is expected that any ^{235}U that may be contained within subterranean piping is attached to the interior of piping structure. This is due to the fact that over 50 years of water running through the subterranean process piping and storm water system would have ensured that any loose ^{235}U would have been flushed out. Therefore, based on the in-pipe probe measurements, the majority of subterranean piping is expected to contain only trace amounts of *Fissile Material*.

However, excavation operations are conservatively assumed to provide disturbance to the subterranean structures at a greater force than that provided by flowing water. Once disturbed, the subterranean piping has the potential to dislodge a portion of its *Fissile Material*. Since it is impossible to ensure that the contents of subterranean piping remain immobile during excavation, the primary prevention of a criticality accident during pipe removal is based on a combination of ensuring that only a safe mass and/or concentration is being disturbed and ensuring that any ^{235}U that is potentially contained within non-NCS Exempt piping remains inside the pipes, if excavated intact.

There are two methods for excavating piping. The subterranean pipe section can be removed either intact or crushed in place. The decision to extract the pipe section intact or as crushed debris relies in part on the encountered condition of the pipe section prior to exhumation. That is, although excavation operations entail careful removal of soil that surrounds the subterranean piping, it is expected that these operations will cause certain sections of the subterranean piping to be crushed (e.g., vitrified clay pipes are expected to be easily crushed due to excavation operations). In either case, prior to initiating pipe exhumation activities, the area overlaying the piping is clearly marked. The size of the area targeted for pipe exhumation activities is selected such that the total amount of *Fissile Material* contained within the *non-NCS Exempt* pipes does not exceed 700 $g^{235}U$. Results of the in-pipe probe measurements, which are listed in Appendix A, are used to map out pipe sections adhering to this total mass limit. The overlaying soil debris can then be removed using the soil exhumation procedures and processes, as described in Section 1.4.2 and evaluated in Section 2.4.2.

If the excavation operations resulted in maintaining the integrity of the pipe section targeted for extraction, and if the method of excavation is to lift an intact pipe section from the ground, a mapping is created that is subsequently used to determine cut locations for the *non-NCS Exempt* piping. Each *non-NCS Exempt* section of piping to be removed from the ground intact in any given time is limited to a maximum of 350 $g^{235}U$, which is defined as the *Extracted Piping*

Fissile Material Limit. The total amount (length) of piping that can be extracted at one time is therefore limited to 350 $g^{235}U$. Note that removal of the entire pipe section as one piece is not required. However, prior to removing the pipe section (or its segments), if the pipe section was identified to be non-*NCS Exempt* (based on the in-pipe probe measurements or based on supplemental pipe surface surveys performed once the pipe section is exposed), all ends of the pipe section are capped (or bagged) prior to removal from the ground. Note that capping (or bagging) off the pipe section ends is not required if the pipe section is determined to meet *NCS Exempt Material* criteria. Pipe sections that meet *NCS Exempt Material* criteria are not subjected to further NCS controls.

Once the pipe sections are exposed by removal of the overlaying soil debris, a supplemental surface assay of the exposed pipe sections can be performed. Results of the surface surveys can then be used to assist in discerning pipe segments that are *NCS Exempt Material* from pipe segments that are non-*NCS Exempt*. These surface surveys can be performed prior to removal of the pipe sections from the ground or following pipe extraction.

It should be noted that when piping is excavated from the ground from a low elevation to a higher elevation, extracted pipe sections that are capped (or with its open ends bagged), i.e., pipe sections (or segments) demonstrated or suspected to be *non-NCS Exempt* can be staged inside an SISA, provided the total mass of ^{235}U contained within the SISA does not exceed 700 $g^{235}U$. Alternatively, exhumed pipe sections may be cut into smaller lengths, ends capped (or bagged), and consolidated inside a CD provided the total ^{235}U mass contained within the CD does not exceed site-wide fissile material loading limit of 350 $g^{235}U$ for each CD.

If necessary or beneficial to operations, pipe sections may be crushed in-situ provided that the subject pipe section satisfies the applicable *NCS Exempt Material* criteria defined in Appendix A or does not comprise greater than 350 $g^{235}U$ total.

Crushed piping debris is exhumed identically as if it were soil, as described in Section 1.4.2 and evaluated in Section 2.4.2. Refer to Section 2.4.2 for details of these excavation and packaging requirements.

In the event that segments of intact piping or portions of crushed piping debris are determined by the is-situ survey measurements to contain *Fissile Material* with a mass greater than the *Extracted Piping Fissile Material* Limit and *Fissile Material Extraction Limit, respectively* (both are 350 $g^{235}U$), then excavation operations shall be limited to a reduced portion of the pipe debris such that up to only a maximum total mass of 350 $g^{235}U$ is exhumed at one time.

2.4.3.2 __Risk Assessment__

A criticality accident cannot be realized during exhumation of subterranean pipe sections or piping debris as long as one of the two following criteria is met:

- The ^{235}U associated with the subterranean pipe sections or piping debris does not exceed the applicable minimum subcritical mass limit;
- The ^{235}U associated with the subterranean pipe sections piping debris does not exceed the applicable maximum subcritical concentration limit.

OR

- The ^{235}U associated with the subterranean piping debris and comingled soil does not exceed the applicable minimum subcritical mass limit;
- The ^{235}U associated with the subterranean piping debris and comingled soil does not exceed the applicable the maximum subcritical concentration limit.

Subcritical mass limits for ^{235}U have been derived for a vast number of materials. Reference 8 establishes a maximum subcritical mass limit of 760 g^{235}U, which is based on full water-reflection of optimally-moderated, spherical aqueous solutions containing 100 wt.% enriched ^{235}U. For conservatism, this assessment will utilize 760 g^{235}U as maximum subcritical mass limit for ^{235}U.

Results of these in-pipe probe measurements concluded that all but four individual segments totaling ≈ 190' exhibited an average concentration in excess on the *NCS Exempt Material* criteria (a) [derived Appendix A] of 1.4 g ^{235}U/L. Because the assayed pipe length represents a significantly large sample, and the assayed pipes represent pipes with drains that were in the vicinity of the fuel manufacturing operations, results of the in-pipe radiological surveys are also expected to bound the ^{235}U activity in all other subterranean piping. However, the in-pipe probe measurements of the remaining subterranean piping resulted in assigning ^{235}U linear deposits at MLD, and the applicable MLDs are pipe size dependent. For example, examination of the results listed in Appendix A, indicate that the subterranean line MH-12 → MH-15, which is a 15" pipe, is assigned an MLD ^{235}U segment deposit of 2.28g^{235}U/ft. In either case, due to the length of the piping in which the *Fissile Material* is distributed, extracting pipe sections that exceed the *Fissile Material Extraction Limit* does not pose a criticality concern. That is, the 760 g^{235}U subcritical mass limit established in Reference [8] is based on an optimized geometry (spherical) in a very limited volume (≈14 L), whereas the measured ^{235}U in the subterranean pipe is dispersed over a relatively large extent of piping.

- The ^{235}U mass estimates assigned to the subterranean pipes have been derived based on conservative analysis in Reference 6, which include modeling the ^{235}U enrichment at 100%, assuming the measured dose rates are due to localized uranium contamination, neglecting contributions to the dose rates from neighboring contamination, employing a highly attenuating media for the debris inside the analyzed pipes, and utilizing a larger than actual volume for the probe. These modeling assumptions result in over-predicting the amount of ^{235}U that would be otherwise present. For example, sensitivity studies performed in Reference 6 indicate that assuming that the uranium held up in the subterranean piping is 100 wt.% ^{235}U versus 5 wt.% results in over-predicting the amount of ^{235}U by a factor of two.
- The calculated concentration does not account for crushed debris volume due to intermixing of surrounding soil with the crushed piping structure.
- The calculated concentration is limited in volume to a region with a depth that does not constitute an infinite media.

Furthermore, it is considered at least *unlikely* that excavation of subterranean piping could result in release of sufficient quantities of fissile material, and it is also considered to be at least *unlikely* for the released fissile material to be bulked into a configuration leading to a critical configuration. This is due to the fact that over 50 years of water running through the subterranean process piping and storm water system would have ensured that any loose ^{235}U would have been flushed out and as such, uranium that remains in these subterranean piping is essentially fixed in place. Excavation operations would not be expected to result in any significant release of uranium from the subterranean piping. In order for a criticality safety concern to be significant, large quantities of *Fissile Material* must be mobilized and accumulated in a localized region. This potential is extremely small, especially given the large area where the subterranean piping is buried.

It is *likely* that pipe excavation operations will result in mixing the crushed piping debris with portions of the underlying soil debris. However, it is considered *unlikely* that surrounding soil debris will contain ^{235}U in significant concentrations. This is because the majority of the subterranean piping is expected to be free of cracks and thereby is expected to have provided an effective barrier between potentially contaminated water flowing through the pipes and the surrounding soil. However, cracks or breaches in some of subterranean piping is anticipated to have occurred, and consequently, it is assumed that the soil debris surrounding such pipe cracks and breaches is contaminated with ^{235}U.

The credible NCS risks associated with subterranean pipe extraction are as follows:

- Significant deposits of *Fissile Material* not identified within subterranean piping are released during intact section lifting and collect in the surrounding soil debris during excavation;
- Intact pipe sections with significant ^{235}U concentration are inadvertently bulked;
- Significant *Fissile Material* deposits within intact pipe sections are mobilized and released during excavation and handling activities;
- Batching of multiple pipe sections into a CD results in greater than 350 g^{235}U within a single CD;
- Collection of multiple pipe sections into a SISA results in greater than 700 g^{235}U within a single SISA;
- Crushing of pipe sections in-situ results in the generation of crushed piping debris with significant fissile mass/concentration; and
- Field Containers loaded with crushed piping debris comprise in excess of 350 g^{235}U.

Each of the potential adverse conditions listed above are evaluated in the following subsections.

2.4.3.2.1 *Significant Deposits of Fissile Material Not Identified within Subterranean Piping are Released during Intact Section Lifting and Collect in the Surrounding Soil Debris*

It is important to ensure accurate pipe assay prior to excavating a *non-NCS Exempt* section of subterranean piping. Recall that a *non-NCS Exempt* intact pipe section to be lifted must meet the *Extracted Piping Fissile Material Limit* prior to its removal from the ground (i.e., no greater than 350 grams of ^{235}U per pipe section). This low threshold allows for more than a factor of two in the pipe *Fissile Material* mass quantification error before an unsafe mass is handled at any given time (without consideration for the additional margin of safety provided by the resultant large volume of the extracted piping). It is considered *highly improbable* that error in the in-pipe assay could lead to inadvertent underestimation by a factor of two. Contrary to this, and as discussed above, analysis of the radiological survey data collected from the in-pipe probe measurements were performed in a manner that results in overestimating the ^{235}U mass assigned to the surveyed piping. This is further justified by the requirement that multiple personnel are responsible for proper calibration, procedural use, and interpretation of the results regarding in-pipe assay equipment. Training is essential for any nuclear facility decommissioning activity and this excavation activity is treated no differently. The operators are knowledgeable, trained and qualified to perform their assigned tasks, and fully recognize the importance in performing their tasks independently and according to procedure. The cumulative features presented above ensure that results interpreted by the pipe assay results are *highly improbable* to exceed underestimation in assay by a factor of two, particularly since multiple personnel are responsible for the effectiveness of the assay.

Furthermore, recall that in-pipe measurements that have already been performed conclude that the average ^{235}U linear concentration in the subterranean piping is expected to be significantly less than 4 g^{235}U/ft. This relatively small linear activity indicates that, on the average, well over 100' of piping is required to achieve a combined ^{235}U mass that is comparable to the subcritical mass limit of 760 g^{235}U, which is derived based on a compact spherical geometry (≈14 L) of optimally moderated ^{235}U in an aqueous solution with full water reflection

Based on the preceding discussion, it is judged that pipe extraction activities resulting in the extraction and accumulation of a ^{235}U mass that is sufficiently high to result in a criticality accident is not credible.

The only credible risk to criticality safety in regards to inaccurate quantification of *Fissile Material* within an intact lifted pipe section involves accumulation of pipe residue on the ground over time due to occasional evacuation of pipe contents. Consequently, a second independent control involves capping (or bagging) all ends of the pipe section prior to removal from the ground for pipe sections that are classified as *non-NCS Exempt Material*. Enclosing all open ends of the pipe section is performed and managed by multiple personnel. In addition, the lifting of pipe sections from the ground is controlled to ensure that the potential for spills from piping is minimal

Once the pipe section is removed, soil that surrounded the removed pipe section is assayed to ensure that any ^{235}U contamination is identified and properly handled per the contaminated soil exhumation process described in Section 1.4.2 and evaluated in Section 2.4.2. Doing so ensures that the potential for accumulation of *Fissile Material* is minimized. Refer to Section 2.4.2 for justification of the effectiveness of soil ^{235}U contamination identification and subsequent handling/packaging.

In the event the pipe removal operations result in breaking or fracturing *the non-NCS Exempt* pipe, the pipe is required to be carefully placed on the ground and any observable cracks or broken segments are then required to be sealed (bagged). A surface assay is then performed to ensure that regions of the ground remain free of any ^{235}U contamination. If the area is found to be contaminated, the affected area is handled pursuant to contaminated soil remediation procedures described in Section 1.4.2 and evaluated in Section 2.4.2.

It should be recognized that both the loss of *Fissile Material* mass accountability (of the extracted pipe section AND of the soil that surrounded the pipe sections) and the loss of its confinement is required before a criticality accident could occur due to lifting intact pipe sections from the ground. If the *Fissile Material* content within intact pipe sections was underestimated by more than an *unlikely* factor of two, criticality safety is still maintained by ensuring its confinement to the pipe section AND ensuring the traveled path remains free of any spilled debris. Note, failure of mass control on the pipe section beyond a factor of two (i.e., greater than 760 grams ^{235}U within the section); in conjunction with failure of ensuring all open ends of the pipe section are enclosed, and not performing (or inaccurately performing) a surface assay, is each considered *highly improbable*.

Utilizing the three sets of independent safety controls as described above effectively prevents an unsafe quantity of *Fissile Material* from accumulating into an unsafe configuration on the ground during subterranean pipe excavation operations. This independence and likelihood of failure satisfies the Double Contingency Principle because at least two (in this case three) unlikely independent process upsets must occur before a criticality accident could occur.

2.4.3.2.2 <u>Intact Pipe Sections with Significant ^{235}U Concentration are Inadvertently Bulked</u>

Excavated pipe sections classified as *non-NCS Exempt Material* are not permitted to be bulked in an uncontrolled manner – rather, these pipe sections must be controlled and containerized in only a CD or an SISA, with total mass limits of 350 g^{235}U and 700 g^{235}U, respectively.

Since multiple personnel are responsible for all steps in the excavation and handling of piping, failure at any particular point that could culminate into under-determining or under-reporting the ^{235}U concentration in excess of the *NCS Exempt Material* criteria could be considered at least *unlikely*. On the contrary, however, this one-time failure is conservatively considered *likely* (i.e., anticipated). The failure point that is considered at least *unlikely* to occur inadvertently is: 1) a repeat failure up to three times whereby pipe sections are bulked even though one of the pipe sections does not meet *NCS Exempt Material* criteria or 2) failure such that multiple personnel conclude that a particular pipe section meets *NCS Exempt Material* criteria when (in actuality) the segment does not.

2.4.3.2.3 *Significant Fissile Material Deposits within Intact Pipe Sections are Mobilized and Released During Excavation and Handling Activities*

Excavated intact pipe sections are bulked once each pipe section is confirmed to meet *NCS Exempt Material* criteria. The bulking process is approved after this confirmation, which is determined using the existing in-pipe probe measurement results or by using supplemental surface assays of the pipe sections once exposed during excavation of the overlying soil. For pipe sections that are classified as non-*NCS Exempt Material*, all ends of the pipe sections are capped (or bagged) before the pipe section is removed from the ground. Furthermore, it is considered at least *unlikely* that excavation of subterranean piping could result in release of sufficient quantities of fissile material, and it is also considered to be at least *unlikely* for the released fissile material to be bulked into a configuration leading to a critical configuration. This is due to the fact that over 50 years of water running through the subterranean process piping and storm water system would have ensured that any loose ^{235}U would have been flushed out and as such, uranium that remained in the subterranean piping is essentially fixed in place. Excavation operations would not be expected to result in any significant release of uranium from the subterranean piping. In order for a criticality safety concern to be significant, large quantities of *Fissile Material* must be mobilized and accumulated in a localized region. This potential is extremely small, especially given the large area where the subterranean piping is buried coupled with the relatively low ^{235}U linear concentration that is expected to be present, which is supported by results of the in-pipe radiological surveys performed on over 1,600' of subterranean piping indicate that all but four individual segments totaling ≈ 190' exhibited an average concentration in excess of the *NCS Exempt Material* concentration criteria defined by criteria (a) of Appendix A, with the remaining piping assigned ^{235}U deposits that are consistent with the MLD. . Because the assayed pipe length represents a significantly large sample, and the assayed pipes represent pipes with drains that were in the vicinity of the fuel manufacturing operations, results of the in-pipe radiological surveys are also expected to bound the ^{235}U activity in all other subterranean piping. These results indicate that significant pipe sections are required to be extracted at any given one time before handling of 760 g^{235}U is possible.

Utilizing both sets of independent safety controls as described above for *non-NCS Exempt Material* (i.e., ensuring that no more than the *Extracted Piping Fissile Material Limit* of intact pipe sections are extracted at any given time and ensuring that all ends of the pipe section being extracted are capped such that *Fissile Material* cannot reasonably seep out of the intact pipe section), effectively prevents an unsafe quantity of *Fissile Material* from accumulating into an unsafe configuration during the process of bulking. This independence and likelihood of failure meets the criteria of the Double Contingency Principle, because two independent unlikely concurrent failures would be required before a criticality accident could be possible.

2.4.3.2.4 *Batching of Multiple Pipe Sections into a CD Results in Greater Than 350 g^{235}U within a Single CD*

Recall that a *non-NCS Exempt Material* intact pipe section to be lifted must meet the *Extracted Piping Fissile Material Limit* prior to removing from the ground (i.e., no greater than 350 grams of ^{235}U per pipe section). This low threshold allows for more than a factor of two in-pipe *Fissile Material* mass quantification error before an unsafe mass is reached, based on a subcritical mass limit of 760 g^{235}U.

Note further that intact pipe sections must have a length of less than ≈3' to physically fit within a nominal 55-gallon CD. In-pipe probe measurements that surveyed over 1,600' feet of subterranean piping indicate that only 190' exhibited an average concentration in excess on the *NCS Exempt Material* defined by criteria (a) of Appendix A, with the remaining piping indicating a ^{235}U average concentration below *NCS Exempt Material* criteria Note further, results of the in-pipe probe measurements also indicate that the highest ^{235}U activity measured along three contiguous feet of piping (results of in-pipe probe measurements presented in Appendix A is less than 34 g^{235}U, with the bulked average maximum linear ^{235}U activity in the subterranean piping was measured to be 3.6 g^{235}U/ft or less than 11 g^{235}U over 3' of piping. Assuming that all the extracted pipes are only 4" pipes, the maximum number of 4" pipe segments that can fit inside a 55-gallon CD is significantly less than 25, each with no more than 85 cm in length (the height of a nominal 55-gallon CD). This implies that the total length of 4" piping that can be placed inside a CD is less than 70', or a total of 252 g^{235}U, which is well below the CD *Fissile Material Loading Limit*. Because the assayed pipe length represents a significantly large sample, and the assayed pipes represent pipes with drains that were in the vicinity of the fuel manufacturing operations, results of the in-pipe radiological surveys are also expected to bound the ^{235}U activity in all other subterranean piping. It is therefore considered *highly improbable* that in-pipe assay error could result in the loading of a single CD with in excess of a maximum subcritical mass limit of 760 g^{235}U, because it would require inadvertent underestimation of the piping ^{235}U mass content by a factor of three.

2.4.3.2.5 *Collection of Multiple Pipe Sections into a SISA Results in Greater Than 700 g^{235}U within a Single SISA*

Each SISA is limited to a total mass content of 700 g^{235}U. Based on the arguments provided in the previous subsection, it is considered at least *unlikely* that multiple personnel involved in the pipe extraction activities could allow pipe sections with a total mass content exceeding 700 g^{235}U to be placed inside a single SISA. Furthermore, and as stated previously, the ^{235}U is present in dilute amounts within the subterranean piping, i.e., well over 100' of 4" piping are required to achieve a combined *Fissile Material* amount that exceeds 760 g^{235}U. Thus, it is expected that kg quantities of ^{235}U are required in configurations that involve short segments of piping before a criticality concern can even be envisioned. That is, subterranean piping exhibit poor neutronic characteristics, especially when compared with the configuration representing the 760 g^{235}U subcritical limit, because the presence of structural material/media (e.g., PVC or steel) between the segregated *Fissile Material* enhances parasitic neutron absorption.

2.4.3.2.6 *Crushing of Pipe Sections In-Situ Results in the Generation of Crushed Piping Debris with Significant Fissile Mass/Concentration*

If necessary or beneficial to operations, pipe sections may be crushed in-situ provided that either the results of the in-pipe probe measurements or the results of supplemental surface assays indicate that the subject pipe section satisfies *NCS Exempt Material* criteria or does not comprise greater than 350 g^{235}U total.

Crushed piping debris is exhumed identically as if it were soil, as described in Section 1.4.2 and evaluated in Section 2.4.2. Refer to Section 2.4.2 for details of these excavation and packaging requirements.

In the event that segments of intact piping or portions of crushed piping debris are determined to contain *Fissile Material* with a mass greater than the *Extracted Piping Fissile Material* Limit and *Fissile Material Extraction Limit, respectively (*both are 350 g^{235}U), then excavation operations shall be limited to a reduced portion of the associated piping/pipe debris such that up to only a maximum total mass of 350 g^{235}U is exhumed at one time.

Based on the arguments provided in the previous subsections, it is considered *highly improbable* that crushing of pipe sections could result in a criticality accident. Specifically,

- The ^{235}U concentration within the pipe section determined by the in-pipe assay must be inaccurate or the assay result interpreted incorrectly to such a degree would lead to a ^{235}U concentration up to 4 g^{235}U/L (factor of 2.5 error in pipe assay – beyond this value is considered *highly unlikely*); and
- Combining the ^{235}U concentration along more than a piping length required to achieve more than 760 g^{235}U in a favorable geometry and in condensed volume is considered no more than *unlikely*.

During crushing of pipe sections while they are situated in the ground, it is likely that surrounding soil will be added to the mixture of pipe fragments and residues within the pipe. To ensure that no material is bulked without confirmation that the material meets *NCS Exempt Material* criteria, two independent scans with assay equipment are performed on the crushed debris prior to bulking. This is performed by two different operators using two different assay devices. By requiring this stringent approach to material classification after crushing a piping section, it is considered *highly improbable* that crushed pipe debris will be bulked that does not meet *NCS Exempt Material* criteria. When exhuming debris, the same bulking method is used which entails lifting debris no greater in depth than the *cut depth* dictated by the assay equipment calibration basis document.

If the assay results do not establish that the crushed piping debris meets *NCS Exempt Material* criteria then the associated debris portion is carefully extracted into a *Field Container* as long as the *Fissile Material* content is determined to be lower than the *Fissile Material Exhumation Limit*. Note, remediation of this debris is identical to collection of soil not meeting *NCS Exempt Material* criteria and is not repeated here for brevity.

Utilizing both sets of independent safety controls as described above (i.e., ensuring pipe sections meet *NCS Exempt Material* criteria prior to crushing and ensuring exhumation of subterranean piping is limited to the *Extracted Piping Fissile Material Limit* effectively prevents an unsafe quantity of *Fissile Material* from accumulating into an unsafe configuration during the process of in ground pipe crushing activities. In addition, utilizing independent and reliable surface assays of crushed debris effectively prevents an unsafe quantity of *Fissile Material* from accumulating into an unsafe configuration during the process of bulking (or any other process downstream). This independence and likelihood of failure meets the criteria of the Double Contingency Principle, because two unlikely concurrent failures would be required before a criticality accident could be possible.

2.4.3.2.7 Field Containers Loaded with Crushed Piping Debris Comprise in Excess of 350 g ^{235}U

This scenario is discussed in Section 2.4.2.2 for soil and is equally applicable to crushed piping debris. Refer to Section 2.4.2.2 for details.

2.4.3.3 Summary of Risk Assessment

Based on the risk assessment provided in Section 2.4.3.2, the following conditions must exist before a criticality accident due to subterranean pipe excavation would be possible:

Criticality during Excavation of Subterranean due to the presence of Significant Fissile Material:

- Significant *Fissile Material* during past production operations was discarded into non-fissile process piping and storm water system flowing into the site creek or septic and/or sewage treat system(s); and
- Intact subterranean piping must contains *Fissile Material* above the *Extracted Piping Fissile Material Limit*; and
- Capping/bagging all open ends of *non-NCS Exempt* extracted pipe section is ineffective of containing ^{235}U inside piping; and
- Extraction of intact pipe section results in a severe angling, fracture, or load drop; and

- Residue within intact piping section does not configure into a slab or mound on the ground but rather into a *de minimis* surfaced sphere (i.e., into a hole) repeatedly.

Criticality during intact pipe bulking activities due Significant ^{235}U Concentration in Intact Pipe Sections:

- Significant *Fissile Material* during past production operations was discarded into non-fissile process piping and storm water system flowing into the site creek or septic and/or sewage system(s); and
- Multiple intact pipe sections are incorrectly determined for ^{235}U mass content by multiple personnel;

Criticality during intact pipe bulking activities due to ineffective immobilization of residues:

- Significant *Fissile Material* during past production operations was discarded into non-fissile process piping and storm water system flowing into the site creek or septic and/or sewage system(s); and
- Multiple intact subterranean piping sections are extracted from the ground without having all ends capped/bagged or are capped/bagged in an ineffective matter; and
- Multiple intact pipe sections are bulked together in such a manner whereby all of its *Fissile Material* loading is accumulated in single location; and
- Residue within intact piping section does not configure into a slab spread out within the bulked debris but rather into a *de minimis* surfaced sphere (i.e., into a corner or pocket of the bulked pipe sections) repeatedly.

Criticality due to collecting pipe sections in CDs with Greater than 350 g^{235}U within a Single CD:

- Significant *Fissile Material* during past production operations was discarded into non-fissile process piping and storm water system flowing into the site creek or septic and/or sewage system(s); and
- Multiple pipe section assays inaccurately reports *Fissile Material Exhumation Limit* is not met; and
- Multiple personnel allow loading CDs with greater than the CD loading limit of 350 g^{235}U.

Criticality due to collecting pipe sections in an SISA with Greater than 700 g^{235}U within a Single SISA:

- Significant *Fissile Material* during past production operations was discarded into non-fissile process piping and storm water system flowing into the site creek or septic and/or sewage system (s); and

- Multiple pipe section assays inaccurately reports *Fissile Material Exhumation Limit* is not met; and
- Multiple personnel allow loading an SISA with greater than the SISA loading limit of 700 g^{235}U.

<u>Criticality as result of in-situ pipe crushing and subsequent bulking</u>:

- Significant *Fissile Material* during past production operations was discarded into non-fissile process piping and storm water system flowing into the site creek or septic and/or sewage system(s); and
- Subterranean piping must be significantly above the *NCS Exempt Material* criteria
- Multiple personnel would need to incorrectly calibrate, misinterpret, or otherwise improperly perform surface assay procedure multiple times with two sets of assay devices prior to bulking crushed debris; and

<u>Criticality due to exhuming crushed piping debris with *Field Container*s</u>:

- Subterranean piping must be cracked or breached resulting in surrounding soil to contain greater than 4 g^{235}U/L **or** soil is located underneath cracked concrete or seams in concrete resulting in surrounding soil to contain greater than 4 g^{235}U/L; **and**
- Multiple soil assays inaccurately report *Fissile Material Exhumation Limit* is not met; **and**
- *Field Container* assay inaccurately reports *Fissile Material Exhumation Limit* is not met; **and**
- Containers other than *Field Container*s are used to collect soil classified as *Fissile Material* **or** multiple *Field Containers* are situated together in a single excavation location.

2.4.3.4 <u>Safety Controls</u>

The explicit CSCs relied on to provide the criticality safety barriers identified above (and thus relied on to preclude a criticality accident as a result of improper container movement/handling) are listed below. These controls, coupled with the control reliability arguments presented above, and combined with the use of multiple persons, ensures that this event sequence satisfies the DCP, because two unlikely concurrent failures would be required before a criticality accident could be possible.

> **Safety Related Equipment 02:** *Assay equipment used to classify intact sub-surface piping and crushed piping debris as NCS Exempt Material (i.e., ≤ 1.4 g^{235}U/L for intact piping, and ≤ 0.1 g^{235}U/L for crushed piping debris, respectively) or non-NCS Exempt Material (i.e., ≤ 1.4 g^{235}U/L for intact piping, and > 0.1 g^{235}U/L for crushed piping debris, respectively) (when used in support of a CSC).*

Administrative CSC 09: *All non-NCS Exempt subterranean pipe sections (defined as intact pipe sections comprising a concentration of > 1.4 g^{235}U/L) SHALL be exposed prior to excavation by removing the overlying soil burden. The maximum extent of non-NCS Exempt subterranean pipe sections that may be exposed at one time SHALL be limited to either:*

a) a total linear length of 300' (three-hundred feet), or

b) a total fissile mass content of 700 g^{235}U, based on the results of the in-pipe probe assay measurements or supplemental assay measurements, or

c) any desired total linear length provided that each continuous section that complies with the criteria defined in (a) or (b) is clearly demarcated using a readily identifiable mark (e.g., paint or flags) indicating the beginning and end of the non-NCS Exempt subterranean pipe section.

Administrative CSC 10: *Prior to extracting an exposed non-NCS Exempt subterranean piping section, the Fissile Material mass loading of the exposed pipe section SHALL be determined using calibrated assay equipment and the cut location determined for the pipe section SHALL correspond to the pipe section containing no greater than 350 grams ^{235}U total per intact section. Each of these determinations SHALL be ensured accurate by at least two qualified individuals.*

NOTE: *Determination of the fissile mass content of a non-NCS Exempt pipe segment is based on the results of assay data obtained via either in-pipe probe measurements or supplemental assays (in-pipe or surface-assays) of the exposed piping while in-situ.*

Administrative CSC 11: *Prior to crushing an exposed non-NCS Exempt subterranean piping section for bulk removal, the ^{235}U concentration of the pipe section SHALL be determined using the in-pipe probe measurements or supplemental assays (in-pipe assays or surface-assays) using calibrated assay equipment. The section of piping to be crushed SHALL contain ≤ 350 g^{235}U total prior to crushing. This determination SHALL be ensured accurate by at least two qualified individuals.*

Administrative CSC 12: *All non-NCS Exempt Pipe sections SHALL be handled as follows:*

- ⇨ *All open ends of the pipe segment SHALL be capped (or bagged) prior to excavation and movement.*
- ⇨ *All reasonably practicable measures SHALL be taken to minimize the potential to fracture or break non-NCS Exempt intact pipe sections during excavation.*
- ⇨ *This CSC SHALL be followed by at least two qualified individuals.*

Administrative CSC 13: *Following extraction of non-NCS Exempt Pipe sections, the soil/ground region where the extracted pipe resided SHALL be independently assayed prior to exhumation using independent assay instruments. The average ^{235}U concentration of the soil debris SHALL be demonstrated to not exceed 0.1 $g^{235}U/L$ prior to treating as NCS Exempt Material.*

NOTE: *This CSC does not apply to underground utilities such as electrical conduit or gas lines.*

Administrative CSC 14: *If a breach, break, or fracture occurs during the movement of a non-NCS Exempt pipe section occurs, the following SHALL be performed:*

- ⇨ *The entire pipe section SHALL be carefully placed on the ground.*
- ⇨ All observable cracks or broken segments SHALL be sealed (bagged).
- ⇨ *All separated pipe sections SHALL be moved one at a time.*
- ⇨ *The environs of the ground area(s) where the pipe break or fracture occurs SHALL be monitored for fissile material consistent with **Administrative CSC 15**.*

Administrative CSC 15: *Only Field Containers SHALL be used for collection of crushed piping debris classified as non-NCS Exempt Material (i.e., piping debris comprising > 0.1 $g^{235}U/L$).*

Administrative CSC 16: *CDs used for collection of non-NCS Exempt crushed piping debris (contained inside Field Containers) and non-NCS Exempt intact pipe sections SHALL be limited to containing only intact pipe sections or Field Containers loaded with piping debris and comprising a collective total fissile mass content not exceeding 350 $g^{235}U$. In all cases, the total fissile mass content of the CD SHALL not exceed 350 $g^{235}U$.*

Administrative CSCs 07, 08, 09, and *10* and related *Safety Features 01* and *02* established in Section 2.4.2.4 equally apply to this event sequence but are not repeated here for brevity.

Administrative CSC 17: *SISAs used for collection of non-NCS Exempt intact pipe sections SHALL be limited to a total fissile mass content not exceeding 700 g ^{235}U. Addition requirements related to use of SISAs are as follows:*

- ⇨ *All open ends of non-NCS Exempt pipe segments placed inside a SISA SHALL be capped (or bagged).*
- ⇨ *Each loaded SISA SHALL be separated by ≥ 12' from other loaded SISAs, CDs, and other Fissile Material, other than the Fissile Material associated with pipe sections that are in the process of being loaded into the respective SISA.*
- ⇨ *Are not moved without prior approval of the NCS Organization.*
- ⇨ *Are access controlled.*
- ⇨ *At least two qualified individuals SHALL ensure each of these requirements is completed accurately.*

2.4.4 Unexpected *Fissile Material* Quantities/Concentration in Septic Tank and/or Sewage Treatment Tanks and Drain Fields

2.4.4.1 Discussion

As discussed in Section 2.3.4, sewage treatment tanks and septic tank are not anticipated to contain significant quantities of *Fissile Material* since the vast majority of content stems from lavatories. However, because the septic and sewage treatment systems were connected to the laboratory sinks and industrial washing machine drain lines used during fuel manufacturing operations, the septic and sewage treatment systems may be contaminated. Therefore, it is conservatively assumed that there is no upper bound in terms of *Fissile Material* quantity or concentration within the septic tank and sewage treatment tanks.

The remediation of the septic tank and sewage treatment tanks' content is performed identically to that for soil remediation. Specifically, the contents are independently assayed with confirmation of results by multiple personnel. If the results satisfy *NCS Exempt Material* criteria, the contents are exhumed to a *cut depth* consistent with the calibration basis of the assay equipment, which in turn is based, in part, on the material composition of the septic tank and sewage treatment tanks' contents. If the results do not satisfy *NCS Exempt Material* criteria but do not exceed the *Fissile Material Exhumation Limit*, then the septic tank and sewage treatment tanks' content is recovered using the process described for *non-NCS Exempt* soil debris in Section 1.4.2 and evaluated in Section 2.4.2.

Once the current in use sewage treatment tank is completely emptied and the entire content has been exhumed meeting the *NCS Exempt Material* criteria, then the current sewage treatment tank structure and the associated drain line may be excavated without NCS controls. Otherwise, if the in use sewage treatment tank content is determined to contain any *non-NCS Exempt Material*, then exhumation of the associated drain line and the tank structure is not permitted without further evaluation and instruction from the NCS Organization.

However, this approach cannot be used for the decommissioned sewage treatment tank or concrete septic tank. Based on the premise that both of the aforementioned treatment tanks have been decommissioned (i.e., filled with gravel), the material residing within the treatment tanks cannot be interpreted as representative of the material in the associated common drain field. Thus, the drain field and tank structures associated with the previous sewage treatment tank and concrete septic tank are not permitted without further evaluation and instruction from the NCS Organization.

It is noted that the soil above a drain field or drain line is not considered part of the drain field or drain line in this NCSA. Exhumation of this top soil may be performed without implementing any CSCs, irrespective of the conditions encountered in the septic tank and sewage treatment tanks. However, the perforated tubing of the drain field and soil/gravel/sand/rock below is considered part of the drain field and must not be exhumed without further evaluation and instruction from the NCS Organization if any portion of the connected in use sewage treatment contents is established to meet *non-NCS Exempt Material* classification.

2.4.4.2 ***Risk Assessment***

The risks associated with exhumation of the septic tank and sewage treatment tank content are bounded by the risks associated with soil debris excavation and packaging in Section 2.4.2. In addition, there is no credible criticality risk associated with exhumation of the current sewage treatment tank structure or the connected drain line as long as the complete in use sewage treatment tank contents are established to meet *NCS Exempt Material* criteria.

2.4.4.3 ***Summary of Risk Assessment***

The risks associated with exhumation of the septic tank and sewage treatment tanks content are bounded by the risks associated with soil debris excavation and packaging in Section 2.4.2.

2.4.4.4 ***Safety Controls***

Many of CSCs associated with exhumation of the septic tank and sewage treatment tanks content are identical to the CSCs established for soil debris excavation and packaging operations in Section 2.4.2.4, except that the CSC emphasis is on the septic tank and sewage treatment tanks content material rather than soil. These CSCs are repeated below but with emphasis the septic tank and sewage treatment tanks content material. Additional CSCs are captured as relevant to the process described and evaluated above. These controls, coupled with the control reliability arguments presented in this document, and combined with the use of multiple persons, ensure that this event sequence satisfies the DCP, because two unlikely concurrent failures would be required before a criticality accident could be possible.

> **Safety Related Equipment 03:** *Assay equipment used to classify the content of the septic tank and sewage treatment tanks as NCS Exempt Material (i.e., $\leq$ 0.1 g^{235}U/L) or non-NCS Exempt Material (i.e., > 0.1 g^{235}U/L) (when used in support of a CSC).*
>
> **Administrative CSC 18:** *The material content of the septic tank and sewage treatment tanks SHALL be evaluated for fissile content using independent assay instruments. The average ^{235}U concentration of the material content of the septic tank and sewage treatment tanks SHALL be demonstrated to not exceed 0.1 g^{235}U/L prior to treating as NCS Exempt Material.*
>
> NOTE: *The exhumation of the associated drain field, drain line, and the septic tank and sewage treatment tank structure is not permitted and SHALL not occur without approval from the NCS Organization.*
>
> **Administrative CSC 19:** *Each assayed layer of debris associated with the material content of the septic tank and sewage treatment tanks SHALL be exhumed cognizant of the maximum permitted cut depth established in the assay equipment calibration basis document. At least two qualified individuals SHALL ensure that the exhumed debris is deposited in the excavation area and re-assayed if its exhumation results in the removal of a layer of material exceeding the maximum permitted cut depth.*

Administrative CSC 20: *All reasonably practicable measures SHALL be taken to minimize the potential to exhume a layer of debris exceeding the maximum permitted cut depth. Consideration should be given to:*

- *Controlling the excavation depth to a value smaller than the maximum permitted cut depth to provide margin;*
- *Employing excavation techniques and equipment that allow for an optimally controlled depth excavation; and*
- *Use of markers or other tools to provide indication when exceeding the maximum permitted cut depth.*

Administrative CSC 21: *Only Field Containers SHALL be used for collection of septic tank and sewage treatment tank content classified as non-NCS Exempt Material (i.e., debris comprising > 0.1 g ^{235}U/L).*

Administrative CSCs 07, 08, 09, and *10* and related *Safety Features 01* and *02* established in Section 2.4.2.4 equally apply to this event sequence but are not repeated here for brevity.

2.4.5 Hydrogenous Solutions other than Water are Commingled with Exhumed Subterranean Structures and Debris

2.4.5.1 Discussion

Fissile Material limits used in the criticality safety assessment of activities associated with decommissioning activities of subterranean structures have been derived assuming homogeneous mixtures of 100 wt. % enriched ^{235}U in aqueous solutions. This approach is very conservative with respect to the actual conditions associated with *Fissile Material* contained within the subterranean structures. However, in theory, some solutions represent excellent moderators, and in some cases, are more effective than full density water. Solutions with the potential to represent more effective moderators than full density water include hydro-carbon based solutions such as oils and hydraulic fluids, with high bulk densities (i.e., >0.7 g/cc).

As with any manufacturing and processing facilities, use of hydrogenous fluids (such as oils and hydraulic fluids) is common. Spillage of these hydrogenous fluids into piping drains, on concrete pads, and onto ground areas covering subterranean structures may have occurred. Furthermore, any spillage of hydrogenous fluids (e.g., oils and hydraulic fluids) from equipment operated over the various HDP process areas could have potentially resulted in the introduction of hydrogenous and hydrocarbon based fluids with moderating properties superior to that provided by full density water.

2.4.5.2 Risk Assessment

Subterranean structures, crushed subterranean debris, and exhumed soil containing uranium residues generally represent a low-risk *Fissile Material* because the form and associated matrix conditions are far from optimum for a neutron chain reaction. Typically, subterranean structures, crushed subterranean debris, and exhumed soil comprise inefficient moderating materials (e.g., PVC and steels). The comingling of the *Fissile Material* with soil does not generally improve the moderating characteristics of the *Fissile Material* because soil is a significantly poorer moderator than water. For example, the minimum critical mass in a plutonium system moderated by fully water saturated soil (40 vol. % soil-in-water) (Fig III.A.6(97)-4 of Ref. 11) is a factor of ≈2.5 greater than the minimum critical mass for an otherwise equivalent aqueous system (Fig III.A.6-1 of Ref. 11). Scaling the minimum critical mass of ^{235}U in water (820 g, Ref. 8 and 10) by this ratio (2.5), it is estimated that a minimum of ≈2 kg^{235}U would be required for a criticality to be possible by adsorption in soil. Some variability in soil composition is to be expected. However, it is clear that no credible soil composition could result in moderation conditions superior to that provided by full density water for a compact geometry.

The poor moderating characteristics of subterranean structures, crushed subterranean debris, and exhumed soil containing uranium residues, relative to full density water, could potentially be improved given the presence of hydrocarbon-based solutions such as oils and hydraulic fluids, with high bulk densities (i.e., > 0.7 g/cc). However, without very high levels of purity (i.e., absence of other non-*Fissile Materials*) and sufficient quantity, the presence of any such liquids could not erode the criticality safety margin presented in other event sequences. The probability that a maximum safe mass of ^{235}U could be assembled in a highly idealized compact spherical geometry comprising only ^{235}U and a high-density hydrocarbon based solution is exceptionally small. The presence of even very small quantities of soil, subterranean debris material, or non-

Fissile Materials associated with *Fissile Material* is essentially guaranteed, and would result in dilution, parasitic neutron absorption, and consequently, an increase in the maximum subcritical mass limit of 760 g^{235}U (Ref. 8 and 10).

Even if there were an abundance of high-density hydrocarbon based solutions in conjunction with highly favorable ^{235}U migration/entrainment conditions, the criticality safety margin presented in other event sequences would still not be eroded. Mechanisms that could potentially cause entrainment or migration of *Fissile Material* into localized pockets or regions of a waste matrix have been analyzed in Reference 8 and have been found to be incapable of resulting in a collection of a significant mass of ^{235}U. Furthermore, no mechanisms have been identified that could promote preferential migration/entrainment of ^{235}U. Thus, any entrainment/ migration mechanism would also result in the collection of non-*Fissile Materials* (e.g., soil sediments), which would diminish the moderating capability of any hydrocarbon based solutions. In addition, the process employed during the excavation of the subterranean structures, crushed subterranean debris, and soil debris is expected to identify and segregate any *non-NCS Exempt Material,* thus reducing the chances of creating an optimum configuration with moderators more effective than water.

2.4.5.3 Summary of Risk Assessment

Based on the discussion provided in Section 2.4.5.2, it is concluded that there are no credible scenarios in which a criticality accident could occur as a result of the commingling of contaminated solids or buried wastes with hydrogenous solutions other than water. This determination is founded on the conservative approach used in the criticality safety assessment, which uses fissile limits derived for idealized homogeneous mixtures of ^{235}U and water (H_2O).

2.4.5.4 Safety Controls

No CSCs or additional practicable measures for further reducing criticality risk have been identified in the risk assessment. It is judged that the risks from criticality are as low as is reasonably achievable.

3.0 SUMMARY OF CRITICALITY SAFETY CONTROLS

3.1 CRITICALITY SAFETY PARAMETERS

The extent of control of each of the various criticality safety parameters introduced in Section 2.1 is summarized in Table 3.1.

Table 3.1: Criticality Safety Parameters

Nuclear Parameter	Controlled (Y/N)	Table 3.1: Criticality Safety Parameters Basis	Reference
Mass	Y	*Fissile Material* mass control is necessary because many operations associated with sub-surface structure decommissioning could potentially involve heterogeneous forms of *Fissile Material* in a volume potentially larger than a maximum safely subcritical volume. Accumulation of heterogeneous *Fissile Material* is demonstrated to be adequately limited below the maximum safely subcritical ^{235}U mass limit (i.e., 760 g^{235}U) under all credible conditions.	Section 2.4.1 Section 2.4.2 Section 2.4.3 Section 2.4.4
Isotopic/ Enrichment	N	The safety assessment of sub-surface structure decommissioning activities is conservatively based on subcritical limits derived for uranium with 100 wt.% $^{235}U/U$ enrichment.	N/A
Volume	Y	The safety assessment of sub-surface structure decommissioning activities credits administrative CSCs that ensure that exhumed *Fissile Materials* will be packaged into limited volume *Field Containers* (or limited volume CDs in regards to intact pipe sections).	Section 2.4.1 Section 2.4.2 Section 2.4.3 Section 2.4.4
Geometry	N	There is no specific geometric shape of equipment or containers credited in this NCSA.	N/A
Concentration	Y	Upper limits on ^{235}U concentration have been established to prevent criticality in this analysis. Many forms of decommissioning debris are anticipated to consist of a relatively uniform mixture of *Fissile Material* and other debris leading to the acceptability of concentration control.	Section 2.4.1 Section 2.4.2 Section 2.4.3 Section 2.4.4
Density	N	The safety assessment of sub-surface structure decommissioning activities is conservatively based on subcritical limits derived for uranium metal at maximum theoretical density.	N/A
Moderation	N	The safety assessment of sub-surface structure decommissioning activities is conservatively based on bounding credible moderation conditions.	Section 2.4.5

Table 3.1: Criticality Safety Parameters

Nuclear Parameter	Controlled (Y/N)	Basis	Reference
Interaction	Y	*Field Container*s are used to collect debris (other than concrete debris) that does not meet *NCS Exempt Material* criteria but is less than or equal to *Fissile Material Exhumation Limit* of 350 g^{235}U. The 20-liter maximum capacity of the *Field Container* helps to ensure that it is beyond *highly improbable* to assemble more than a maximum safely subcritical ^{235}U mass (i.e., 760 g ^{235}U). Therefore, multiple *Field Container*s are prevented from being within a particular excavation site to adequately minimize the risk of accumulating too much *Fissile Material* in a single location. CDs are used to collect intact, capped pipe sections that do not meet *NCS Exempt Material* criteria but are less than or equal to *Fissile Material Exhumation Limit*. Each CD is limited to no more than 350 g^{235}U. Therefore, multiple CDs are prevented from being within a particular excavation site to adequately minimize the risk of accumulating too much *Fissile Material* in a single location. SISA are used to stage extracted pipe sections that have not been demonstrated to meet sections that do not meet *NCS Exempt Material* criteria. Each SISA is limited to no more than 700 g^{235}U and are separated from all other SISA and other fissile material containers by ≥ 12'.	Section 2.4.1 Section 2.4.2 Section 2.4.3 Section 2.4.4
Reflection	N	The safety assessment of sub-surface structure decommissioning activities is conservatively based on bounding credible reflection conditions.	N/A
Neutron Absorber	N	No neutron absorbers are credited in this NCSA.	N/A
Heterogeneity	N	The safety assessment of sub-surface structure decommissioning activities is conservatively based on subcritical limits derived for homogeneous uranium-moderator mixtures (with 100 wt.% ^{235}U/U enrichment), for which subcritical limits are smaller than equivalent heterogeneous uranium-moderator mixtures. The potential reduction in safety factors (due to credible non-homogeneity) credited for concentration limits derived for homogenous systems is addressed in the various event sequences of this NCSA.	N/A

Source: Original

3.2 ENGINEERED AND ADMINISTRATIVE CONTROLS

This section provides a schedule of Systems Structures and Components (SSCs) and CSCs that have been established as important to safety in the risk assessment of sub-surface structure decommissioning activities. The SSCs and CSCs are numbered sequentially according to their identification in Section 2.4 of this document. Note that when SSCs and CSCs captured in an NCSA are used in other documents (including other NCSAs), they are referenced using the numeric identifier from the originating NCSA and proceeded by the NCSA document number. For example, other documents citing the first CSC captured in this NCSA use the following reference; *NSA-TR-09-08 Administrative CSC 01*.

3.2.1 Systems Structures and Components

The following SSCs have been recognized as important to ensuring the criticality safety of sub-surface structure decommissioning activities. The SSCs are identified as Safety Features (passive function) and Safety Related Equipment (active function). Based on their safety designation, the equipment listed in this Section is integral to this NCSA and sub-surface structure decommissioning activities would not be able to continue in their absence.

> **Safety Related Equipment 01:** *Assay equipment used to classify soil debris as NCS Exempt Material (i.e., ≤ 0.1 g ^{235}U/L) or non-NCS Exempt Material (i.e., > 0.1 g ^{235}U/L) (when used in support of a CSC).*

> **Safety Related Equipment 02:** *Assay equipment used to classify intact sub-surface piping and crushed piping debris as NCS Exempt Material (i.e., ≤ 1.4 g ^{235}U/L for intact piping, and ≤ 0.1 g ^{235}U/L for crushed piping debris, respectively) or non-NCS Exempt Material (i.e., ≤ 1.4 g ^{235}U/L for intact piping, and > 0.1 g ^{235}U/L for crushed piping debris, respectively) (when used in support of a CSC).*

> **Safety Related Equipment 03:** *Assay equipment used to classify the content of the septic tank and sewage treatment tanks as NCS Exempt Material (i.e., ≤ 0.1 g ^{235}U/L) or non-NCS Exempt Material (i.e., > 0.1 g ^{235}U/L) (when used in support of a CSC).*

> **Safety Feature 01:** *Field Containers (when used in support of a CSC) possess a maximum internal volume of 20 liters (equivalent to the volume of a nominal 5 gallon container).*

> **Safety Feature 02:** *CDs (when used in support of a CSC) possess a maximum volumetric capacity of ~208 liters (equivalent to the volume of a nominal 55 gallon drum).*

3.2.2 Criticality Safety Controls

In addition to CSCs identified in Reference 8 pertaining to handling of *Fissile Containers* post lidding and CDs, the following CSCs have been recognized as important to ensuring the criticality safety of Sub-Surface Structure Decommissioning.

Administrative CSC 01: *Each assayed layer of soil debris SHALL be exhumed cognizant of the maximum permitted cut depth established in the assay equipment calibration basis document. At least two qualified individuals SHALL ensure that the exhumed soil debris is deposited in the excavation area and re-assayed if its exhumation results in the removal of a layer of material exceeding the maximum permitted cut depth.*

Administrative CSC 02: *All reasonably practicable measures SHALL be taken to minimize the potential to exhume a layer of soil debris exceeding the maximum permitted cut depth. Consideration should be given to:*

- ⇨ *Controlling the excavation depth to a value smaller than the maximum permitted cut depth to provide margin;*
- ⇨ *Employing excavation techniques and equipment that allow for an optimally controlled depth excavation; and*
- ⇨ *Use of markers or other tools to provide indication when exceeding the maximum permitted cut depth.*

Administrative CSC 03: *Soil in the vicinity of subterranean structures (e.g., subterranean piping, the septic tank and sewage treatment tanks, etc.) and underlying soil and ground regions beneath concrete slabs within the environs of buildings 240 and 260 SHALL be independently assayed prior to exhumation using independent assay instruments. The average ^{235}U concentration of the soil debris SHALL be demonstrated to not exceed 0.1 $g^{235}U/L$ prior to treating as NCS Exempt Material.*

NOTE:

1. *Soil in the vicinity of subterranean structures shall encompass all regions within 12" of the surface of the affected subterranean structure. Assay of the soil region extending beyond 12" from the surface of the subterranean structure shall continue until the soil in the vicinity of the affected subterranean structures is determined to be below the NCS Exempt Material criteria.*
2. *This CSC does not apply to underground utilities such as electrical conduit or gas lines*

Administrative CSC 04: *Only Field Containers SHALL be used for collection of soil debris classified as non-NCS Exempt Material (i.e., soil debris comprising > 0.1 $g^{235}U/L$).*

Administrative CSC 05: *The fissile mass content of Field Containers SHALL be limited to a maximum 350 $g^{235}U$. In the event that the exhumation of surveyed debris could result in loading a single Field*

Container with greater than 350 g^{235}U then the subject operation SHALL not proceed without approval from the NCS Organization.

Administrative CSC 06: *In the event that the fissile nuclide mass content of any surveyed debris is estimated (i.e., not confirmed) to exceed 700 g^{235}U, the debris exhumation activities in the associated remediation area SHALL cease and the NCS Organization informed as soon as is practicable and at least before excavation operations in the subject area resume.*

NOTE: *Remediation areas separated by an edge-to-edge distance of at least 12 ft may be considered neutronically isolated and thus separate.*

Administrative CSC 07: *All Field Containers loaded with non-NCS Exempt Material SHALL be over-packed with a CD prior to removal from the respective remediation area, and prior to loading an additional Field Container within the respective remediation area.*

NOTE: *Remediation areas separated by an edge-to-edge distance of at least 12 ft may be considered neutronically isolated and thus separate.*

Administrative CSC 08: *CDs SHALL be closed/lidded after completion of loading activities. Closing/Lidding of a CD in use SHALL occur prior to loading an additional CD within the respective remediation area, and prior to exporting the CD to an approved downstream area.*

Administrative CSC 09: *All non-NCS Exempt subterranean pipe sections (defined as intact pipe sections comprising a concentration of > 1.4 g^{235}U/L) SHALL be exposed prior to excavation by removing the overlying soil burden. The maximum extent of non-NCS Exempt subterranean pipe sections that may be exposed at one time SHALL be limited to either a total linear length of 75' (seventy-five feet), or to a total fissile mass content of 700 g^{235}U, based on the results of the in-pipe probe assay measurements or supplemental assay measurements.*

d) a total linear length of 300' (three-hundred feet), or

e) a total fissile mass content of 700 g^{235}U, based on the results of the in-pipe probe assay measurements or supplemental assay measurements, or

f) any desired total linear length provided that each continuous section that complies with the criteria defined in (a) or (b) is clearly demarcated using a readily identifiable mark (e.g., paint or flags) indicating the beginning and end of the non-NCS Exempt subterranean pipe section.

Administrative CSC 10: *Prior to extracting an exposed non-NCS Exempt subterranean piping section, the Fissile Material mass loading of the exposed pipe section SHALL be determined using calibrated assay equipment and the cut location determined for the pipe section SHALL correspond to the pipe section containing no greater than 350 grams ^{235}U total per intact section. Each of these determinations SHALL be ensured accurate by at least two qualified individuals.*

NOTE: *Determination of the fissile mass content of a non-NCS Exempt pipe segment SHALL be based on the results of assay data obtained via either in-pipe probe measurements or supplemental assay (in-pipe assays of surface-assays of the exposed piping while in-situ.*

Administrative CSC 11: *Prior to crushing an exposed non-NCS Exempt subterranean piping section for bulk removal, the ^{235}U concentration of the pipe section SHALL be determined using the in-pipe probe measurements or supplemental assays (in-pipe assays or surface assays) using calibrated assay equipment. The section of piping to be crushed SHALL contain ≤ 350 g^{235}U total prior to crushing. This determination SHALL be ensured accurate by at least two qualified individuals.*

Administrative CSC 12: *All non-NCS Exempt Pipe sections SHALL be handled as follows:*

- ⇨ *All open ends of the pipe segment SHALL be capped (or bagged) prior to excavation and movement.*
- ⇨ *All reasonably practicable measures SHALL be taken to minimize the potential to fracture or break non-NCS Exempt intact pipe sections during excavation.*
- ⇨ *This CSC SHALL be followed by at least two qualified individuals.*

Administrative CSC 13: *Following extraction of non-NCS Exempt Pipe sections, the soil/ground region where the extracted pipe resided SHALL be independently assayed prior to exhumation using independent assay instruments. The average ^{235}U concentration of the soil debris SHALL be demonstrated to not exceed 0.1 g^{235}U/L prior to treating as NCS Exempt Material.*

NOTE: *This CSC does not apply to underground utilities such as electrical conduit or gas lines*

Administrative CSC 14: *If a breach, break, or fracture occurs during the movement of a non-NCS Exempt pipe section occurs, the following SHALL be performed:*

- ⇨ *The entire pipe section SHALL be carefully placed on the ground.*
- ⇨ All observable cracks or broken segments SHALL be sealed (bagged).
- ⇨ *All separated pipe sections SHALL be moved one at a time.*
- ⇨ *The environs of the ground area(s) where the pipe break or fracture occurs SHALL monitored for fissile material consistent with* ***Administrative CSC 15.***

Administrative CSC 15: *Only Field Containers SHALL be used for collection of crushed piping debris classified as non-NCS Exempt Material (i.e., piping debris comprising > 0.1 g^{235}U/L).*

Administrative CSC 16: *CDs used for collection of non-NCS Exempt crushed piping debris (contained inside Field Containers) and non-NCS Exempt intact pipe sections SHALL be limited to containing only intact pipe sections or Field Containers loaded with piping debris and comprising a collective total fissile mass content not exceeding 350 g^{235}U. In all cases, the total fissile mass content of the CD SHALL not exceed 350 g^{235}U*

Administrative CSC 17: *SISAs used for collection of non-NCS Exempt intact pipe sections SHALL be limited to a total fissile mass content not exceeding 700 g^{235}U. Addition requirements related to use of SISAs are as follows:*

- ⇨ *All open ends of non-NCS Exempt pipe segments placed inside a SISA SHALL be capped (or bagged).*
- ⇨ *Each loaded SISA SHALL be separated by ≥ 12' from other loaded SISAs, CDs, and other Fissile Material, other than the Fissile Material associated with pipe sections that are in the process of being loaded into the respective SISA.*
- ⇨ *Are not moved without prior approval of the NCS Organization.*
- ⇨ *Are access controlled.*
- ⇨ *At least two qualified individuals SHALL ensure each of these requirements is completed accurately.*

Administrative CSC 18: *The material content of the septic tank and sewage treatment tanks SHALL be evaluated for fissile content using independent assay instruments. The average ^{235}U concentration of the* *material content of the septic tank and sewage treatment tanks SHALL be demonstrated to not exceed 0.1 g^{235}U/L prior to treating as NCS Exempt Material.*

NOTE: *The exhumation of the associated drain field, drain line, and the septic tank and sewage treatment tank structure is not permitted and SHALL not occur without approval from the NCS Organization.*

Administrative CSC 19: *Each assayed layer of debris associated with the material content of the septic tank and sewage treatment tanks SHALL be exhumed cognizant of the maximum permitted cut depth established in the assay equipment calibration basis document. At least two qualified individuals SHALL ensure that the exhumed debris is deposited in the excavation area and re-assayed if its exhumation results in the removal of a layer of material exceeding the maximum permitted cut depth.*

Administrative CSC 20: *All reasonably practicable measures SHALL be taken to minimize the potential to exhume a layer of debris exceeding the maximum permitted cut depth. Consideration should be given to:*

- ⇨ *Controlling the excavation depth to a value smaller than the maximum permitted cut depth to provide margin;*
- ⇨ *Employing excavation techniques and equipment that allow for an optimally controlled depth excavation; and*
- ⇨ *Use of markers or other tools to provide indication when exceeding the maximum permitted cut depth.*

Administrative CSC 21: *Only Field Containers SHALL be used for collection of septic tank and sewage treatment tanks content classified as non-NCS Exempt Material (i.e., debris comprising > 0.1 g^{235}U/L).*

3.2.3 Defense-in-Depth Controls

This section lists those controls that do not directly support event sequence Double Contingency Principle (DCP) compliance determinations, or directly support a not credible determination. These DinD controls either reinforce CSCs or provide additional protection to ensure that the risk of criticality is as low as is reasonably achievable.

Administrative DinD Control 01: *The upper surface of the concrete slabs residing in the following former facilities SHALL be ensured to have been coated with a fixative prior to exhumation:*

- ⇨ *Building 235*
- ⇨ *Building 240*
- ⇨ *Building 252*

- *Building 253*
- *Building 254*
- *Building 255*
- *Building 256*
- *Building 260*

Administrative DinD Control 02: *Following excavation of concrete debris, the underside of the excavated concrete SHALL be inspected for any attached sub-surface debris (e.g., mounds of soil, embedded piping, etc.). Any identified attached debris SHALL be radiologically surveyed for* ^{235}U *content, or removed and later radiologically surveyed for* ^{235}U *content during survey of the surrounding exposed soils. Any identified non-NCS Exempt debris SHALL be handled and containerized as non-NCS Exempt Material.*

Note: *This CSC only applies to concrete surfaces within the environs of Building 240 and Building 260.*

4.0 CONCLUSION

This criticality safety assessment demonstrates that activities related to Sub-Surface Structure Decommissioning will be safe under all normal and foreseeable abnormal conditions. The assessment has determined that there are very large margins of safety under normal (i.e., expected) conditions and that there is considerable tolerance to abnormal conditions.

All event sequences identified in the *What-if/Checklist* analysis and assessed in this NCSA are shown to result in no criticality consequences, or are demonstrated to not have the potential to result in a criticality accident on account of:

- There being no credible sequence of events that could result in a criticality accident; or
- Demonstration that the event sequence complies with the DCP.

It is noted that all analysis is assessed against limits derived for optimally moderated and idealized uranium systems. Thus, the presence of moderator during the assessed operations would not impact the analysis. Furthermore, there are no restrictions on the use of water for operations or for fire suppression.

5.0 REFERENCES

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3. NSA-TR-10-02, Rev. 0, *Calculation to Establish an Estimate of the Mass of ^{235}U Associated with the Floors, Walls, and Ceilings, of Auxiliary Buildings at the Hematite Site*, Henkel, February 2010.

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7. NC-09-001, Rev. 0, *Hazards and Operability Study for Decommissioning Activities in Support of the Hematite Decommissioning Project*, April 2009.

8. NSA-TR-09-15, Rev. 1, *Buried Waste Exhumation and Contaminated Soil Remediation NCSA*, B. Matthews, Dec 2010.

9. NSA-TR-09-03, Rev. 0, *Nuclear Criticality Safety Calculations for 350 g ^{235}U Drum Arrays*, D. Vaughn, April 2009.

10. ANSI/ANS-8.1-1998, *American National Standard for Nuclear Criticality Safety in Operations with Fissionable Material Outside Reactors*, American Nuclear Society, Reaffirmed September 2007.

11. Atlantic Richfield Hanford Company (1969), *Criticality Handbook Volume II*, R. D. Carter, G. R. Kiel, K. R. Ridgway.

12. HEM-11-MEMO-011, Memorandum, *Nuclear Criticality Safety (NCS) Exempt Material at the Westinghouse Hematite Site*, February 2011.

13. NUREG/CR-6505, Vol. 1, The Potential for Criticality Following Disposal at Low-Level Waste Facilities, June 1997.

14. NSA-TR-09-14, Rev. 0, Nuclear Criticality Safety Assessment of the US Ecology Idaho (USEI) Site for the Land Fill Disposal of Decommissioning Waste from the Hematite Site, Robert Maurer and B. Matthews, May 2009.

15. Westinghouse Software/Calculation Validation Report of Concrete Core Sample Results, A. Wilding, January 12, 2011

Appendix A

Assay Data for Subsurface Piping at the Hematite Site

As discussed in Section 1.4.3, there are believed to be several thousand feet of subterranean piping located within the Hematite Facility. Much of the piping comprises the site storm water system that flows into a nearby local creek, which due to its former use, is considered to present a low criticality risk. Other low criticality risk piping includes the sanitation lines that feed into underground septic tank and sewage treatment tanks, and down spouts which were used to divert precipitation collected on the roof of the site buildings into the subsurface piping system. The remaining subsurface piping encompasses the piping associated with waste from the former fuel manufacturing operations (e.g., evaporator overflows, process water runoff, etc.) and related operations such as laboratory sink waste, and industrial washing machine waste water. In practice, the design of the equipment used in various former production operations that were connected to these lines would have ensured that release of significant quantities of *Fissile Material* into these drain lines was not a frequent occurrence. However, to demonstrate criticality safety during operations in involving the exhumation, handling, and consolidation of subsurface piping and associated debris, CSCs have been established in Section 2.4.3 and are separately listed in Section 3.0. These CSCs establish requirements that must be observed whenever a pipe section is designated as *non-NCS Exempt Material*.

The objective of this appendix is to explicitly define the subterranean pipe sections that qualify as *NCS Exempt Material* due to low fissile concentration or other criteria, and the pipe sections that must be designated as *non-NCS Exempt Material* due to relatively high fissile concentration or other criteria. This is achieved by:

- Presenting the results of assay data obtained from recent in-situ in-pipe probe measurements conducted for the subsurface piping at the Hematite site (as described in Section 1.4.3), and using the assay results to designate the various pipe sections as *NCS-Exempt Material* or *non-NCS-Exempt Material*; or
- Applying qualitative criteria to determine if a particular pipe section that does not have assay data still qualifies as *NCS-Exempt Material* based on knowledge of its location, interconnections, and former use.

The quantitative analysis described above first requires determining the explicit criteria that should be applied to pipe sections to gauge whether they qualify as *NCS-Exempt Material*. This involves establishing and justifying the *NCS Exempt Material* concentration limit that is appropriate for and applicable to intact piping. The *NCS Exempt Material* concentration limit established and employed in this appendix is as follows:

a) Assayed intact pipe sections that comprise a concentration (averaged over a linear 1 ft length section of piping) not exceeding 1.4 g^{235}U/L may be designated as *NCS Exempt Material*, provided that the derivation of the fissile concentration for each 1 ft segment credits only the volume of the structural materials of the pipe (e.g., the pipe wall) and not any contained non-fissile debris.

The analytical basis for the above concentration limit is derived from the fictitious minimum critical concentration of 1.4 $g^{235}U/L$ for bounding soil consisting of only SiO_2 per NUREG/CR-6505 [13]. This fictitious bounding minimum critical concentration is also discussed in [14] and shown to represent a very conservative minimum subcritical limit to apply to waste materials generated during decommissioning operations at the Hematite site. It is this same limit that provides the basis for the 0.1 $g^{235}U/L$ *NCS Exempt Material* concentration limit that is employed for buried waste and contaminated soil remediation operations, in addition to other remediation operations involving contaminated materials (including crushed piping debris, contaminated soil surrounding subterranean piping, etc.). Unlike these other decommissioning waste materials, the *NCS Exempt Material* limit applied to intact pipe sections is set at a higher limit of 1.4 $g^{235}U/L$ in recognition of the low risk presented by piping with low concentrations of predominantly fixed surface contamination. When compared to the highly idealized fictitious system on which the 1.4 $g^{235}U/L$ minimum critical concentration limit is based (an infinite sea comprising only ^{235}U and SiO_2. These considerations provide abundant assurance that establishing an *NCS Exempt Material* concentration limit of 1.4 $g^{235}U/L$ to intact pipe sections will ensure that their exhumation and subsequent handling presents no credible NCS concerns and therefore does not warrant any NCS controls.

It is important to note that in this NCSA the *NCS Exempt Material* concentration limit of 1.4 $g^{235}U/L$ only applies to intact pipe sections. Crushed piping and other decommissioning debris evaluated in this NCSA is subject to an *NCS Exempt Material* concentration limit of 0.1 $g^{235}U/L$.

In addition to the quantitative criteria defined above, certain qualitative criteria are established in this appendix and apply to pipe sections that do not have existing assay data. The pipe sections without existing assay data are categorized in this appendix as *non-NCS Exempt Material* or *NCS Exempt Material* according to one of the following criteria.

b) Unassayed intact pipe sections that are part of a storm water line without any other non–storm water piping interconnections. Note that an interconnecting storm water line with any non-storm water line piping interconnection would not qualify under this particular criterion.

c) Unassayed intact pipe sections that are part of a storm water line that is situated upstream of any interconnected piping designated as *non-NCS Exempt Material*.

d) Unassayed intact pipe sections that are part of a down spout which was used to divert precipitation collected on the roof of the site buildings into the subsurface piping system. Note that this exemption applies only to the piping up to the point at which it intersects with any piping designated as *non-NCS Exempt Material*.

e) Unassayed intact pipe sections that are part of a sanitary system which was used to divert washroom waste water from only lavatories and sinks into the subsurface piping system. Note that this exemption applies only to the piping up to the point at which it intersects with any piping designated as *non-NCS Exempt Material*.

f) Unassayed intact pipe sections that are down-stream of assayed intact pipe sections that qualify as *NCS Exempt Material.* It is important to note that all upstream pipe sections that have assay results must qualify as *NCS Exempt Material* in order for the unassayed downstream intact pipe sections to be designated as *NCS Exempt Material* under this criterion. It is also important to note that if any upstream pipe sections do not have assay results then the downstream unassayed pipe sections must be treated as *non-NCS Exempt Material*, unless the unassayed upstream pipe section is designated as *NCS Exempt Material* by another exemption criteria defined in this appendix.

The technical basis for exemption criteria (b), (c), (d), and (e) are founded on the principle that these particular systems would not be expected to comprise *non-NCS Exempt Material* based on their purpose and former use, but also because the subject piping is situated upstream of any interconnected piping comprising potentially *non-NCS Exempt Material.*

The technical basis for exemption criteria (f) is founded on the principle that a downstream pipe section would not be expected to comprise *non-NCS Exempt Material* whenever all interconnected upstream sections (that are by definition closer to the point of feed liquid influx) are shown to comprise only *NCS-Exempt Material.*

The *NCS Exempt Material* criteria (a) through (f) established above are employed in Tables A-1 through A-8 in conjunction with the in-pipe probe assay data (discussed in Section 1.4.3 and reported in [6]) to designate each explicit subterranean pipe section as either *NCS Exempt Material* or *Non-NCS Exempt Material*. Note that Tables A-1 through A-8 are adapted from the data reported in [6].

Table A-1. NCS Classification of Subterranean Piping Associated with Building 110 at the Hematite Site

Building-Room	Line Designation		Direction	Length (ft)	Pipe OD (")	Pipe ID (")	Pipe Material of Construction	Dose Reading (mrem/hr)	^{235}U Distribution Model	^{235}U Distribution Basis	Average $g^{235}U/ft$ Estimate	Total $g^{235}U$ Estimate	NCS Exempt? [Y/N]	NCS Exempt Basis
	From	To/Toward												
110	FD-300	MH04-MH10	South	81	4.50000	4.026	PVC	No visual inspection data or in-pipe assay data available					Y	E
110	FD-301	FD-300	East	8	4.5	4.026	PVC	No visual inspection data or in-pipe assay data available					Y	E
110	FD-302	FD-300	East	8	4.5	4.026	PVC	No visual inspection data or in-pipe assay data available					Y	E
110	FD-303	CO-300	South	40	4.5	4.026	PVC	No visual inspection data or in-pipe assay data available					Y	E
110	CO-300	FD-300	SouthEast	12	4.5	4.026	PVC	No visual inspection data or in-pipe assay data available					Y	E
110	WC-300	MH04-MH10	South	30	4.5	4.026	PVC	No visual inspection data or in-pipe assay data available					Y	E

Table A-2. NCS Classification of Subterranean Piping Associated with Building 230 at the Hematite Site

Building-Room	Line Designation		Direction	Length (ft)	Pipe OD (")	Pipe ID (")	Pipe Material of Construction	Dose Reading (mrem/hr)	^{235}U Distribution Model	^{235}U Distribution Basis	Average $g^{235}U/ft$ Estimate	Total $g^{235}U$ Estimate	NCS Exempt? [Y/N]	NCS Exempt Basis
	From	To/Toward												
Building 230 Northernmost System														
230	CO-231	CO-301	South	37	4.50000	4.026	PVC	No visual inspection data or in-pipe assay data available					Y	E
230	WC-301	CO 231 - CO301	East	5	4.50000	4.026	PVC	No visual inspection data or in-pipe assay data available					Y	E
230	FD-308	CO 231 - CO301	East	8	4.50000	4.026	PVC	No visual inspection data or in-pipe assay data available					Y	E
230	WC-303	CO 232 - CO302	West	11	4.50000	4.026	PVC	No visual inspection data or in-pipe assay data available					Y	E
230	CO-232	CO302	South	37	4.50000	4.026	PVC	No visual inspection data or in-pipe assay data available					Y	E
230	FD-304	CO 232 - CO302	East	8	4.50000	4.026	PVC	No visual inspection data or in-pipe assay data available					Y	E
230	FD-312	CO 232 - CO302	West	6	4.50000	4.026	PVC	No visual inspection data or in-pipe assay data available					Y	E
230	WC-302	CO 231 - CO301	West	7	4.50000	4.026	PVC	No visual inspection data or in-pipe assay data available					Y	E
230	FD-306	CO 232 - CO302	SouthWest	8	4.50000	4.026	PVC	No visual inspection data or in-pipe assay data available					Y	E
230	FD-307	FD-306	North	8	4.50000	4.026	PVC	No visual inspection data or in-pipe assay data available					Y	E
230	WC-303	CO 231 - CO301	West	11	4.50000	4.026	PVC	No visual inspection data or in-pipe assay data available					Y	E
230	FD-309	CO 232 - CO301	West	7	4.50000	4.026	PVC	No visual inspection data or in-pipe assay data available					Y	E
230	CO-301	CO-303	East	34	4.50000	4.026	PVC	No visual inspection data or in-pipe assay data available					Y	E
230	FD-310	CO 301 - CO303	West	11	4.50000	4.026	PVC	No visual inspection data or in-pipe assay data available					Y	E
230	FD-308	CO 232 - CO 302	East	8	4.50000	4.026	PVC	No visual inspection data or in-pipe assay data available					Y	E
230	FD-311	CO 302 - CO 303	South	8	4.50000	4.026	PVC	No visual inspection data or in-pipe assay data available					Y	E
230	CO-302	CO-304	East	35	4.50000	4.026	PVC	No visual inspection data or in-pipe assay data available					Y	E
230	CO-303	MH 05 - MH 21	SouthEast	70	4.50000	4.026	PVC	No visual inspection data or in-pipe assay data available					Y	E
230	CO-304	MH 04 - MH 13	SouthEast	60	4.50000	4.026	PVC	No visual inspection data or in-pipe assay data available					Y	E
Building 230 Middle System														
230	CO-305	MH 04 - MH 13	East	72	4.50000	4.026	PVC	No visual inspection data or in-pipe assay data available					Y	E
230	FD 312	CO 305	West	15	4.50000	4.026	PVC	No visual inspection data or in-pipe assay data available					Y	E
230	FD 313	FD 312	South	8	4.50000	4.026	PVC	No visual inspection data or in-pipe assay data available					Y	E
230	FD 315	CO 305	North	10	4.50000	4.026	PVC	No visual inspection data or in-pipe assay data available					Y	E
230	FD-316	CO-305	North	10	4.50000	4.026	PVC	No visual inspection data or in-pipe assay data available					Y	E
Building 230 Southernmost System														
230	CO-233	FD-319	East then SouthEast	21 20	4.50000	4.5	PVC	No visual inspection data or in-pipe assay data available					Y	E
230	FD-317	CO-233	South	4	4.50000	4.026	PVC	No visual inspection data or in-pipe assay data available					Y	E
230	FD-318	CO-233	South	4	4.50000	4.026	PVC	No visual inspection data or in-pipe assay data available					Y	E
230	FD-319	MH 22 - MH 01	East then South	40 73	4.50000	4.026	PVC	No visual inspection data or in-pipe assay data available					Y	E

Table A-3. NCS Classification of Subterranean Piping Associated with Building 240 at the Hematite Site

Building-Room	Line Designation		Direction	Length (ft)	Pipe OD (")	Pipe ID (")	Pipe Material of Construction	Dose Reading (mrem/hr)	^{235}U Distribution Model	^{235}U Distribution Basis	Average $g^{235}U/ft$ Estimate	Total $g^{235}U$ Estimate	NCS Exempt? [Y/N]	NCS Exempt Basis
	From	To/Toward												
Northernmost System Building 240														
240-09	FD 203	SD-204- MH 17	North then South	4 20	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					Y	A
240-09	FD-202	FD-320	North	44	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
240-09	FD-201	FD-202	East	2	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
240-05	FD-320	FD-321 (CO-Lab_North)	West	50	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
240-09	CO-306	FD-321	West	8	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
240-07	FD-321 (Co Lab North)	CO-308	South West	35 84	5.00000	4	Cast Iron	See Data Sheet					N	N/A
240-09	CO-306	FD-321	West	8	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
240-09	FD-322	FD-321	West	3	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
240-07	FD-326	FD-321	West	8	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
240-07	FD-327	FD-321	West	8	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
240-07	CO-307	MH 04 - MH-13	West North West	18 46 89	4.50000	4.5	PVC	No visual inspection data or in-pipe assay data available					N N N	N/A
240-07	CO-308	FD-321	West then North	32 6	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
240-07	FD-325	CO-307	North	2	4.50000	4	PVC	No visual inspection data or in-pipe assay data available					N	N/A
240-07	FD-328	CO-307	North	2	4.50000	4	PVC	No visual inspection data or in-pipe assay data available					N	N/A
240-07	FD-324	CO-307	North	2	4.50000	4	PVC	No visual inspection data or in-pipe assay data available					N	N/A
240-07	FD-329	CO-307	West	8	4.50000	4	PVC	No visual inspection data or in-pipe assay data available					N	N/A
Middle System Building 240														
240-02	Co-209	8" Process Drain	West	110	5.00000	4	Cast Iron	See Data Sheet					N	N/A
240-02	PD-209	Co-209	South	6	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
240-02	PD-208	Co-209	South	5	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
240-02	PD-207	Co-209	North	3	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
240-02	CO-37	Co-209	North	57	5.00000	4	Cast Iron	See Date Sheet					Y	A
240-02	PD-37	CO-37	North	5	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
240-03	PD-336	PD-333	West	46	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
240-03	PD-335	PD-336	North	37	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
240-03	PD-334	PD-335	East	18	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
240-03	PD-332	PD-333	North	38	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
240-03	PD-333	Co-209	North	56	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
240-02	FP-36	PD-333	West	4	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
240-03	PD-331	PD-333	West	4	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
240-03	PD-330-1	PD-333	West	4	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
Southernmost System Building 240														
240-14	CO-311 (NEMS)	8" Process Drain	West	88	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
240-14	PD-339	CO-311	South	4	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
240-14	PD-338	CO-311	South	4	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
240-14	PD-41	CO-311	South	4	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
240-14	PD-337	CO-311	North	35	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
240-14	CO-312	PD-337	West	20	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
240-14	CO-313	CO-311	West	31	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
240-14	PD-44	CO-313	East	9	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
240-14	PD-43	CO-313	West	10	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
240-14	CO-45	CO-311	East	19	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A

Table A-4. NCS Classification of Subterranean Piping Associated with Building 253 at the Hematite Site

Building-Room	Line Designation		Direction	Length (ft)	Pipe OD (")	Pipe ID (")	Pipe Material of Constructi	Dose Reading (mrem/hr)	^{235}U Distributio nModel	^{235}U Distributio n Basis	Average $g^{235}U/ft$ Estimate	Total $g^{235}U$ Estimate	NCS Exempt? [Y/N]	NCS Exempt Basis
	From	To/Toward												
253	FD-360	MH10-MH 05	West North	30 100	4.5000	4	PVC	No visual inspection data or in-pipe assay data available					Y	E
253	MH-08	MH-15	East	114	4.5000	4	PVC	No visual inspection data or in-pipe assay data available					Y	E
253	DS-113	MH-15 - MH 08	North	12	4.5000	4	PVC	No visual inspection data or in-pipe assay data available					Y	B
Sanitary and Grey Water lines in Building 253														
253	FD-361	FD-360	East	15	4.5000	4	PVC	No visual inspection data or in-pipe assay data available					Y	E
253	FD-362	FD-361	North	2	4.5000	4	PVC	No visual inspection data or in-pipe assay data available					Y	E
253	FD-363	FD-361	North	2	4.5000	4	PVC	No visual inspection data or in-pipe assay data available					Y	E
253	FD-364	FD-361	South	2	4.5000	4	PVC	No visual inspection data or in-pipe assay data available					Y	E
Storm Water Lines Building 253														
253	DS-57	MH08-MH 15	East North	35 209	4.5000	4	PVC	See Data Sheet					Y	B
253	DS-105	DS-57 - MH 08	West	10	4.5000	4	PVC	No visual inspection data or in-pipe assay data available					Y	B
253	DS-50	DS-57 - MH 08	East	35	4.5000	4	PVC	No visual inspection data or in-pipe assay data available					Y	B
253	DS-49	DS-57 - MH 08	East	35	4.5000	4	PVC	No visual inspection data or in-pipe assay data available					Y	B
253	DS-48	DS-57 - MH 08	East	35	4.5000	4	PVC	No visual inspection data or in-pipe assay data available					Y	B
253	DS-210	DS-57 - MH 08	East	37	4.5000	4	PVC	No visual inspection data or in-pipe assay data available					Y	B
253	DS-106	DS-57 - MH 08	West	18	8.6250	8	PVC	No visual inspection data or in-pipe assay data available					Y	B
253	DS-107	DS-57 - MH 08	West	48	4.5000	4	PVC	No visual inspection data or in-pipe assay data available					Y	B
253	DS-WH	DS-57 - MH 08	West	18	4.5000	4	PVC	No visual inspection data or in-pipe assay data available					Y	B

Table A-5. NCS Classification of Subterranean Piping Associated with Building 254 at the Hematite Site

Building-Room	Line Designation		Direction	Length (ft)	Pipe OD (")	Pipe ID (")	Pipe Material of Construction	Dose Reading (mrem/hr)	235U Distribution Model	235U Distribution Basis	Average g235U/ft Estimate	Total g235U Estimate	NCS Exempt? [Y/N]	NCS Exempt Basis
	From	To/Toward												
254	FD-354	MH-11 -MH-05	South	8	4.5	4	PVC	No visual inspection data or in-pipe assay data available					Y	E
			East	20										
			North	30										
254	FD-351	FD-354	North	6	4.5	4	PVC	No visual inspection data or in-pipe assay data available					Y	E
240-07	FD-355	FD-354	South	8	5	4	PVC	No visual inspection data or in-pipe assay data available					Y	E
			West	33										
254	FD-356	FD-354	North	6	4.5	4	PVC	No visual inspection data or in-pipe assay data available					Y	E
254	FD-353	FD-354	North	8	4.5	4	PVC	No visual inspection data or in-pipe assay data available					Y	E
			East	12										
			North	20										
254	352	FD-353	West	8	4.5	4	PVC	No visual inspection data or in-pipe assay data available					Y	F
254-256	MH-12	MH15	North	225	19.75	15	RCP	No visual inspection data or in-pipe assay data available					Y	F
254-256	DS-97	MH15	West	14	19.75	15	RCP	No visual inspection data or in-pipe assay data available					Y	D
254-256	DS-96	MH15	West	14	19.75	15	RCP	No visual inspection data or in-pipe assay data available					Y	D
254-256	DS-95	MH15	West	14	19.75	15	RCP	No visual inspection data or in-pipe assay data available					Y	D
254-256	DS-94	MH15	West	14	19.75	15	RCP	No visual inspection data or in-pipe assay data available					Y	D
254-256	DS-93	MH15	West	14	19.75	15	RCP	No visual inspection data or in-pipe assay data available					Y	D

Table A-6. NCS Classification of Subterranean Piping Associated with Building 255 at the Hematite Site

Building-Room	Line Designation From	Line Designation To/Toward	Direction	Length (ft)	Pipe OD (")	Pipe ID (")	Pipe Material of Construction	Dose Reading (mrem/hr)	^{235}U Distribution Model	^{235}U Distribution Basis	Average g^{235}U/ft Estimate	Total g^{235}U Estimate	NCS Exempt? [Y/N]	NCS Exempt Basis
Northernmost Process System in Building 255														
255	PD-340	CO-226	South	15	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
255	PD-233	CO-226	South	15	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
255	PD-341	CO-226	South	15	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
255	PD-342	CO-226	South	15	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
255	PD-226	CO-225	West	74	5.00000	4	Cast Iron	See Data Sheet					Y	A
255	Co-225	MH 15 - MH-12	South West	40 30	5.00000	4	PVC	See Data Sheet					Y	A
255	PD-343	CO-225	South	10	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
255	CO-315	CO-316	West	74	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
255	CO-344	CO-315	North	24	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
255	CO-345	CO-315	South	3	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
255	PD-229	CO-315	North	24	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
255	PD-228	CO-315	South	2	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
255	CO-316	CO-225	North	15	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
Southernmost Process System in Building 255														
255	CO-320	MH 15 - MH 12	West	100	5.00000	4	Cast Iron	See Data Sheet					Y	A
255	PD-142	CO-320	South	40	5.00000	4	Cast Iron	See Data Sheet					Y	A
255	Co-232	CO-320	North	39	5.00000	4	Cast Iron	See Data Sheet					Y	A
255	PD-232	CO-320	North	8	5.00000	4	Cast Iron	See Data Sheet					Y	A
255	PD-231	CO-320	North	8	5.00000	4	Cast Iron	See Data Sheet					N	N/A
255	PD-153	CO-320	South	15	5.00000	4	Cast Iron	See Data Sheet					N	N/A
255	PD-152	CO-320	South	15	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
255	CO-319	CO-320	South	30	5.00000	4	Cast Iron	See Data Sheet					N	N/A
255	CO-230	CO-320	North	41	5.00000	4	Cast Iron	See Data Sheet					Y	A
255	CO-317	CO-318	West	64	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
255	PD-345	CO-317	North	3	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
255	PD-346	CO-317	North	3	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
255	PD-230	CO-317	North	3	5.00000	4	Cast Iron	No visual inspection data or in-pipe assay data available					N	N/A
Sanitary Lines in Building 255														
255	FD-120	MH 10 - FD224	North East North	9 15 50	4.50000	4.5	PVC	No visual inspection data or in-pipe assay data available					Y	E
255	FD-121	FD-120	North	5	4.50000	4	PVC	No visual inspection data or in-pipe assay data available					Y	E
255	FD-122	FD-120	south	4	4.50000	4	PVC	No visual inspection data or in-pipe assay data available					Y	E
255	FD-123	FD-120	South	4	4.50000	4	PVC	No visual inspection data or in-pipe assay data available					Y	E
255	FD-124	FD-120	North	8	4.50000	4	PVC	No visual inspection data or in-pipe assay data available					Y	E
255	CO-220	FD-120	North	34	4.50000	4	PVC	No visual inspection data or in-pipe assay data available					Y	E
Sanitary and Grey Water lines in Building 255														
255	FD-224	MH-10	North NorthWest West	10 24 50	4.50000	4	PVC	No visual inspection data or in-pipe assay data available					Y	E
255	FD-348	FD-224	North	10	4.50000	4	PVC	No visual inspection data or in-pipe assay data available					Y	E
255	Co-222	MH-11	West North West	10 39 20	4.50000	4	PVC	No visual inspection data or in-pipe assay data available					Y	E
255	FD-347	FD-224	SouthWest	8	4.50000	4	PVC	No visual inspection data or in-pipe assay data available					Y	E
255	FD-349	FD-224	East	12	4.50000	4	PVC	No visual inspection data or in-pipe assay data available					Y	E
255	Co-221	MH-11	East North	25 33	4.50000	4	PVC	No visual inspection data or in-pipe assay data available					Y	E
255	FD-350	FD-221	East	12	4.50000	4	PVC	No visual inspection data or in-pipe assay data available					Y	E

Table A-7. NCS Classification of Subterranean Piping Associated with Building 260 at the Hematite Site

Building-Room	Line Designation		Direction	Length (ft)	Pipe OD (")	Pipe ID (")	Pipe Material of Construction	Dose Reading (mrem/hr)	^{235}U Distribution Model	^{235}U Distribution Basis	Average $g^{235}U/ft$ Estimate	Total $g^{235}U$ Estimate	NCS Exempt? [Y/N]	NCS Exempt Basis
	From	To/Toward												
2260	PD-170	MH-16	East	20	4.50000	4	PVC	See Data Sheet					Y	A
			North	43										
255	PD-164	MH-16	East	21	5.00000	4	Cast Iron	See Data Sheet ☐ ☐ ☐					Y	A

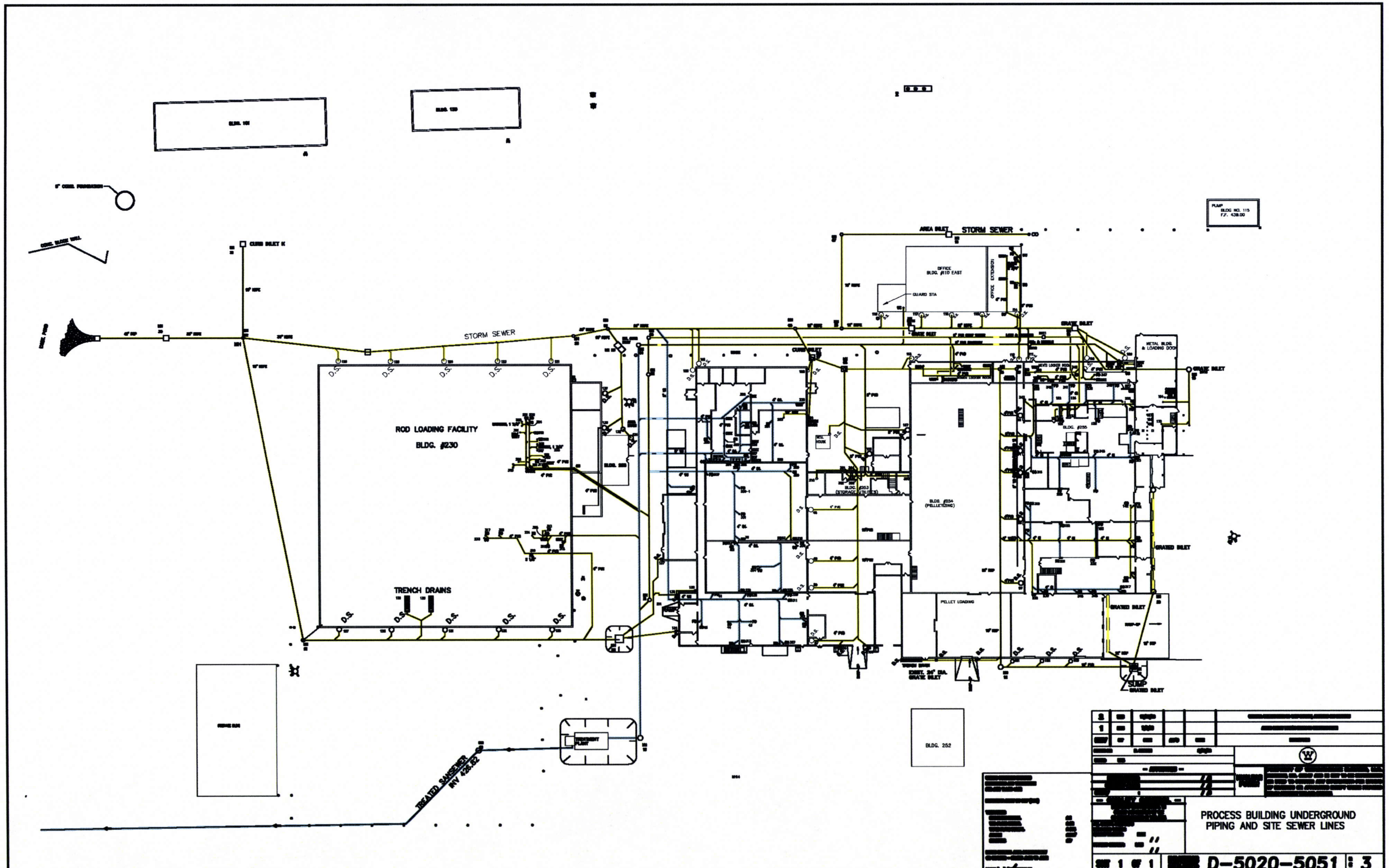
Table A-8. NCS Classification of Subterranean Piping Associated with the Environs of Buildings at the Hematite Site

Building-Room	Line Designation		Direction	Length (ft)	Pipe OD (")	Pipe ID (")	Pipe Material of Construction	Dose Reading (mrem/hr)	^{235}U Distribution Model	^{235}U Distribution Basis	Average $g^{235}U/ft$ Estimate	Total $g^{235}U$ Estimate	NCS Exempt? [Y/N]	NCS Exempt Basis
	From	To/Toward												
N/A	MH-40	MH-27	South	150	16.50000	12	HDPE	No visual inspection data or in-pipe assay data available					Y	A
N/A	LD Dock	MH-27	South	75	16.5	12	HDPE	No visual inspection data or in-pipe assay data available					Y	A
N/A	MH-27	MH-12	West	95	10.75	12	HDPE	No visual inspection data or in-pipe assay data available					Y	B
N/A	DS-103	DS-57 - MH 08	South	5	4.5000	4	PVC	No visual inspection data or in-pipe assay data available					Y	A
N/A	DS-104	DS-57 - MH 08	South	5	4.5000	4	PVC	No visual inspection data or in-pipe assay data available					Y	A
N/A	DS-105	DS-57 - MH 08	South	5	4.5000	4	PVC	No visual inspection data or in-pipe assay data available					Y	A
N/A	Storm Grait	MH-12	East	75	10.75	12	HDPE	No visual inspection data or in-pipe assay data available					Y	A
N/A	Mh-10	MH-04	East	292	8.625	7.981	HDPE	No visual inspection data or in-pipe assay data available					Y	A
N/A	Mh-11	MH-05	East	296	8.625	7.981	HDPE	No visual inspection data or in-pipe assay data available					Y	A
N/A	Mh-04	MH-13	South	296	8.625	7.981	HDPE	No visual inspection data or in-pipe assay data available					N	N/A
N/A	Mh-05	MH-04 MH-13	South	170	8.625	7.981	HDPE	No visual inspection data or in-pipe assay data available					Y	A
N/A	Mh-31	CO-311	South	180	8.625	7.981	HDPE	No visual inspection data or in-pipe assay data available					N	N/A
N/A	Mh-18	MH-09	West	122	12.75	12	HDPE	See Data Sheet					Y	A
N/A	DS-109	MH 09- MH 18	North	34	4.5000	4	PVC	No visual inspection data or in-pipe assay data available					Y	D
N/A	DS-110	MH 09- MH 18	North	28	4.5000	4	PVC	No visual inspection data or in-pipe assay data available					Y	D
N/A	DS-111	MH 09- MH 18	North	25	4.5000	4	PVC	No visual inspection data or in-pipe assay data available					Y	D
N/A	DS-112	MH 09- MH 18	North	25	4.5000	4	PVC	No visual inspection data or in-pipe assay data available					Y	D
N/A	DS-114	MH 09- MH 18	South	12	4.5000	4	PVC	No visual inspection data or in-pipe assay data available					Y	D
N/A	DS-115	MH 09- MH 18	South	12	4.5000	4	PVC	No visual inspection data or in-pipe assay data available					Y	D
N/A	DS-116	MH 09- MH 18	South	12	4.5000	4	PVC	No visual inspection data or in-pipe assay data available					Y	D
N/A	DS-117	MH 09- MH 18	South	12	4.5000	4	PVC	No visual inspection data or in-pipe assay data available					Y	D
N/A	DS-118	MH 09- MH 18	South	12	4.5000	4	PVC	No visual inspection data or in-pipe assay data available					Y	D
N/A	Mh-25	MH-07	North	72	8.625	7.981	HDPE	No visual inspection data or in-pipe assay data available					Y	E
N/A	MH-07	MH-19	North	80	8.625	7.981	HDPE	No visual inspection data or in-pipe assay data available					Y	E
N/A	Mh-25	MH-03	East	173	8.625	7.981	HDPE	No visual inspection data or in-pipe assay data available					Y	B
N/A	Mh-03	Outfall	South	314	8.625	7.981	HDPE	No visual inspection data or in-pipe assay data available					Y	B
N/A	Mh-03	DS-134	South	87	4.5000	4	HDPE	No visual inspection data or in-pipe assay data available					Y	B
N/A	DS-136	MH-03 - MH DS	West	14	4.5000	4	PVC	No visual inspection data or in-pipe assay data available					Y	D
N/A	DS-137	MH-03 - MH DS	West	14	4.5000	4	PVC	No visual inspection data or in-pipe assay data available					Y	D
N/A	DS-124	MH-03 - MH 02	South	18	4.5000	4	PVC	No visual inspection data or in-pipe assay data available					Y	D
N/A	DS-121	MH-03 - MH 02	South	14	4.5000	4	PVC	No visual inspection data or in-pipe assay data available					Y	D
N/A	DS-123	MH-03 - MH 02	South	12	4.5000	4	PVC	No visual inspection data or in-pipe assay data available					Y	D
N/A	DS-125	MH-03 - MH 02	South	10	4.5000	4	PVC	No visual inspection data or in-pipe assay data available					Y	D
N/A	DS-126	MH-03 - MH 02	South	11	4.5000	4	PVC	No visual inspection data or in-pipe assay data available					Y	D
N/A	MH-17	MH06	West	25	4.50000	4	PVC	See Data Sheet					Y	A
		MH08	North	24										
		240 laundry room	West	44										
N/A	DS-137	MH-17	South	8	4.5000	4	PVC	No visual inspection data or in-pipe assay data available					Y	D
N/A	MH-22	MH-01	East	150	8.625	7.981	HDPE	No visual inspection data or in-pipe assay data available					Y	B
N/A	DS-133	MH-01 - MH-22	South	8	4.5000	4	PVC	No visual inspection data or in-pipe assay data available					Y	D
N/A	DS-	MH-01 - MH-22	South	8	4.5000	4	PVC	No visual inspection data or in-pipe assay data available					Y	D
N/A	DS-	MH-01 - MH-22	South	8	4.5000	4	PVC	No visual inspection data or in-pipe assay data available					Y	D
N/A	DS-	MH-01 - MH-22	South	30	4.5000	4	PVC	No visual inspection data or in-pipe assay data available					Y	D
N/A	DS-	MH-01 - MH-22	South	11	4.5000	4	PVC	No visual inspection data or in-pipe assay data available					Y	D
N/A	DS-	MH-01 - MH-22	South	8	4.5000	4	PVC	No visual inspection data or in-pipe assay data available					Y	D
N/A	DS-	MH-01 - MH-22	South	8	4.5000	4	PVC	No visual inspection data or in-pipe assay data available					Y	D
N/A	Mh-01	MH-02	North	233	8.625	7.981	HDPE	No visual inspection data or in-pipe assay data available					Y	B
N/A	Mh-02	MH-31	North	69	8.625	7.981	HDPE	No visual inspection data or in-pipe assay data available					Y	E

Table A-9. Data Sheet for Subsurface Piping Results

Building-Room	Line Designation		Direction	Surveyed Length (ft)		Percentage of Line Surveyed	Pipe OD (")	Pipe ID (")	Pipe Material of Construction	Estimated Average Debris Volume	Dose Reading (mrem/hr)	^{235}U Distribution Model	Average g ^{235}U/ft Estimate	Total g ^{235}U Estimate	Volume of Piping Structural Materials (L/ft)	Average g ^{235}U/L Estimate	Average Concentration /Pipe	NCS Exempt? [Y/N]
	From	To/Toward		From	To													
N/A	MH-5	MH-11	East	0	190	100%	8.625	8	PVC	10.00%					1.6257	N/A	N/A	
N/A	MH-9	MH18	East	0	120	100%	12.75"	12	HDPE	1.50%	< 0.1	Segment	1.51	181	3.0481	0.50	0.50	Y
N/A	MH-12	MH-27	East	0	60	100%	16.5"	12	RFC	1.50%					19.9910	N/A	N/A	
N/A	MH-12	MH15	North	0	220	100%	19.75	15	RCF	1.50%	< 0.1	Segment	2.28	502	25.0915	0.09	0.09	Y
N/A	MH-17	MH06	North-West	0	30	100%	8.625	8	PVC	1.50%	< 0.1	Segment	1.06	32	1.6257	0.62	0.62	Y
		MH08	East	0	20	100%	6.625	6	PVC	1.50%	< 0.1	Segment	1.03	21	1.0802	0.97	0.97	Y
		240 laundry room	South	0	30	100%	6.625	6	PVC	1.50%	< 0.1	Segment	1.03	31	1.0802	0.97	0.97	Y
														84				
N/A	MH-16	South	South	0	47	100%	5	4	Cast Iron	5.00%	< 0.1	Segment	1.01	48	1.3681	0.74	0.74	Y
		MH18	West, then	0	45	48%	8.625	8	PVC	1.50%	< 0.1	Segment	1.06	48	1.6257	0.64	0.57	Y
			West - NW	45	95	52%	12.75	12	PVC	1.50%	< 0.1	Segment	1.51	144	3.0481	0.50		Y
						100%												
N/A	Bldg 240-SWDS-2		West	0	26	100%	6.625	6	PVC	1.50%	< 0.1	Segment	1.06	28	1.0802	1.00	1.00	Y
N/A	MH-8	MH15	East	0	120	100%	12.75"	12	HDPE	1.50%	< 0.1	Segment	1.51	181	3.0481	0.50	0.50	Y
		PD-57	South	0	200	100%	10.75	10	HDPE	1.50%	< 0.1	Segment	1.27	254	1.6257	0.64	0.64	Y
N/A	Bldg 240-SWDS-1		West	0	38	100%	6.625	6	HDPE	1.50%	< 0.1	Segment	1.06	41	1.0802	0.93	0.93	Y
N/A	Bldg 240-SWDS-3		West	0	60	100%	6.625	6	HDPE	1.50%	< 0.1	Segment	1.06	64	1.0802	0.98	0.98	Y
255-56	CO-230		North	0	5	15%	5	4	Cast Iron	25.00%	< 0.1	Annular	1.88	12	1.3681	1.37	1.34	Y
				6	34	68%				15.00%	< 0.1	Annular	1.75	51	1.3681	1.27		Y
					36	5%				15.00%	0.18	Annular	3.2	3	1.3681	2.34		Y
				37	41	12%				15.00%	< 0.1	Annular	1.75	9	1.3681	1.27		Y
						100%								75	56.0921			
255-54	PD-142		South	0	45	100%	5	4	Cast Iron	10.00%	< 0.1	Annular	1.59	72	1.3681	1.16	1.16	Y
														1	61.5645			
255-46	CO-226		South	0	78	100%	5	4	Cast iron	10.00%	< 0.1	Annular	1.59	124	1.3681	1.16	1.16	Y
255-61	CO-232		North	0	30	100%	5	4	Cast Iron	10.00%	< 0.1	Annular	1.59	48	1.3681	0.99	0.99	Y
			West	0	30	100%					< 0.1	Annular	1.59	48	1.3681	0.99		Y
240-3	CO NE MS		West	0	2	5%	5	4	Cast Iron	50.00%	< 0.1	Annular	2.01	6	1.3681	1.46	1.36	Y
				3	7	9%				20.00%	< 0.1	Annular	1.75	9	1.3681	1.27		Y
				0	8	2%					0.12	Annular	2.11	2	1.3681	2.19		Y
				9	38	53%					< 0.1	Annular	1.75	53	1.3681	1.27		Y
				0	39	2%					0.12	Annular	2.11	2	1.3681	2.19		Y
				40	44	7%					< 0.1	Annular	1.75	9	1.3681	1.27		Y
				0	45	2%					0.12	Annular	2.11	2	1.3681	2.19		Y
				46	52	15%					< 0.1	Annular	1.75	13	1.3681	1.27		Y
				0	53	2%					0.12	Annular	2.11	2	1.3681	2.19		Y
				54	55	4%					< 0.1	Annular	1.75	4	1.3681	1.27		Y
						100%								102	75.2455			
240-11	CO-37		North	0	10	23%	5	4	Cast Iorn	20.00%	< 0.1	Annular	1.75	19	1.3681	1.32	1.30	Y
				11	47	77%					< 0.1	Annular	1.75	65	1.3681	1.28		Y
						100%								84	64.3007			
240-11	CO-209		West	0	23	100%	5	4	cast iron	40.00%	< 0.1	Annular	1.94	45	1.3681	1.43	1.43	N
240-7	CO-Lab-North		South	0	43	70%	5	4	Cast Iron	40.00%	< 0.1	Annular	1.94	86	1.3681	1.43	1.52	N
				0	44	2%					0.12	Annular	2.33	2	1.3681	2.19		N
			West	45	51	11%					< 0.1	Annular	1.94	14	1.3681	1.46		N
				0	51	2%					0.24	Annular	4.7	5	1.3681	2.19		N
				52	63	16%					< 0.1	Annular	1.94	24	1.3681	3.65		N
						100%								131	86.1903			
240-14	CO-45		North	0	2	4%	5	4	Cast iron	50.00%	< 0.1	Annular	2.01	6	1.3681	1.46	2.21	N
				3	6	6%				20.00%	< 0.1	Annular	1.75	7	1.3681	1.21		N
				0	7	1%					0.3	Annular	5.42	5	1.3681	4.39		N
				8	20	19%					0.24	Annular	4.31	56	1.3681	3.29		N
			West	21	24	4%					0.24	Annular	4.31	17	1.3681	3.17		N
				0	25	1%					0.48	Annular	8.82	9	1.3681	6.58		N
				26	40	21%					0.18	Annular	3.2	48	1.3681	2.30		N
			North	41	70	43%					0.12	Annular	2.11	63	1.3681	1.54		N
						100%								212	95.7670			
255-59	PD-232		North	0	12	33%	5	4	Cast Iron	10.00%	< 0.1	Segment	1.22	16	1.3681	0.91	0.90	Y
			West	13	24	28%					< 0.1	Segment	1.22	13	1.3681	0.86		Y
				25	28	10%					0.12	Segment	1.45	4	1.3681	0.97		Y
				0	29	3%					0.24	Segment	2.87	3	1.3681	2.19		Y
				30	39	26%					< 0.1	Segment	1.22	12	1.3681	0.89		Y
						100%								48	53.3559			
255-53	PD-228		West	0	12	38%	5	4	Cast Iron	20.00%	< 0.1	Annular	1.75	23	1.3681	1.40	3.42	N
				0	13	3%					0.24	Annular	4.31	4	1.3681	2.92		N
				14	19	18%					< 0.1	Annular	1.75	11	1.3681	1.61		N
				0	20	3%					0.84	Annular	15.89	16	1.3681	11.70		N
			North	21	26	18%					< 0.1	Annular	1.75	11	1.3681	1.61		N
				27	33	18%					0.6	Annular	11.13	78	1.3681	9.50		N
				0	34	3%					0.84	Annular	15.89	16	1.3681	11.70		N
						100%								159	46.5154			
260-65	CO-164		East	0	12	25%	5"	4	Cast Iron	10.00%	< 0.1	Annular	1.59	21	1.3681	11.70	1.37	Y
				0	13	2%					0.84	Annular	14.89	15	1.3681	1.61		Y
				14	20	13%					< 0.1	Annular	1.59	11	1.3681	9.50		Y
			South	21	53	60%					< 0.1	Annular	1.59	53	1.3681	11.70		Y
						100%								100	72.5093			
255-59	Co-225		South	0	32	48%	5	4	Cast Iron	10.00%	< 0.1	Annular	1.59	52	1.3681	1.37	0.73	Y
			North	0	33	1%					0.24	Annular	4.31	4	1.3681	2.92		Y
				34	39	9%					< 0.12	Annular	2.11	13	1.3681	1.94		Y
				0	40	1%					0.4	Annular	3.31	3	1.3681	2.19		Y
				41	69	41%					< 0.1	Annular	1.59	46	1.3681	1.15		Y

Figure A-1. NCS Classification of Other Subterranean Piping Associated at the Hematite Site



The data presented in Tables A-1 through A-7, in conjunction with the *NCS Exempt Material* technical bases provided above, demonstrate that the subterranean piping system at the Hematite site (comprising a total of approximately 7,700 linear ft of piping) consists of approximately 17% *non-NCS Exempt* Piping (~1349 ft), with the remaining 83% (6,372 ft) (Figure A-1) designated as *NCS Exempt Material*.