Ashman Center
March 1, 2003

The Dow Chemical Company
Midland, Michigan 48674

Mr. Sam Nalluswami
U.S. Nuclear Regulatory Commission
11545 Rockville Pike
Rockville, MD 20852

SUBJECT: TDCC Responses to NRC Comments on Final Status Survey Reports for Verification Areas VA-1 through VA-VI

Enclosed are The Dow Chemical Company's (TDCC) responses to the comments provided in the USNRC letter of August 16, 2002, *Review of Final Status Survey Reports for the Previously Remediated Areas VA-I through VA-VI, Dow Chemical Company's Bay City, MI, SDMP Site (TAC# L60463).* Enclosure 1 provides the responses to each NRC comment and Enclosure 2 provides Revision 1 to the Final Status Survey reports for Verification Areas VA-I through VA-VI. Revision 1 of the reports incorporates the additional information and clarifications described in TDCC's responses and are intended to replace Revision 0 in their entirety.

Please contact me at (989) 636-0787 or David Fauver at (772) 492-0163 if you have any questions.

Sincerely,

Ben Baker

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Enclosures (2)

cc: Ed Kulzer, NRC Region 3
Jerry Sgro, URS Corporation
David Fauver, Babcock Services

NRC Comments and DOW Responses
DOW Chemical Company's Bay City, MI
Magnesium-Thorium Slag Storage Area
Final Status Survey Reports for VA-I through VA-VI

Introduction

The following are Dow Chemical Company's responses to the comments provided in the USNRC letter of August 16, 2002, *Review of Final Status Survey Reports for the Previously Remediated Areas VA-I through VA-VI, Dow Chemical Company's Bay City, MI, SDMP Site (TAC3 L60463).*

General Comments

Comment

1A. The decommissioning and decontamination efforts of the magnesium-thorium slag storage area have been performed in part with the NUREG/CR-5849 guidance document. In some cases this guidance appears not to have been followed.

1B. Several concerns were identified such as the contradictory statements between the report text and the data presented. For example, page 11 of the report for VA-VI states, "since none of the verification soil sample concentrations exceeded the guideline values (no hot spots), it was not necessary to apply averaging techniques in any of the grids." However, in reviewing the residual soil activity results, numerous individual samples were identified in the various FSSRs, that exceeded the stated gross activity guideline of 14.5 pCi/g total thorium and/or the unity rule. Therefore staff recommends that the reports be revised to clearly document in the data table that the 100 m^2 average activity levels satisfy the guideline and unity rule.

Response

1A. See response to Specific Comment #1.

1B. Individual soil samples exceeding the total thorium guideline value were identified in VA-IV and VA-VI. The statement, "since none of the verification soil sample concentrations exceeded the guideline values (no hot spots), it was not necessary to apply averaging techniques in any of the grids", has been deleted from VA-IV and VA-VI. Section 4.2.2 of VA-IV and VA-VI has been revised to describe the actions taken by Dow when an individual sample exceeded the guideline value. In the case of VA-IV, the samples were a composite over 100 m^2 and therefore, the hot spot averaging criteria could not be applied. The sample areas were remediated and re-surveyed as part of the VA-VI survey unit (BCS-K4-9-v1, BCS-K5-7-v1, BCS-K5-8-v1). In the case of VA-VI, two of the individual samples exceeded the guideline value (BCS-J6-1-A and BCS-I4-9-C). Since the samples were a composite over 25 m^2, the 100 m^2 and $(100/A)^{1/2}$ hot spot averaging criteria were applied. One of the samples passed and one failed. The failed sample has been deleted from the VA-VI database and will be remediated and re-surveyed at a later date as part of a subsequent Verification Area Report.

Comment

2. The reports are not clear as to how each thorium isotope concentration was quantified. The procedures state that the Th-232 was analyzed in the field using a NaI detector coupled to an MCA and that final verification soil samples were subjected to gamma and alpha analyses in Dow's Freeport, Texas laboratory. Additionally, 10 percent of the samples were shipped off-site to a contract laboratory for quality assurance analysis. The reports need to explain how the Th-228 and Th-230 concentrations were inferred and reference the applicable procedures and documents.

Response

2. Sections 3.4.4 and 3.6 in each of the FSSRs have been revised to describe in more detail the soil sample collection and analysis methods employed. Additional procedure references have been provided in each FSSR. For all verification areas, the samples were analyzed for Th-232 in the field using a NaI detector coupled to an MCA to provide a rapid turnaround for remediation decisions. For VA-I, VA-II and VA-III, all of the final FSS samples were analyzed by gamma and alpha spectroscopy at the Freeport laboratory to obtain Th-232, Th-228, and Th-230 concentrations. Ten percent of these samples were sent to a contractor laboratory for QA analysis using similar counting techniques. For VA-IV, VA-V and VA-VI, the FSS samples were analyzed for Th-232 using the onsite gamma spectroscopy laboratory. Five percent of the FSS samples were sent to the Freeport laboratory for QA analysis. A conversion factor was applied to the Th-232 gamma spec results to obtain the Th-228 and Th-230 concentrations (see response to NRC Comment 7A). The onsite laboratory was found to be acceptable as documented in NRC Inspection Reports 040-00017/98001, 040-00017/98002, 040-00017/99001.

Comment

3. NRC staff performed confirmatory surveys on all six of the verification areas promptly after the licensee had completed the final status survey of each area. Based on these confirmatory surveys, only VA-I was initially found to comply with the release criteria. All of the other verification areas (i.e., VA-II to VA-VI) were found to have locations that contained radioactive material exceeding the release criteria. (Note that NRC performed a follow-up confirmatory only in VA-II) Although these locations were subsequently remediated by the licensee, it appears the FSSRs reviewed have not been revised to include the findings of the NRC confirmatory surveys nor do they indicate that the final status surveys and analyses were redone to verify release criteria compliance. Table 1 shows that the FSSRs predate the confirmatory surveys. In the case of VA-III, the FSSR was revised after the confirmatory survey identified slag exceeding the release criteria; however, the revision addressed only the re-labeling of sub-grids. Staff concludes that until these FSSRs are revised to include data and analyses for final status surveys conducted after the NRC confirmatory surveys, the information provided is incomplete for demonstrating compliance with the release criteria.

Response

3. Section 4.2.4, NRC Confirmatory Surveys, has been added to each of the FSSRs to address confirmatory findings and Dow actions to those findings. Each of the confirmatory survey findings indicated in Table 1 of NRC's comments has been fully resolved in Section 4.2.4 of Reports I-VI.

Comment

4. In general, the FSSRs do not discuss surface scan findings, i.e., what were the range of readings or did the surface scans identify any hot spots during the final status survey and were those hot spots remediated (with location specified) before FSSRs were issued?

Response

4. Section 4.2.1 in each of the FSSRs has been revised to include discussion on the number of hot spots identified during the scan survey and any actions taken by Dow in response to the elevated scan readings.

Comment

5. In general, the FSSRs did not summarize the results of preliminary surveys, such as scoping, characterization, and remedial action surveys. Also, no discussion was provided on how remedial

action survey data was carried forward and integrated with the final status survey data analysis to demonstrate compliance with the release criteria.

Response

5. Section 1.0 of each of the FSSRs has been revised to include discussion on the results of preliminary surveys. Section 3.2 of each of the FSSRs has been revised to clarify how remedial action survey data was carried forward and integrated with final status survey data.

Comment

6. The FSSR format and content is inconsistent between the six reports reviewed. The reports need to be revised to be complete and consistent with the requirements in the decommissioning plan, all subsequently approved revisions and correspondence, and all guidance incorporated by reference (e.g., NUREG/CR-5849).

Response

6. All six FSSRs have been revised to be consistent in format and content.

Specific Comments

Comment

1A. For each FSSR, a map of the appropriate verification area was provided. Each grid is comprised of nine sub-grids. The tables for final verification soil concentrations indicate only one sample per sub-grid (about 10m x 10m). Under NUREG/CR-5849 guidance, four systematic soil samples are collected per sub-grid during the FSS to satisfy the average guideline. However, the approved decommissioning plan specifies that for the remedial action surveys nine soil samples will be composited into one sample per sub-grid. It appears that the FSSs for Verification Areas VA-I, VA-II, VA-III, and VA-IV were based on one composite sample per sub-grid (i.e., just the results of the remedial action surveys), whereas, four samples (without compositing) were taken in VA-V and VA-VI. Only the latter follows the guidance in NUREG/CR-5849.

1B. The FSSRs need to clearly explain how the remedial action survey was conducted and the data integrated with the final status survey.

1C. In addition, to clarify how the final status survey was performed, each report needs to include an example figure of a sub-grid with the sampling locations shown.

Response

1A. Section 3.4.2 and 3.4.4 of each FSSR have been revised to clarify the respective soil sampling method used. The sampling method used for the final verification of areas VA-I through VA-IV consisted of nine individual samples from each 100 m^2 sub-grid that were combined into one composite. This method was described in the Decommissioning Plan (and TDCC response to RAIs) approved in License Amendment No. 7. The final verification samples for areas VA-V and VA-VI consisted of 4 composite samples, from each 100 m^2 sub-grid, one from each 25 m^2 quadrant. The method used for VA-V and VA-VI was implemented by the RSO to be more consistent with NUREG/CR-5849. It is more conservative than that used in VA-I through VA-IV in that a minimum of 3 individual samples were included in each quadrant composite, providing a total of 12 individual soil samples for each 100 m^2 sub-grid. This exceeds the decommissioning plan commitment to collect 9 individual soil samples in each 100 m^2 sub-grid.

1B. Section 3.2 of each of the FSSRs has been revised to clarify how remedial action survey data was carried forward and integrated with final status survey data. The final samples collected during the remediation control survey were used as input to the final status survey, providing the sample concentrations did not exceed the soil guideline value. The sampling and analysis scheme used during the remediation control survey was designed to meet the quality and design requirements for FSS as described in the Decommissioning Plan.

1C. Figure 3-3, Reference Grid System, and Figure 3-4, Sub-Grid Quadrant Designation, have been included in each FSSR.

Comment

2. The survey unit maps indicate specific areas called "excavation limit". The FSSRs need to explain this term and explain any impacts that these areas had on the conduct of the final status survey (e.g., VA-III).

Response

2. The term "excavation limit" only appeared on the map for VA-III. The term originally referred to a previously excavated area and had no bearing on the FSS data provided in the report. All maps have been revised in each of the FSSRs and this term has been deleted from the VA-III map.

Comment

3. For Verification Areas VA-1 to VA-VI, the FSSRs explain that the 30 background soil sample locations are shown in the "background sample" figure. However, the figures show only background sample locations 1 through 25.

Response

3. Figure 3-5, Background Sample Locations, has been revised and included in each of the FSSRs. The original map did show all 30 sample locations; however, it was unclear in that the five samples taken east of the site (across the river) were labeled as 1-5 instead of being correctly labeled as 26-30.

Comment

4. For VA-I and VA-II FSSRs, the final verification soil concentration data (Table A3 (a) and (b)) does not indicate the analytical technique used to determine the isotopic thorium concentrations. A footnote needs to be provided that summarizes this technique with reference to the appropriate procedural document.

Response

4. Neither of the original FSSRs reviewed contained a footnote to the soil concentration data tables explaining the analytical technique used to determine the isotopic thorium concentrations. Section 3.6 of each of the FSSRs has been revised to provide additional discussion on sample analysis technique as well as the appropriate procedure reference.

Comment

5. The FSSR for VA-III does not contain a Section 3. Section 3 in the other reports discusses the survey procedure methodology. Also, this FSSR does not include a section on surface scans.

Response

5. The FSSR for VA-III has been revised to include a Section 3 and a section on surface scans.

Comment

6. The FSSR for Verification Area VA-IV contains several sub-grids with final verification soil concentrations in excess of the release criteria (i.e., K4-9, K5-7, and K5-8). Regarding these sub-grids, the report contains no information on satisfying the area weighted average over 100 m^2 or the hot spot criteria. In addition, no summary statistics were provided for the final status survey.

Response

6. Since the above referenced samples were a composite over 100 m^2, the weighted average test could not be applied. These three areas were removed from the scope of VA-IV and were subsequently remediated and re-surveyed as part of VA-VI. FSS Summary Statistics have been included in the all of the revised FSRRs, including VA-IV.

Comment

7A. The footnote to Table 4-4, Final Verification Soil Concentrations, in the FSSRs for VA-V and VA-VI, contains factors of 1.63 to convert concentrations of Th-232 to Th-230 and 0.94 to convert Th-232 to Th-228. How these factors were derived needs to be explained. Also, these factors do not appear to be consistent with the factors used to determine the thorium soil concentrations for VA-I through VA-IV.

7B. Finally, there needs to be a discussion in each report on the derivation of the site specific thorium release criteria of 14.5 pCi/g. Relevant information is provided in the Decommissioning Plan Supplement (December 1996) and the Dow Response to Comments in NRC Letter of February 5, 1996 (March 1996).

Response

7A. A detailed review was conducted of the analytical methods used to generate the data provided in FSSRs VA-I – VA-VI. There was no clear documentation in the Thorad project files describing the basis for the 0.94 and 1.63 correction factors. It appears that the 1.63 Th-230/Th-232 conversion factor was based on the background data provided in the FSSRs. The 0.94 Th-228/Th-232 conversion factor could be derived assuming that all of the pure thorium metal feedstock arrived at the site in 1970, the last year of thorium alloy production at the site, and that the onsite gamma spectroscopy analyses were performed in 1998. The Th-228 concentration would be about 94% of the Th-232 concentration, i.e., 0.94 conversion factor. The actual equilibrium would be closer to 1.0 since onsite thorium processing started in the early 1940's.

The 1.63 and 0.94 conversion factors were used to generate the results provided in FSSRs IV – VI. However, the data provided in FSSRs I – III was generated using isotope specific analyses for Th-232, Th-228, and Th-230.

The 0.94 conversion factor is technically justified based on the decay calculation shown above. However, without additional documentation, the use of the 1.63 correction factor for Th-230 does not appear justified since it was based on background data as opposed to licensed material. The only clearly documented Th-230/Th-232 ratio appears to be that provided in the March 1996 Dow Response to NRC Comments, i.e., 3:1.

The use of a 3:1 ratio, as opposed to 1.63:1 has an insignificant affect on the reported average and standard deviation of the FSS data in FSSRs IV-VI and therefore the previously reported data was not modified in Revision 1 of the respective FSSRs. However, the data was reviewed to

identify any results that did not exceed the 14.5 pCi/g limit using the 1.63 correction factor but would exceed the 14.5 pCi/g limit if a 3.0 correction factor were applied. In addition, a review of the gamma spectroscopy procedures for the Thorad site NaI system indicated that the Th-232 results were determined by the analysis of Pb-212, assuming equilibrium of all daughter products. This is reasonable considering that all of the samples are very close to background and that thorium processing on the site began in the early 1940's. However, the assumption of equilibrium used in the gamma spectroscopy analyses could be interpreted as potentially non-conservative data if a Th-228/Th-232 ratio of 0.94 is assumed. Therefore, the recalculation test of the higher results in FSSRs IV-VI included not only the 3/1 correction factor for Th-230, but also an adjustment for the fact that Pb-212 represents Th-228, not Th-232, and assuming a 0.94 Th-228/Th-232 ratio. Attachment 1 contains a memorandum from the site RSO to the project files that contains the recalculated results for the highest reported values to demonstrate that the affect is insignificant.

The recalculation is a very minor technical/administrative correction that is performed to satisfy all potential future questions about the reported data and does not justify a revision to the FSS data tables and does not change any conclusions regarding the acceptability of areas VA-I – VA-VI for unrestricted use.

For all future FSS sample analysis, a Th-232/Th-228 ratio of 1:1 and a Th-230/Th-232 ratio of 3:1 will be assumed.

7B. The derivation of the 14.5 pCi/g total thorium criteria is included in Section 2.3 of each FSSR.

Comment

8. Section 3.1 Survey Objectives of the FSSRs for Verification Areas VA-I and VA-II states, "The entire Bay City storage area (affected area) is treated as a single survey unit, and the 95% level of confidence will be applied to the entire survey unit. While the residual concentration values are being provided for individual VAs for convenience of the final validation, the 95% level of confidence will be demonstrated for the entire site (survey unit) upon completion of the project." The licensee needs to explain how the statistical tests (i.e., *t* test) will be done, since some of the final status surveys involved sample compositing while others did not. Also, it needs to be explained how FSS data from the yet to be remediated area will be considered in this statistical analysis.

Response

8. Section 3.1 of VA-I and VA-II has been revised to state, "A 95% minimum level of confidence that the above conditions have been met was to be demonstrated. The entire Section (VA-I or VA-II) of the Bay City storage area (affected area) is treated as a single survey unit, and the 95% level of confidence was applied to the entire survey unit. This statement is consistent with FSSRS VA-III – VA VI and NUREG/CR-5849.

Comment

9. A list of specific reference was not provided in any of the FSSRs.

Response

9. Section 6.0, References, has been provided in each of the FSSRs.

MEMORANDUM

To: TDCC Thorad Project Files
From: Robert F. Yetter, RSO
Date: February 26, 2003
RE: Soil Concentration Tests for VA-I through VA-VI

To ensure the soil concentrations in VA-I through VA-III pass the Unity Rule release criteria, the test was performed on the three samples containing the highest total thorium concentrations from each survey unit. The following formula was used in the test:

$$\frac{Th^{232} + Th^{228}}{10} + \frac{Th^{230}}{21} \leq 1$$

The following table summarizes the test results. All samples tested passed the Unity Rule test. Soil concentrations are in pCi/g.

Sample #	Th^{232} net	Th^{228} net	Th^{230} net	Total Thorium	Test Result
VA-I					
BCS-07-2v1	0.93	0.57	5.33	6.83	0.4
BCS-P7-9v1	0.81	0.53	6.35	7.69	0.44
BCS-R8-3v1	0.12	0.43	5.50	6.04	0.31
VA-II					
BCS-K3-3Av1	1.98	1.77	4.19	7.95	0.57
BCS-K5-3Av1	3.14	2.82	8.02	13.98	0.97
BCS-K5-4v2	2.16	2.15	3.39	7.70	0.59
VA-III					
BCS-F13-3v1	1.48	1.24	9.49	12.21	0.72
BCS-I11-9v1	0.95	0.81	9.38	11.14	0.62
BCS-I13-9v1	0.71	1.45	8.95	11.11	0.64

During the final status surveys of VA-IV, VA-V and VA-VI, the soil samples were analyzed on site via gamma spectroscopy through use of the NaI detector coupled with a MCA. To obtain the Th-232 and Th-230 concentrations, a conversion factor was applied to the Th-232 concentration obtained from the gamma spectroscopy. Specifically, a conversion factor of 1.63 was applied to convert concentrations of Th-232 to Th-230 and 0.94 to convert Th-232 to Th-228. There was no documentation found describing how the factor of 1.63 was derived although it appears to be derived from the background data. However, a review of TDCC's March 1996 response to NRC RAI's on the Decommissioning Plan indicated that the Th-230 to Th-232 ratio was 3:1. Therefore, it was concluded that the use of the 1.63 correction factor could have potentially biased the calculated Th-230 results.

In addition, a detailed review of the gamma spectroscopy procedures for the Thorad site NaI system indicated that the Th-232 results were determined by the analysis of Pb-212, assuming equilibrium of all daughter products. This is reasonable considering that thorium processing on the site began in the early 1940's, which leads to conditions very close to equilibrium. However, the assumption of equilibrium could be interpreted as potentially non-conservative data if the Th-228/Th-232 ratio of 0.94 applied in the FSSR's VA-IV – VA-VI is assumed to be more accurate. Therefore, the recalculation test of the higher results in FSSRs IV-VI included not only the 3/1 correction factor for Th-230, but also an adjustment for the fact that Pb-212 represents Th-228, not Th-232. This adjustment entailed 1) assuming that the reported Th-232 concentration represented Th-228, and 2) recalculating the Th-232 results by dividing the reported concentrations by 0.94.

To assess the impact of the potential bias resulting from uncertainty in the radionuclide ratios, all reported net Th-232 values >2.75 pCi/g (<2.75 pCi/g will always pass) have been recalculated using the modified conversion factors. The new results were compared to the release criteria, the $(100/A)^{1/2}$ averaging criteria, and the 100 m^2 averaging criteria.

All soil samples with reported net Th-232 values >2.75 pCi/g are listed in the table below. Since the soil samples obtained in VA-IV represent a concentration over 100 m^2, the averaging criteria cannot be applied. However, a review of the data from VA-IV reveals no samples with net Th-232 values >2.75 pCi/g. All concentrations represent net values in pCi/g.

The data in the following table represent very minor technical/administrative corrections that have been performed to satisfy all potential future questions about the reported data. The small magnitude of the corrections potentially caused by the uncertainty in the correction factors do not justify a revision to the FSS data tables and do not change any conclusions regarding the acceptability of areas VA-I – VA-VI for unrestricted use.

Sample Number	Original Reported Values				Revised Values				Average $100m^2$	Pass/Fail Average Criteria	Pass/Fail Hot Spot Criteria
	Th^{232}	Th^{230}	Th^{228}	Total Th	Th^{232}	Th^{230}	Th^{228}	Total Th			
VA-V											
BCS-A8-8v1-B	3.53	5.75	3.30	12.59	3.76	11.26	3.53	18.59	5.61	Pass	Pass
BCS-A8-5v1-C	0.17	0.28	0.15	0.60	0.18	0.54	0.17	0.89			
BCS-A8-6v1-C	0.48	0.78	0.43	1.70	0.51	1.53	0.48	2.52			
BCS-A8-9v1-A	0.11	0.18	0.09	0.38	0.12	0.35	0.11	0.50			
VA-VI											
BCS-E2-1-C	3.07	5.01	2.87	10.96	3.27	9.80	3.07	16.14	5.28	Pass	Pass
BCS-E2-1-A	-0.16	-0.26	-0.17	-0.59	-0.17	-0.51	-0.16	-0.84			
BCS-E2-1-B	0.39	0.63	0.34	1.36	0.41	1.24	0.39	2.04			
BCS-E2-1-D	0.72	1.17	0.66	2.55	0.77	2.30	0.72	3.78			
BCS-E2-9-C	2.92	4.76	2.73	10.42	3.11	9.32	2.92	15.35	6.87	Pass	Pass
BCS-E2-9-A	1.09	1.77	1.01	3.87	1.16	3.48	1.09	5.72			
BCS-E2-9-B	0.67	1.10	0.62	2.39	0.71	2.14	0.67	3.52			
BCS-E2-9-D	0.55	0.90	0.50	1.96	0.59	1.76	0.55	2.89			
BCS-I3-6-A	3.16	5.15	2.95	11.26	3.36	10.08	3.16	16.60	5.42	Pass	Pass
BCS-I3-6-B	0.21	0.34	0.18	0.73	0.22	0.67	0.21	1.10			
BCS-I3-6-C	0.20	0.32	0.17	0.68	0.21	0.64	0.20	1.04			
BCS-I3-6-D	0.56	0.91	0.51	1.97	0.59	1.79	0.56	2.94			

Sample Number	Original Reported Values				Revised Values				Average $100m^2$	Pass/Fail Average Criteria	Pass/Fail Hot Spot Criteria
	Th^{232}	Th^{230}	Th^{228}	Total Th	Th^{232}	Th^{230}	Th^{228}	Total Th			
VA-VI continued											
BCS-I4-9-C	9.42	15.35	8.83	33.60	10.02	30.06	9.42	49.50	N/A	N/A	Fail
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A			
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A			
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A			
BCS-I6-2-D	3.34	5.44	3.12	11.89	3.55	10.66	3.34	17.55	8.51	Pass	Pass
BCS-I6-2-A	1.28	2.08	1.18	4.55	1.54	4.63	1.28	7.61			
BCS-I6-2-B	0.41	0.66	0.36	1.43	0.44	1.31	0.41	2.16			
BCS-I6-2-C	1.45	2.36	1.35	5.16	1.36	4.09	1.45	6.73			
BCS-J4-9-C	4.05	6.59	3.78	14.42	4.31	12.93	4.05	21.28	9.68	Pass	Pass
BCS-J4-9-A	1.44	2.35	1.34	5.13	1.53	4.60	1.44	7.57			
BCS-J4-9-B	0.33	0.54	0.30	1.17	0.35	1.05	0.33	1.73			
BCS-J4-9-D	1.55	2.53	1.44	5.51	1.65	4.95	1.55	8.14			
BCS-J6-1-A	4.16	6.78	3.89	14.83	4.43	13.28	4.16	21.86	7.67	Pass	Pass
BCS-J6-1-B	0.80	1.30	0.73	2.83	0.85	2.55	0.80	4.20			
BCS-J6-1-B	0.27	0.43	0.23	0.93	0.29	0.86	0.27	1.42			
BCS-J6-1-B	0.61	0.99	0.55	2.15	0.65	1.95	0.61	3.21			

Final Status Survey Report for VA-I
Magnesium-Thorium Slag Storage Area
The Dow Chemical Company's
Bay City, Michigan Facility

DOW U.S.A.

The Dow Chemical Company
Midland, Michigan 48674

Revision 1
March 2003

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TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

1.0 BACKGROUND INFORMATION

The radioactive material at the Dow Chemical Company's Bay City site consisted primarily of foundry slag containing Thorium. This material, and similar material originally stored at Dow's Midland site, was produced in the period from 1940 to 1970 as the residual from the production of a magnesium-thorium alloy. This lightweight alloy was used for defense purposes, including aircraft engines and aeronautical structural components.

A single license (STB-527) was originally granted by the NRC in 1973 for the Bay City and Midland sites to store up to 200,000 pounds of thorium slag. The license expired in 1978, but has remained in effect under timely renewal.

The Midland site was decontaminated with the material removed and transported to Bay City for consolidation with the Bay City material and subsequent transport to the Envirocare facility in Clive, Utah. A final survey was conducted at the Midland site by Dow with the results documented in a Final Status Survey Report of March, 1997, showing that the residual contamination criteria had been met. The NRC subsequently conducted an independent survey of the Midland site and verified that the residual contamination criteria had been met.

The material transported from the Midland site to the Bay City site originally consisted of magnesium with up to two percent thorium. Portions of this process slag were mixed with soil or limited amounts of construction debris. As a result of this mixing, the thorium concentrations, as determined by Dow characterization soil sampling, varied from 2-7000 pCi/g at the Bay City Site (with an average concentration of 188 pCi/g) . A total activity of 9.7 Ci of Th-232 was originally distributed throughout approximately 52,000 cubic yards of soil, slag, and construction debris.

Initial remedial action support surveys, performed in 1996, identified wide spread areas of elevated contamination. The gamma scan surveys were conducted using a sodium iodide detector. Readings were generally higher the closer the proximity to the original thorium pile but several hot spots in the 300,000 to 600,000 cpm range were identified. Construction debris, such as drums, were removed from these areas along with the contaminated soil.

Decontamination of the Bay City site is ongoing. In accordance with NRC and Dow discussions, as confirmed in Dow's letter of June 12, 1997, verification that residual contamination criteria have been achieved on this large site is being performed in sections. This Final Status Survey Report (FSR) provides the descriptive text on the site and the parameters of the survey program and includes the analyzed verification data for Verification Area (VA) I. As the database is acquired for subsequent VAs addendums to the Final Survey Report will be submitted to the NRC containing the analyzed database.

Supporting information on the Bay City site and decommissioning project is presented in the October, 1993 Decommissioning Work Plan, the December, 1995 Supplement to the Decommissioning Work Plan, and the March, 1996 Response to Comments.

This document is a revision to the original Final Status Survey Report for VA-I and VA-II dated July, 1997. For the purposes of this revised report, only changes to the original report pertinent to VA-I are addressed. Changes to the VA-II portion of the original report will be addressed in a separate revised report.

On July 24th and 25th of 1997, after the original report submittal, the NRC Region III conducted an inspection of the VA-I and VA-II portions of the Dow Bay City facility. The primary purpose of the inspection was to conduct an independent confirmatory survey of VA-I and VA-II. This revision to the original report is provided to include the findings of the NRC confirmatory surveys documented in NRC Report No. 040-00017/97002 (DNMS) dated August 14, 1997.

Additionally, this revision to the original report is provided to address deficiencies identified by NRC staff in a letter to Dow dated August 16, 2002 (Review of Final Status Survey Reports for the Previously Remediated Areas VA-I through VA-VI, Dow Chemical Company's Bay City, MI, SDMP Site (TAC# L60463)).

2.0 SITE INFORMATION

2.1 SITE DESCRIPTION

The Bay City thoriated material storage site is on a Dow facility near the Town of Bay City, Michigan about one-mile south of Saginaw Bay. The Bay City site (pile) is shown on Figure 2-1 in relation to adjacent land features and other facilities.

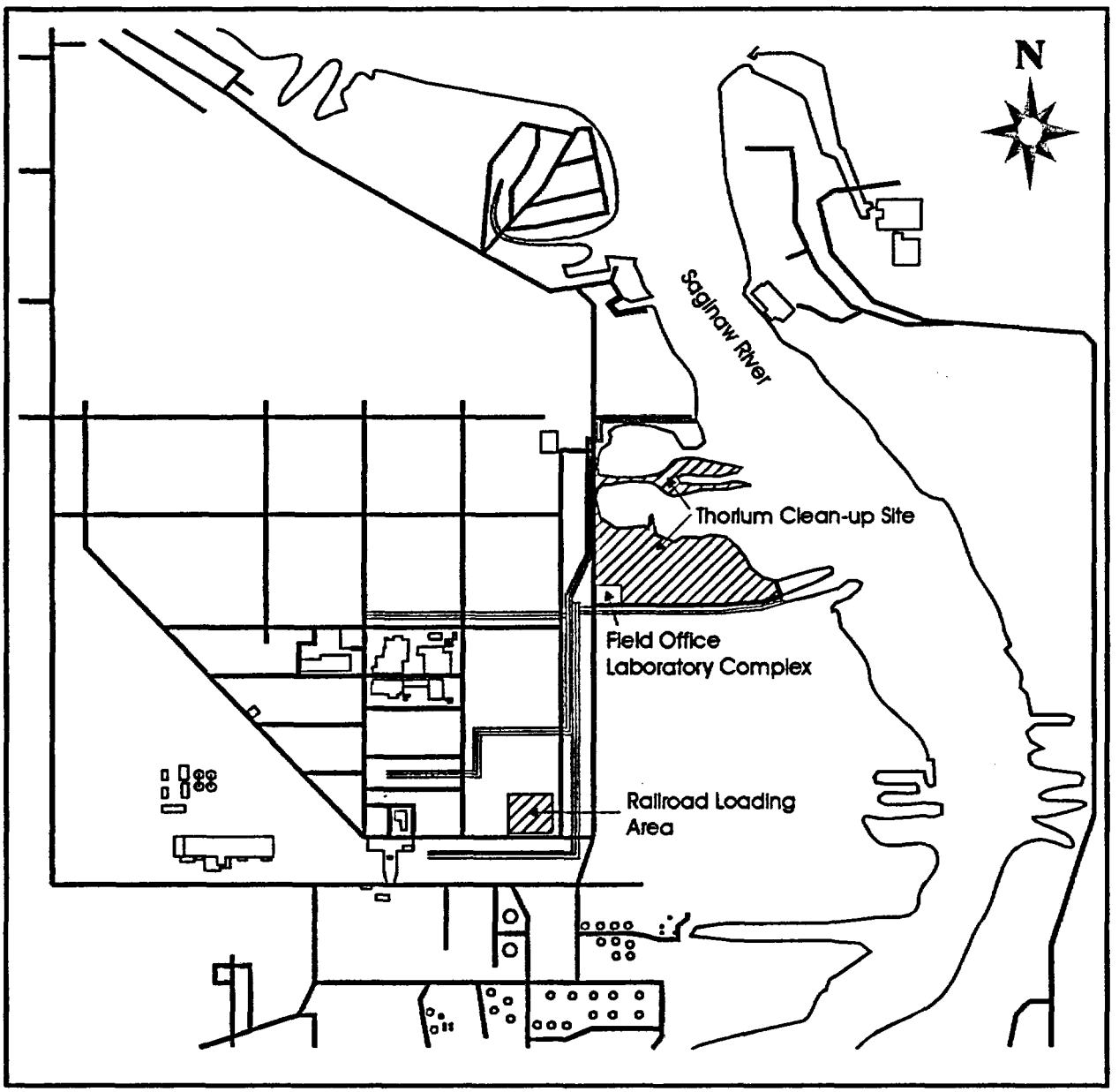
The thoriated material site is located adjacent to and north of an inlet canal, which enters the Saginaw River to the east. The Saginaw River is located to the north and east of the material. Access to the Dow manufacturing facility is restricted to authorized personnel. The storage site within the facility is posted as a radiation control area and delineated with a fence.

The area surrounding the material is relatively level, with some marshy areas and ponds. Any sediments containing elevated levels of thorium are being excavated as part of the decontamination program.

The affected area of the Bay City storage site was initially based on knowledge of the operating history, and subsequently on radiological characterization surveys. While areas immediately surrounding the Bay City storage area were included in the affected area, some further outward adjustment of the affected area boundary was required during site remediation to encompass surface and subsurface contamination uncovered during remedial operations.

Figure 2-1

Bay City Thorium Disposal Site



2.2 SITE CONDITIONS AT TIME OF FINAL SURVEY

The decommissioning activities at the Bay City site involve excavation of the contaminated soil, loading on to trucks, onsite transportation of the material to the stockpile at the railhead, loading on to the rail cars, and transport of the material to the Envirocare burial site in Clive, Utah. Soil removal is to varying depths continuing until sample analysis showed residual concentrations to be within NRC defined limits. Final verification samples were taken in the VA and analyzed on site through gamma spectroscopy. When the gamma spectral analysis results showed the Th-232 levels to be less than the guideline value, the final verification samples were then sent to the Freeport, Texas laboratory for gamma and alpha spectral analysis and confirmation that residual contamination limits have been met. Ten percent of all final verification samples were then sent to an outside contract laboratory for independent QC verification. Dow conducted QA/QC programs which were monitored by the Dow QA coordinator.

2.3 IDENTITY OF POTENTIAL CONTAMINANTS AND RELEASE GUIDELINES

Based on the knowledge of the process that generated the slag material, and the results of the characterization survey, the significant radiological contaminants were determined to be Th-232, Th-230, and Th-228. The above background residual soil concentration measurements used as a basis for the final verification for all the verification samples analyzed to date at Bay City provided the average soil activity ratios at Bay City of approximately:

Th-232	-	22%
Th-230	-	60%
Th-228	-	18%

Using the approach described in Section 3.1 ("Release Criteria") of the December, 1995 Supplement to the Decommissioning Work Plan and response No. 8 of the Response to Comments (on the Work Plan) of March, 1996, in conjunction with the methodology in Appendix A of NUREG/CR 5849 gives a residual soil gross activity guideline of 14.5 pCi/g total

thorium. The site-specific guideline levels for each of the contributory radionuclides is thus 3.2 pCi/g for Th-232, 2.6 pCi/g for Th-228, and 8.7 pCi/g for Th-230.

The gross activity guideline is determined as follows:

$$\textit{Gross Activity Guideline} = \frac{1}{\frac{0.22}{10} + \frac{0.18}{10} + \frac{0.60}{21}} = 14.5\ pCi/g$$

where Th-232, Th-230, and Th-228 are present in net activity ratios of 0.22, 0.60. and 0.18 respectively in the residual soil. The guideline concentrations for Th-232 plus Th-228 are 10 pCi/g and 21 pCi/g for Th-230 (see March, 1996 Response to Comments).

3.0 FINAL STATUS SURVEY OVERVIEW

3.1 SURVEY OBJECTIVES

The purpose of the final status survey was to demonstrate that the residual radiological concentrations in the soil at the Bay City thorium storage site satisfy the NRC guidelines (see 2.3 above) and that the storage site can, therefore, be released for future use without radiological controls. Specifically, the final status survey soil database should show that:

- Average residual radionuclide concentrations are at or below the soil guideline values defined in Section 2.3. Averaging is based on a 100 m^2 (10m x 10m) grid area. Note an actual grid size of 33.3 ft. x 33.3 ft. was used for convenience in measuring rather than 10m x 10m (32.8 ft. x 32.8 ft.).

- Reasonable efforts have been made to identify, evaluate, and remove, if necessary, areas of residual activity exceeding the guideline values. Areas of residual activity exceeding the guideline value (elevated areas) may be acceptable provided they do not exceed the guideline value by greater than a factor of $(100/A)^{1/2}$, where A is the area of residual

activity in m^2, and provided the activity level at any location does not exceed three times the guideline values.

In addition, exposure rates should not exceed 5 μR/h above background at 1 m above the soil surface. Exposure rates may be averaged over a 100 m^2 grid area. Maximum exposure rates over any discrete area may not exceed 10 μR/h above background.

A 95% minimum level of confidence that the above conditions have been met was to be demonstrated. The entire Section I of the Bay City storage area (affected area) is treated as a single survey unit, and the 95% level of confidence was to be applied to the entire survey unit.

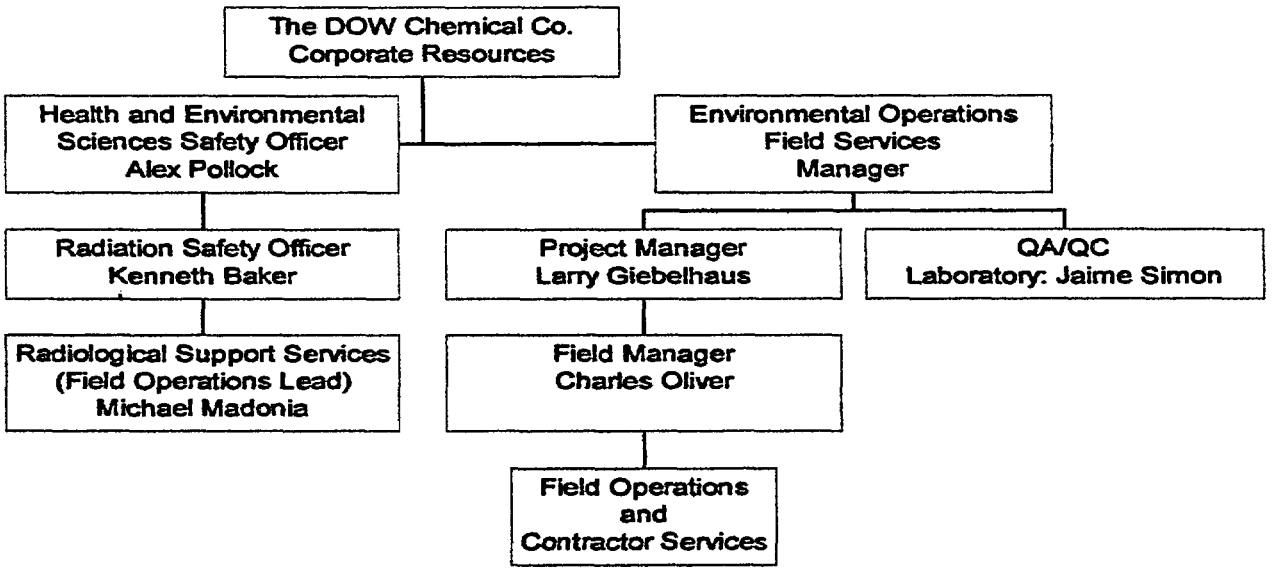
3.2 ORGANIZATION AND RESPONSIBILITIES

The final status survey was conducted by the same qualified Dow and subcontractor personnel who had conducted the characterization survey, and remediation control survey. The Project Organization is shown in Figure 3-1.

The sampling and analysis methods to be used during the remediation control survey was designed to achieve the sampling sensitivity and elevated activity guidelines defined in NUREG/CR-5849 relative to the site specific residual contamination criteria. The approach consisted of first performing a gamma scan survey of the remediated area to determine if any localized areas of elevated activity remained. Elevated areas of activity identified by the scan survey were remediated. If no areas of elevated activity were identified, composite soil samples were then collected and analyzed in the field laboratory using a NaI crystal coupled to the MCA to provide rapid turnaround on the Th-232 levels. If the Th-232 level exceeded the guideline value, further remediation was performed. The soil sample results of the analysis of the final samples collected, that demonstrated that the administrative cleanup level had been achieved, were then used as input into the final status survey.

Figure 3-1

Project Organization for Remediation of the Midland and Bay City Storage Sites



3.3 INSTRUMENTATION

Table 3-1 describes the laboratory instrumentation used for soil analyses along with the detection sensitivities for the instrumentation. The detection sensitivity for both the gamma and alpha spectrometer analyses are less than 25% of the residual concentration guideline values. The laboratory instrumentation calibration procedures and schedule are provided in Appendix D-2 of the March, 1996 Response to Comments.

Table 3-1

Laboratory Radiometric Analyses

Dow Chemical Freeport, Texas

Sample Type	Radionuclide Measured	Instrument	Analytical Procedures	Approx. Sensitivity
250 ml soil sample (polypropylene beaker w/ lid	Th-232 daughters in equilibrium with Th-232 (Ac-228, Bi-212, Pb-212, Ti-208)	Canberra Gamma Spectrometer system. The components include a 51.5 mm closed ended coaxial germanium detector, crystal, pre-amplifier, amplifier, power supply, multi-channel analyzer and computer.	Dow Central Research Index Report: CRI-TSP-92-076	0.2 pCi/g
0.6 sample from 250 ml soil sample	Th-232, Th-228, Th-230	Canberra Model 7404 four channel alpha spectrometer with built-in power supply, vacuum guage, detector bias supply, generator, pre-amplifier/amplifiers, multi-channel analyzer having a mixer-router input. The detectors are four passively implanted planar silicon (PIPS).	Dow Central Research Index Report: CRI-TSP-92-076	0.2 pCi/g

Table 3-2 lists the field radiological monitoring instrumentation used on the project inclusive of the specific use of each instrumentation and detection sensitivities. Each instrument was initially calibrated to NIST-traceable standards prior to use on the project, and then checked for radiation response and efficiency prior to daily use.

Table 3-2

Field Radiological Monitoring Instrumentation

Instrument	Measures	Detector Efficiency*	LLD/MDA
Ludlum Model 43-5 w/ Ludlum Model 12	Alpha Surface	15%	22 dpm
Ludlum Model 43-90 w/ Ludlum Model 2221	Alpha Surface	22%	12 dpm
Ludlum Model 44-9 w/ Ludlum Model 12	Alpha, Beta, Gamma	12% alpha 15% beta 1% gamma	
Ludlum Model 43-10 w/ Ludlum 1000	Alpha (air filters, smears)	43%	0.04 dpm
Ludlum Model 19	Exposure Rate		1 microR/h
Air Particulate			
Eberline RAS-1 Air Pump	Flow Rate = 40-100 lpm		
MSA Escort Lapel Sampler	Flow Rate = 2-3 lpm		
General Metal Works–2000 High Vol Sampler	Flow Rate = 30-60 cfm		
Test/Calibration Equipment			
Ludlum Model 500 Pulser	NIST Traceable		
AFC-85L Air Flow Calibrator	NIST Traceable		
GMW-Calibrator Orifice for High Vol Sampler	NIST Traceable		
MSA Optiflow 660 Air Flow Calibrator	NIST Traceable		
Field Laboratory Equipment			
Canberra Gamma Spectrometer	Soil Th-232 Concentration		0.8 pCi/g

* Detector efficiencies are approximate and appropriate for Th-230, Tc-99, and Co-60

3.4 SURVEY PROCEDURES

Survey planning and procedures are consistent with the methods described in the Decommissioning Plan. The soil survey procedures are summarized in this section and can be found in greater detail in Appendices D-2 and D-3 of the March, 1996 Response to Comments.

3.4.1 Area Classification

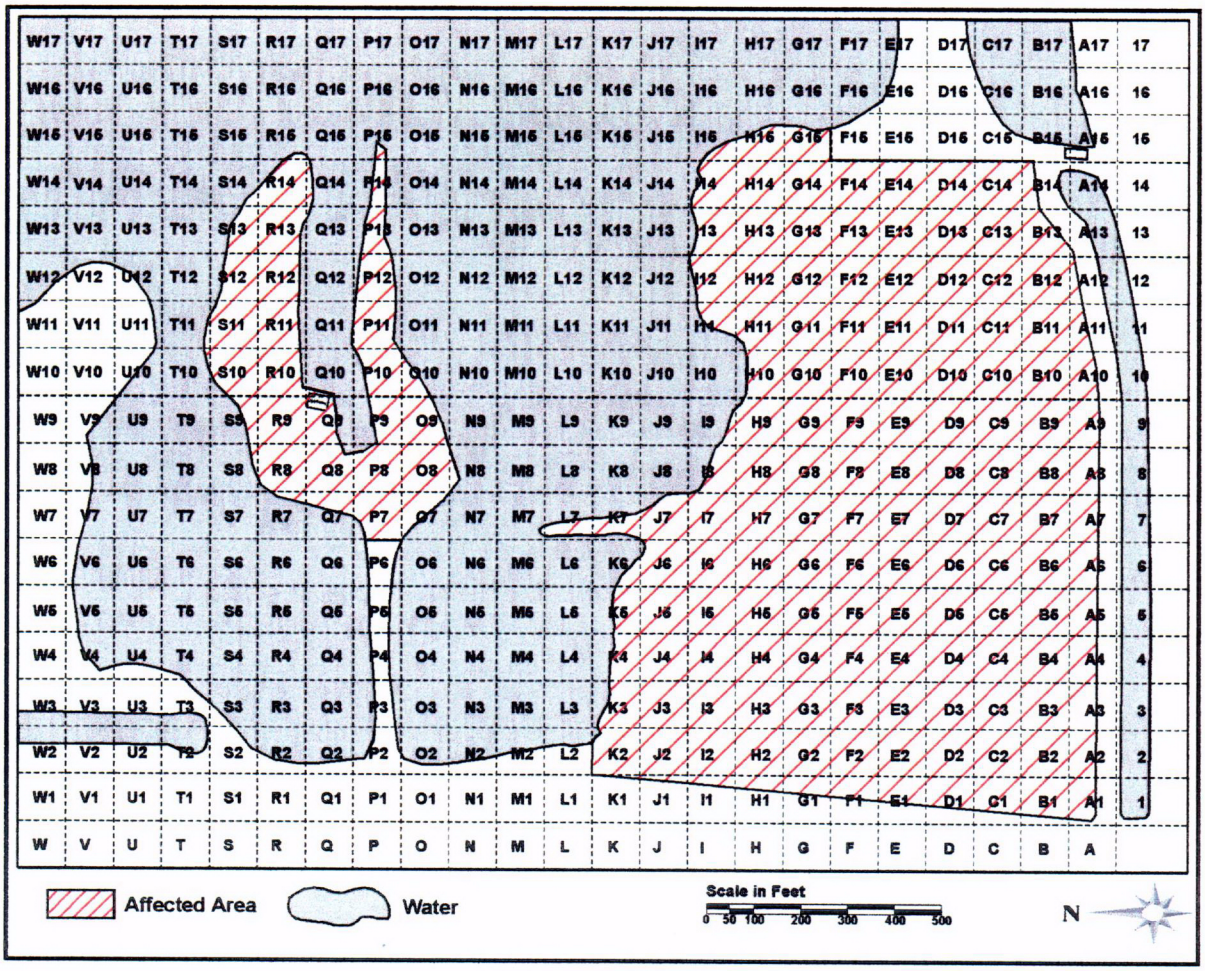
The Bay City storage site was divided into affected and unaffected areas to establish the sampling pattern and frequency. The basis for the affected and unaffected classification, as applied to the Bay City site are:

- **Affected Area** – As shown in Figure 3-2, the thorium material storage area and region immediately surrounding the storage area was defined as the affected area based on both historical records and prior characterization surveys. This location had known thorium contamination in the soil that had been placed there via backfill operations and storage.

- **Unaffected Area** – The region surrounding the affected area (see Figure 3-2) was treated as unaffected since it did not contain residual radioactivity.

Figure 3-2

Bay City Site Affected Areas



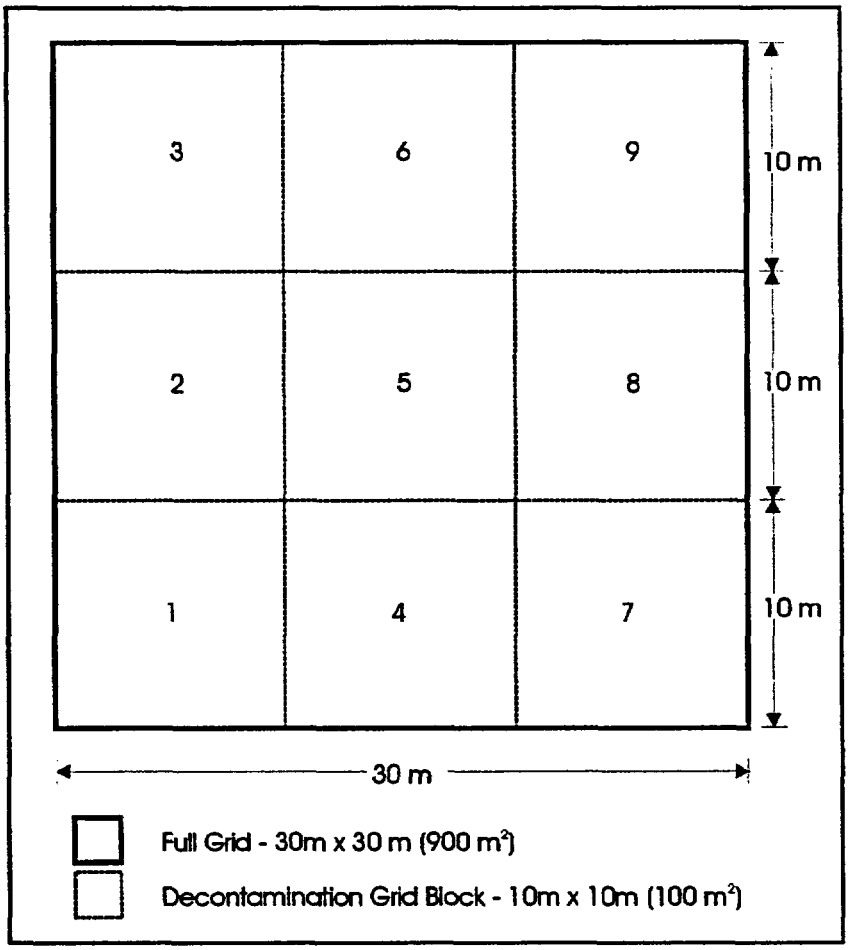
3.4.2 Reference Grid

A grid was established over the affected area upon completion of material excavation for the purpose of referencing locations of samples and measurements (see Figure 3-2). These full grids were 30m x 30m (900 m^2) in size. Each full grid was then divided into nine 10m x 10m sub-grids (100 m^2 each). Each sub-grid was marked into 2.5m increments to establish the nine individual soil sample locations taken to obtain one composite sample per sub-grid. Figure 3-3 depicts the breakdown of the reference grid system. As previously noted, the entire Section I (affected area) constituted the survey unit.

C01

Figure 3-3

Reference Grid System



3.4.3 Surface Scans

One hundred percent of the soil surface was initially scanned to identify locations of elevated activity. The gamma scans were conducted in accordance with procedure SOP 1.5, Measurement of Gamma-Ray Fields using a Sodium Iodide (NaI) Detector. As soil was removed, additional gamma scans were conducted to identify remaining locations of contaminated soil. After completion of contaminated soil removal, a final scan was performed of the soil surface prior to obtaining final verification soil samples.

3.4.4 Soil sampling

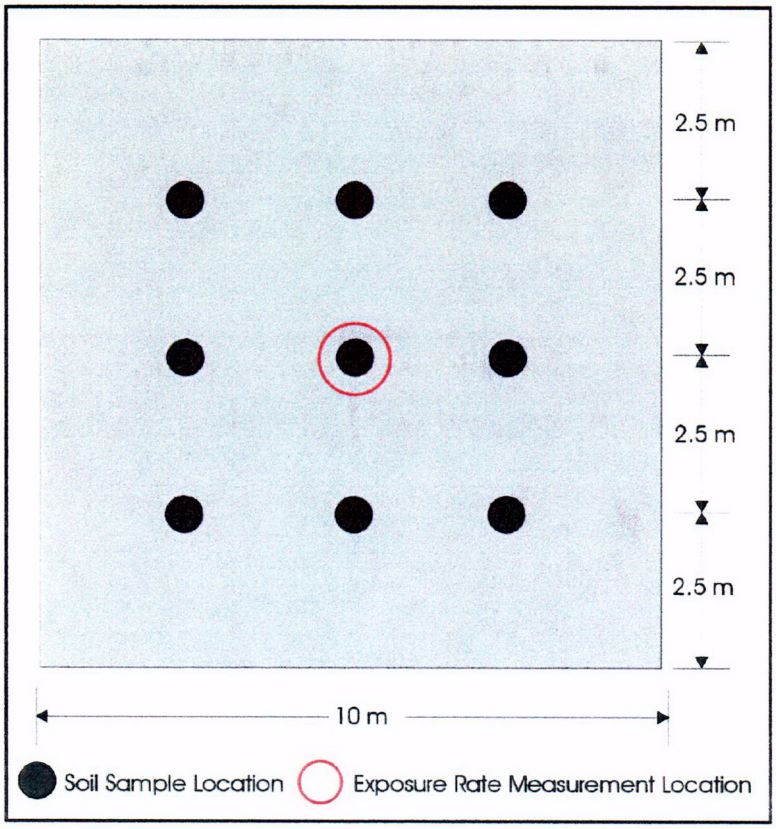
Final survey soil samples consisted of one composite sample obtained from nine individual samples (approximately 1 kg each) from each sub-grid (see Figure 3-4). The samples were collected after gamma levels were measured to preliminarily determine that all contaminated soil had been removed. Each of the nine locations where the individual samples were collected was scanned prior to soil sampling to validate that elevated levels did not exist (>3 times background). These final verification soil samples were analyzed on site through gamma spectroscopy. When the gamma spectral analysis results showed the Th-232 levels to be less than the guideline value, the final verification samples were then sent to the Freeport, Texas laboratory for gamma and alpha spectral analysis and confirmation that residual contamination limits have been met. Ten percent of the samples were split for QA analysis by three outside certified laboratories (Paragon Analytics, American Radiation Services and SRC Analytical). Soil sample collection was performed in accordance with procedure SOP 1.8, Guide to the Handling, Packaging and Shipping of Samples, and SOP 1.9, Sample Control and Documentation.

3.4.5 Exposure Rate Measurements

Gamma exposure rates were measured in the affected area at 1 meter above the soil surface at the midpoint of each sub-grid (see Figure 3-4). Exposure rate measurements were obtained using a Ludlum Model 19 MicroR meter.

Figure 3-4

Sampling Pattern for Composite Preparation Within Decontaminated Grid Block



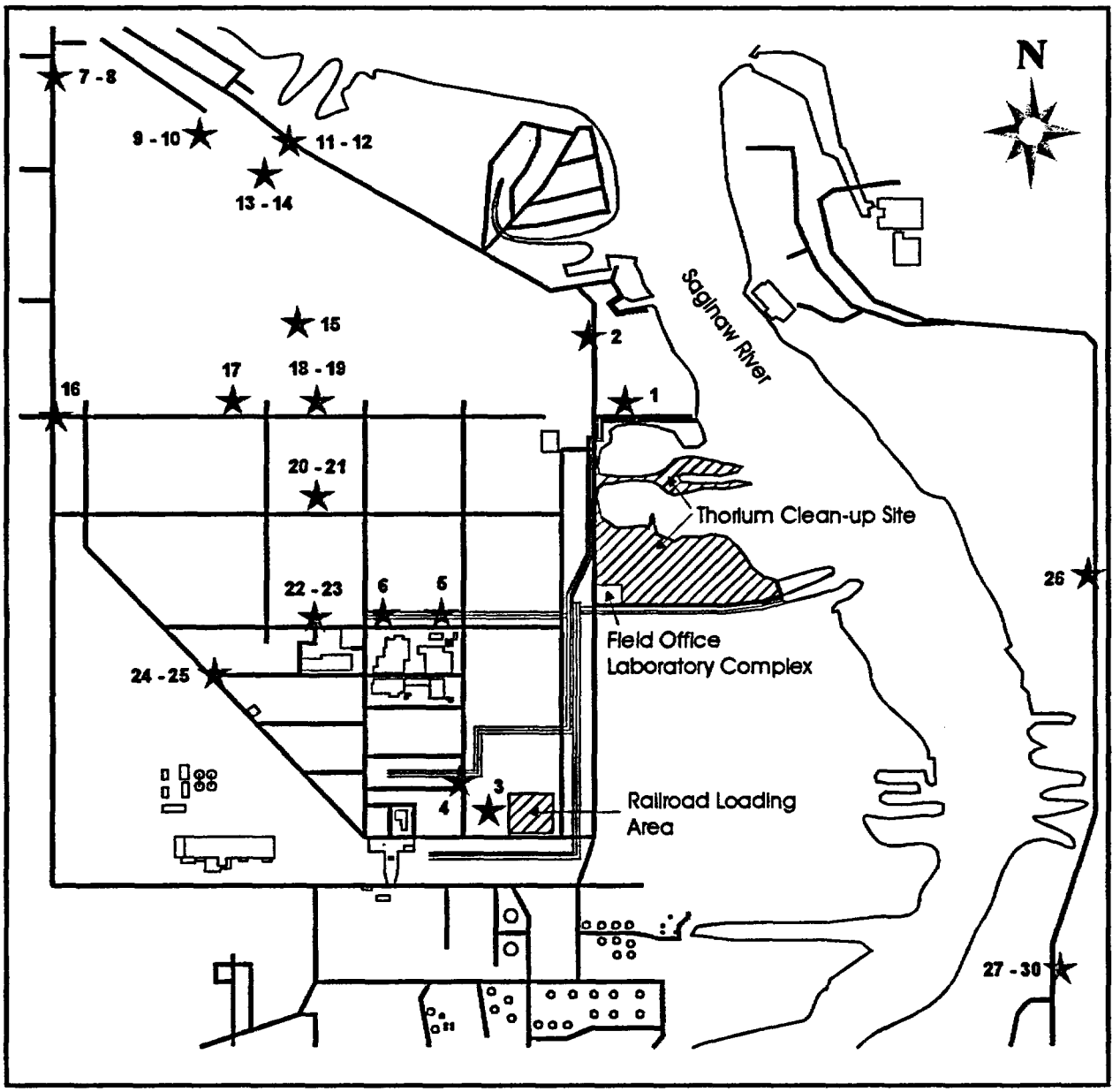
3.5 BACKGROUND LEVEL DETERMINATION

Background soil samples were collected from 30 locations in the unaffected area (Figure 3-5), and 29 samples analyzed for Th-230, Th-232, and Th-228 concentrations in the Freeport Laboratory (sample no. 14 was lost in transit). Sample numbers 1-25 were collected from locations on Dow property that were not impacted by site operations. Sample numbers 26-30 were collected from locations east of the Dow property, across the Saginaw River. Background exposure rates were measured at the same locations as the soil samples. Statistical procedures described in NUREG/CR-5849 (see Table A6) were used to assure that the average thorium concentrations determined were representative of true average background levels.

C02

Figure 3-5

Background Sample Locations



3.6 SAMPLE ANALYSIS

Final survey soil samples were analyzed for Th-232 in the field laboratory using the NaI detector coupled to the MCA. Soil samples were analyzed in accordance with "Procedure for Counting

Soil Samples for EOP Characterization". The final verification samples were analyzed for Th-232, Th-230, and Th-228 using gamma and alpha spectroscopy in the Freeport Laboratory.

3.7 DATA INTERPRETATION

Soil sample locations and survey results for fixed measurements were recorded on data sheets. The data conversion and statistical analysis techniques in NUREG/CR-5849 (Chapter 8.0) were used to convert the reported data into a form that permitted a direct comparison with residual contamination guidelines and thus assess if remediation goals were met. The statistical relationships are shown with the analyzed data in Appendix A (Tables A6, A7). Soil concentrations were converted into units of pCi/g and exposure rates to μR/h. The reported affected area data in Appendix A has been adjusted by subtracting the natural background levels.

Additional soil removal was performed when the remediation control survey measurements showed that residual contamination guidelines were not being met. As a result, there were no remaining "hot spots" and "hot spot" averaging criteria were not applied.

3.8 RECORDS

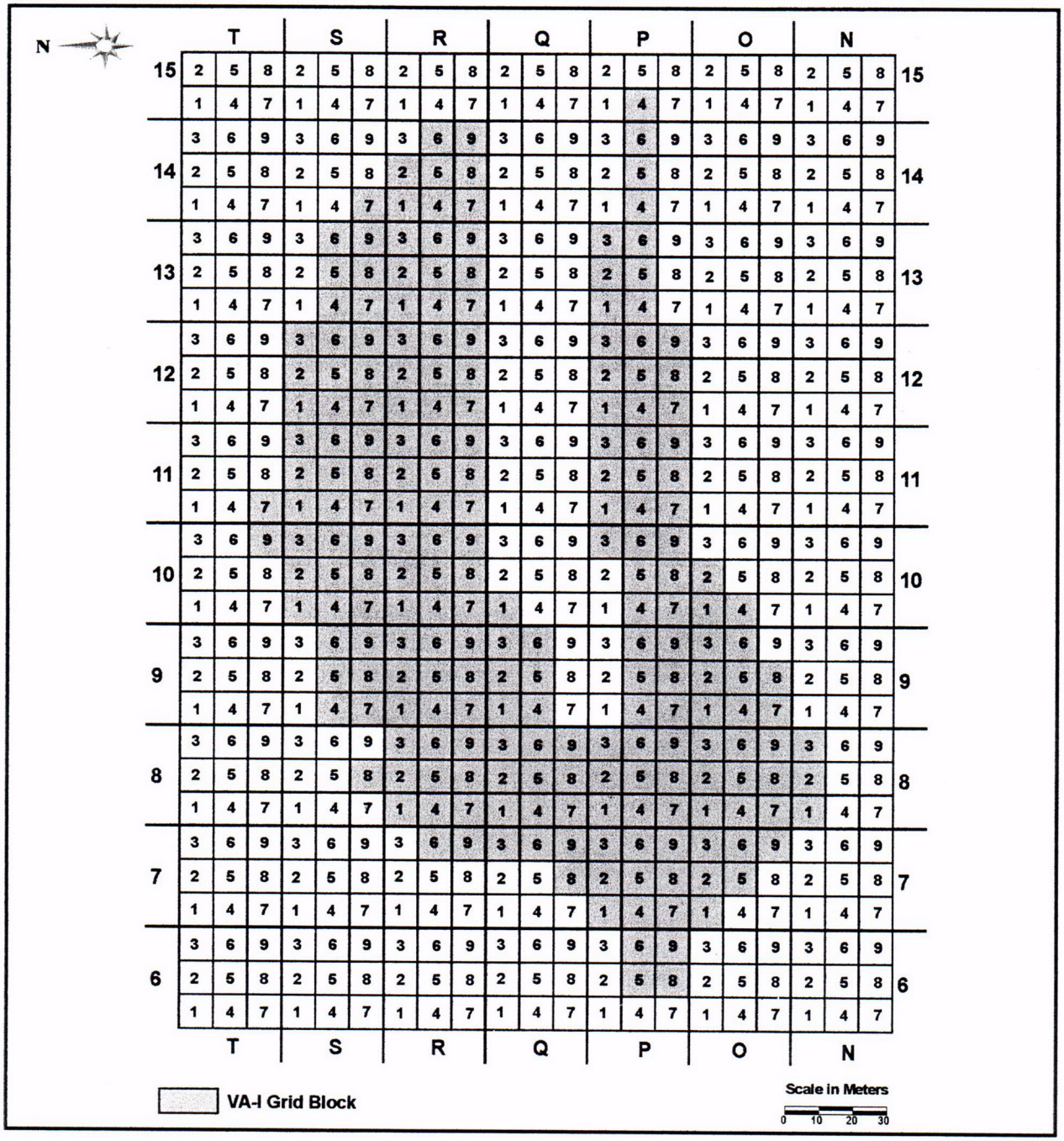
All soil samples, original survey data records, and log-books have been archived at the Dow Bay City facility and will be held until after license termination.

4.0 SURVEY FINDINGS AND RESULTS

Appendix A contains the radiological database collected during the final status survey for VA-I (as defined in Figure 4-1) that provides the basis for verifying that the residual contamination objectives have been achieved for this area at the Bay City thorium site. Summary Tables, data interpretations and statistical comparisons with residual contamination guidelines in VA-I are included in Appendix A.

Figure 4-1

Grid locations for VA-I



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4.1 BACKGROUND LEVELS

Background soil concentrations (Table A1) averaged 0.30 pCi/g for Th-232, 0.49 pCi/g for Th-230, and 0.31 pCi/g for Th-228. Background exterior exposure rates averaged 5 μR/h (Table A2). Both the number of data points collected to obtain the average background soil concentrations and exposure rates are more than sufficient to meet the test for demonstrating that the measured average background is within ± 20% of the true average at the 95% confidence level.

4.2 GROUND SURVEYS

4.2.1 Scans

Surface scans were used during the remediation control survey to identify locations of elevated gamma radiation to guide the excavation of the material and locate remaining hot spots. A total of 16 discreet areas of elevated activity were identified during the scan survey. Additionally, bricks that were strewn throughout VA-I were found to have a high background radiation. The bricks, which were used in the original construction of roads and walkways leading to the lighthouse, were removed prior to the verification survey. After remediation, all areas of elevated activity were re-scanned with satisfactory results.

4.2.2 Thorium Concentrations in Soil

The results of the analyses of the verification soil samples from VA-I are provided in table A3, and related to the grid locations shown in Figure 4-1. QA soil analyses, performed by the outside laboratories on splits of 10 percent of the background and verification samples, are shown in Table A3 together with the analyses of the same soil performed at Dow's Freeport Laboratory. None of the verification or QA samples contained total thorium concentrations in excess of the soil residual activity guideline (see Section 2.3). Analysis of the mean concentration of Th-232 shows that the concentration meets the guideline value at the 95% confidence level (Tables A6, A7). The number of samples collected (237 in VA-I) is much greater than the number (<9)

statistically required to demonstrate that the concentrations satisfies the guideline value at the 95% confidence level Table A7).

The maximum total residual thorium concentrations (above background) as measured in sample BCS-P7-9v1 was 7.69 pCi/g which is less than the residual guideline of 14.5 pCi/g.

Since none of the verification soil sample concentrations in VA-I exceeded the guideline value (no hot spots) it was not necessary to apply averaging techniques in any of the grids.

All of the verification soil samples in VA-I (Table A3) meet the criteria that the sum of the ratios of the concentration of each radionuclide to its respective guideline must not exceed 1 (Appendix A of NUREG/CR-5849).

4.2.3 Exposure Rates

Exposure rate measurements of the remediated VA-I areas (Figure 4-1) and for each grid block are provided in Table A5. All individual values are within the guideline levels of 5 μR/h above background. Analysis of the statistical mean also shows that the exposure rates in VA-I meet the guideline at the 95% confidence level (Tables A6, A7). The number of measurements (183) is in excess of the number required (<9) to demonstrate that the exposure rate satisfies the guideline value at the 95% confidence level Tables A6, A7).

4.2.4 NRC Confirmatory Surveys

The NRC performed an inspection of VA-I on July 24th and 25th of 1997. This inspection included the performance of a confirmatory survey. Approximately 20% of VA-I was scanned using a sodium iodide detector. There were no areas identified which exceeded the "three times background" criteria. Dow personnel collected nine soil samples, per NRC staff direction, at the areas of highest gamma scan readings. All soil samples were analyzed for Th-232 at the Bay City field laboratory, under inspector observation, following QA/QC and calibration checks of the counting systems. All sample results had Th-232 concentrations less than the site guideline

value. Exposure rate measurements obtained at the soil sample locations were found to be within acceptable ranges.

Since the confirmatory survey did not identify any areas of elevated activity, no further remediation was performed and no additional final status surveys were required.

5.0 SUMMARY

Decontamination of the affected area by soil removal at Dow's Bay City facility is an ongoing process. Since the affected area is quite large it is more efficient for Dow to verify that residual contamination criteria have been met in sections, and for the NRC to subsequently validate each section. Thus area VA-I has been verified and the evaluated database from the final status survey provided in the Appendix. Remediation control surveys were performed to guide the decontamination effort, and a final status survey conducted of VA-I during June, 1997. Independent QA analysis of soil samples was performed. Results of the final status survey demonstrate that the decontamination program successfully reduced residual activity in VA-I to within the NRC limits for unrestricted use. As each subsequent VA is surveyed, a FSSR will be submitted to NRC.

6.0 REFERENCES

6.1 Dow Decommissioning Work Plan, October 1993

6.2 Supplement to the Decommissioning Work Plan, December 1995

6.3 Letter from Dow to NRC, Response to Comments, March 1996

6.4 NUREG/CR-5849, Manual for Conducting Radiological Surveys in Support of License Termination (Draft for Comment), December 1993

6.5 NRC Inspection Report No. 040-00017/97002 (DNMS), August 14, 1997

6.6 Letter from NRC to Dow, Review of Final Status Survey Reports for the Previously Remediated Areas VA-I through VA-VI, Dow Chemical Company's Bay City, MI, SDMP Site (TAC# L60463), August 16, 2002

6.7 Dow "Background Radiological Survey", October 11-13, 1989

6.8 Dow Bay City Site Procedures

- 6.8.1 SOP 1.1, Access Control Procedures
- 6.8.2 SOP 1.2, Total Alpha Surface Contamination Measurements
- 6.8.3 SOP 1.3, External Dosimetry Procedure
- 6.8.4 SOP 1.4, Beta-Gamma Radiation Measurements using a Geiger-Muller Detector
- 6.8.5 SOP 1.5, Measurement of Gamma-Ray Fields using a Sodium Iodide (NaI) Detector
- 6.8.6 SOP 1.6, Intermediate Volume Air Particulate Sampling
- 6.8.7 SOP 1.7, Sampling for Removable Alpha Contamination
- 6.8.8 SOP 1.8, Guide to the Handling, Packaging and Shipping of Samples
- 6.8.9 SOP 1.9, Sample Control and Documentation
- 6.8.10 SOP 1.10, Radiation Work Permits
- 6.8.11 SOP 1.11, Respiratory Protection Program
- 6.8.12 "Procedure for Counting Soil Samples for EOP Characterization"
- 6.8.13 Dow Central Research Index Report, CRI-TSP-92-076, "Radiological Analysis of Soil Samples from the Madison, Illinois Storage Facility Utilizing a Revised Alpha Spectroscopic Method"

Appendix A

Final Status Survey

Verification Measurements / Analyses

Table A1

BACKGROUND SOIL CONCENTRATIONS							
Bay City							
Sample Name	^{232}Th (pCi/G)	Error (2σ)	MDA (pCi/G)	^{230}Th (pCi/G)	Error (2σ)	^{228}Th (pCi/G)	Error (2σ)
BCBKG01	0.39	0.08	0.13	1.04	0.84	0.48	0.44
BCBKG02	0.36	0.07	0.14	0.46	0.34	0.41	0.31
BCBKG03	0.28	0.08	0.11	0.38	0.31	0.35	0.29
BCBKG04	0.44	0.10	0.13	0.80	0.91	0.62	0.74
BCBKG05	0.43	0.10	0.15	0.70	0.51	0.52	0.40
BCBKG06	0.51	0.18	0.13	0.68	0.47	0.48	0.35
BCBKG07	0.38	0.19	0.13	2.30	3.69	0.77	1.38
BCBKG08	0.16	0.08	0.11	0.37	0.48	0.12	0.20
BCBKG09	0.13	0.07	0.10	0.21	0.25	0.09	0.12
BCBKG10	0.26	0.09	0.13	0.38	0.39	0.23	0.26
BCBKG11	0.19	0.07	0.11	0.04	0.04	0.14	0.10
BCBKG12	0.18	0.08	0.14	0.18	0.14	0.11	0.09
BCBKG13	0.18	0.08	0.14	0.21	0.12	0.19	0.11
BCBKG15	0.23	0.07	0.11	0.12	0.15	0.32	0.31
BCBKG16	0.56	0.12	0.16	0.76	0.51	0.66	0.46
BCBKG17	0.41	0.10	0.16	0.30	0.47	0.30	0.47
BCBKG18	0.10	0.08	0.12	0.18	0.21	0.16	0.19
BCBKG19	0.12	0.06	0.10	0.15	0.14	0.06	0.07
BCBKG20	0.14	0.07	0.11	0.29	0.25	0.09	0.09
BCBKG21	0.19	0.07	0.15	0.23	0.17	0.13	0.11
BCBKG22	0.20	0.07	0.10	0.36	0.39	0.13	0.18
BCBKG23	0.15	0.06	0.11	0.24	0.24	0.30	0.29
BCBKG24	0.12	0.08	0.11	0.13	0.16	0.05	0.08
BCBKG25	0.22	0.07	0.08	0.93	0.89	0.72	0.70
BCBKG26	0.32	0.09	0.13	0.27	0.23	0.16	0.15
BCBKG27	0.56	0.20	0.20	0.93	0.69	0.90	0.67
BCBKG28	0.68	0.24	0.20	0.41	0.45	0.07	0.14
BCBKG29	0.43	0.19	0.21	0.65	1.22	0.43	0.89
BCBKG30	0.34	0.08	0.15	0.44	0.45	0.10	0.16
AVERAGE	0.30			0.49		0.31	
St. Dev.	0.16			0.44		0.24	

Table A2

Background Exposure Rates – Bay City

Sample	Value (μR/hr)
BCBKG1	5
BCBKG2	7
BCBKG3	5
BCBKG4	6
BCBKG5	4
BCBKG6	4
BCBKG7	5
BCBKG8	5
BCBKG9	5
BCBKG10	6
BCBKG11	5
BCBKG12	6
BCBKG13	5
BCBKG14	5
BCBKG15	7
BCBKG16	5
BCBKG17	4
BCBKG18	5
BCBKG19	5
BCBKG20	4
BCBKG21	4
BCBKG22	4
BCBKG23	4
BCBKG24	3
BCBKG25	3
ACROSS THE RIVER	
BCBKG26(1)	3
BCBKG27(2)	5
BCBKG28(3)	5
BCBKG29(4)	4
BCBKG30(5)	5

Number of measurements: 30
Average: 5 μR/hr
Standard Deviation: 1.3 μR/hr (≅ 1.0 μR/hr)

Table A3

Final Verification Soil Concentrations – VA-I

Sample	^{232}Th	Error	MDA	^{230}Th	Error	^{228}Th	Error	^{232}Th (Net)	^{230}Th (Net)	^{228}Th (Net)	TOTAL
Name	(pCi/G)	(2σ)	(pCi/G)	(pCi/g)	(2σ)	(pCi/g)	(2σ)	(pCi/G)	(pCi/g)	(pCi/g)	Thorium
BCS-S10-8v1	0.55	0.22	0.22	3.44	3.59	0.78	0.96	0.25	2.95	0.47	3.67
BCS-S10-9v1-R	0.78	0.19	0.30	2.77	1.15	0.51	0.27	0.48	2.28	0.20	2.96
BCS-S11-4v1	0.37	0.16	0.13	1.59	0.84	0.21	0.13	0.07	1.10	-0.10	1.08
BCS-S11-5v1	0.15	0.08	0.13	0.32	0.19	0.13	0.08	-0.15	-0.17	-0.18	-0.50
BCS-S11-6v1	0.36	0.13	0.18	1.62	0.75	0.15	0.09	0.06	1.13	-0.16	1.03
BCS-S11-7v1	0.38	0.13	0.16	0.62	0.44	0.26	0.22	0.08	0.13	-0.05	0.16
BCS-S11-8v1	0.29	0.13	0.28	0.09	0.12	0.00	0.00	-0.01	-0.40	-0.31	-0.73
BCS-S11-8v1-R	0.52	0.26	0.35	0.64	0.44	0.51	0.35	0.22	0.15	0.20	0.57
BCS-S11-9v1	0.47	0.25	0.34	0.82	0.58	0.44	0.33	0.17	0.33	0.13	0.62
BCS-S12-1v1	0.17	0.12	0.16	0.72	0.57	0.23	0.19	-0.13	0.23	-0.08	0.01
BCS-S12-2v1-R	0.15	0.10	0.09	0.77	0.60	0.19	0.15	-0.15	0.28	-0.12	0.02
BCS-S12-3v1	0.11	0.10	0.03	0.03	0.03	0.10	0.09	-0.18	-0.46	-0.21	-0.86
BCS-S12-3v1-R	0.35	0.15	0.26	2.06	2.17	0.57	0.69	0.05	1.57	0.26	1.88
BCS-S12-4v1	1.75	0.28	0.30	3.67	1.17	1.43	0.54	1.45	3.18	1.12	5.75
BCS-S12-5v1	0.29	0.10	0.11	1.13	0.47	0.28	0.12	-0.01	0.64	-0.03	0.59
BCS-S12-6v1	0.25	0.12	0.25	2.01	1.43	0.37	0.30	-0.05	1.52	0.06	1.52
BCS-S12-6v1-R	0.23	0.10	0.12	1.40	0.77	0.16	0.10	-0.07	0.91	-0.15	0.69
BCS-S12-7v1	0.44	0.21	0.38	0.87	0.70	0.38	0.34	0.14	0.38	0.07	0.59
BCS-S12-8v1	0.34	0.17	0.26	1.87	1.39	0.27	0.25	0.04	1.38	-0.04	1.39
BCS-S12-9v1	0.45	0.19	0.23	2.48	1.51	0.82	0.53	0.15	1.99	0.51	2.65
BCS-S13-1v1	0.35	0.11	0.14	1.08	0.43	0.37	0.16	0.05	0.59	0.06	0.69
[redacted]S-S13-2v1	0.14	0.11	0.17	0.46	0.40	0.15	0.13	-0.16	-0.03	-0.16	-0.35
BCS-S13-3v1	0.81	0.29	0.27	1.80	0.87	0.59	0.33	0.51	1.31	0.28	2.10
BCS-S13-4v1	1.15	0.27	0.28	3.04	0.99	1.26	0.45	0.85	2.55	0.95	4.35
BCS-S13-4v1-R	0.87	0.27	0.29	1.75	0.69	0.90	0.37	0.57	1.26	0.59	2.41
BCS-S13-5v1	0.52	0.16	0.26	1.61	0.93	0.73	0.47	0.22	1.12	0.42	1.77
BCS-S13-6v1-R	1.42	0.31	0.34	2.55	0.83	1.22	0.43	1.12	2.06	0.91	4.09
BCS-S13-6v1	0.60	0.17	0.20	1.53	0.84	0.88	0.52	0.30	1.04	0.57	1.91
BCS-S13-7v1	0.42	0.22	0.34	0.42	0.68	0.85	1.54	0.12	-0.07	0.54	0.60
BCS-S13-8v1	0.19	0.13	0.13	0.39	0.32	0.20	0.18	-0.11	-0.10	-0.11	-0.32
BCS-S13-9v1	0.53	0.18	0.27	2.27	1.41	0.26	0.23	0.23	1.78	-0.05	1.96
BCS-S14-7v1	0.22	0.09	0.16	1.03	0.52	0.19	0.11	-0.08	0.54	-0.12	0.34
BCS-S8-8v1	0.24	0.14	0.13	2.14	1.44	0.21	0.15	-0.06	1.65	-0.10	1.48
BCS-S9-6v1	0.38	0.15	0.25	1.32	0.77	0.55	0.35	0.08	0.83	0.24	1.16
BCS-S9-7v1	0.24	0.09	0.10	1.66	0.84	0.21	0.13	-0.06	1.17	-0.10	1.01
BCS-S9-8v1	0.34	0.21	0.29	1.30	1.05	0.55	0.47	0.04	0.81	0.24	1.09
BCS-S9-9v1	0.61	0.19	0.26	1.73	0.74	0.42	0.21	0.31	1.24	0.11	1.67
AVERAGE	0.36			1.08		0.34		0.06	0.59	0.03	0.67
St. Dev.	0.22			1.10		0.24		0.22	1.10	0.24	1.40
Maximum	1.75			6.84		1.43		1.45	6.35	1.12	7.69
Note: Net concentrations are gross values less background (Table A1)											

Table A3

Final Verification Soil Concentrations – VA-I

Sample	^{232}Th	Error	MDA	^{230}Th	Error	^{228}Th	Error	^{232}Th (Net)	^{230}Th (Net)	^{228}Th (Net)	TOTAL
Name	(pCi/G)	(2σ)	(pCi/G)	(pCi/g)	(2σ)	(pCi/g)	(2σ)	(pCi/G)	(pCi/g)	(pCi/g)	Thorium
BCS-O7-1v1	0.50	0.18	0.24	0.53	0.30	0.59	0.33	0.20	0.04	0.28	0.52
BCS-O7-2v1	1.23	0.28	0.32	5.82	1.83	0.88	0.34	0.93	5.33	0.57	6.83
BCS-O7-3v1	0.38	0.19	0.16	3.38	2.14	0.29	0.22	0.08	2.89	-0.02	2.95
BCS-O7-4v1	0.34	0.14	0.14	0.21	0.15	0.32	0.22	0.04	-0.28	0.01	-0.23
BCS-O7-5v1	0.61	0.19	0.15	5.20	2.62	0.56	0.35	0.31	4.71	0.25	5.27
BCS-O7-6v1	0.54	0.16	0.15	0.65	0.59	0.49	0.47	0.24	0.16	0.18	0.57
BCS-O7-7v1	0.53	0.16	0.15	0.32	0.25	0.63	0.43	0.23	-0.17	0.32	0.37
BCS-O7-8v1	0.50	0.22	0.20	0.96	0.83	0.46	0.45	0.20	0.47	0.15	0.81
BCS-O7-9v1	0.61	0.29	0.30	1.19	0.84	0.45	0.36	0.31	0.70	0.14	1.15
BCS-O8-1v1	0.36	0.16	0.15	1.95	1.02	0.36	0.21	0.06	1.46	0.05	1.58
BCS-O8-2V1	0.56	0.22	0.29	0.85	0.69	0.49	0.40	0.26	0.46	0.18	0.89
BCS-O8-3v1	0.29	0.15	0.19	0.23	0.14	0.03	0.03	-0.01	-0.26	-0.28	-0.55
BCS-O8-4v1	0.16	0.13	0.16	1.06	0.99	0.19	0.19	-0.14	0.57	-0.12	0.31
BCS-O8-5v1	0.27	0.09	0.14	0.37	0.19	0.23	0.13	-0.03	-0.12	-0.08	-0.22
BCS-O8-6v1	0.26	0.09	0.14	0.23	0.25	0.33	0.33	-0.04	-0.26	0.02	-0.28
BCS-O8-6v1-R	0.22	0.08	0.12	1.12	0.69	0.26	0.18	-0.08	0.63	-0.05	0.51
BCS-O8-7v1	0.16	0.09	0.07	0.75	0.50	0.17	0.13	-0.14	0.26	-0.14	-0.02
BCS-O8-7v1-R	0.20	0.13	0.16	0.28	0.25	0.41	0.36	-0.10	-0.21	0.10	-0.21
BCS-O8-8v1	0.18	0.12	0.18	0.24	0.23	0.18	0.18	-0.13	-0.25	-0.13	-0.50
BCS-O8-9v1	0.17	0.12	0.19	0.28	0.23	0.15	0.13	-0.13	-0.21	-0.16	-0.49
BCS-O9-1V1	0.29	0.13	0.17	0.60	0.37	0.25	0.17	-0.01	0.11	-0.06	0.04
[redacted]S-O9-1V1-R	0.32	0.15	0.18	0.76	0.46	0.47	0.29	0.02	0.27	0.16	0.45
BCS-O9-2v1	0.16	0.14	0.16	0.21	0.22	0.18	0.19	-0.14	-0.28	-0.13	-0.54
BCS-O9-3v1	0.20	0.12	0.17	0.10	0.18	0.15	0.25	-0.10	-0.39	-0.16	-0.65
BCS-O9-4v1	0.37	0.23	0.25	0.73	0.61	0.35	0.32	0.07	0.24	0.04	0.35
BCS-O9-5v1	0.16	0.13	0.15	0.95	0.90	0.16	0.16	-0.14	0.46	-0.15	0.17
BCS-O9-6v1	0.23	0.15	0.18	0.65	0.71	0.23	0.29	-0.07	0.16	-0.08	0.00
BCS-O9-7v1	0.31	0.13	0.17	0.44	0.47	0.52	0.54	0.01	-0.05	0.21	0.16
BCS-O9-7v1-R	0.39	0.26	0.37	0.33	0.26	0.18	0.15	0.09	-0.16	-0.13	-0.20
BCS-O9-8v1	0.47	0.18	0.18	0.93	0.68	0.32	0.28	0.17	0.44	0.01	0.62
BCS-P10-3v1	0.28	0.18	0.24	0.33	0.42	0.14	0.22	-0.02	-0.16	-0.17	-0.35
BCS-P10-4v1	0.49	0.21	0.36	0.45	0.40	0.28	0.27	0.19	-0.04	-0.03	0.12
BCS-P10-5v1	0.26	0.17	0.15	0.71	0.57	0.26	0.22	-0.04	0.22	-0.05	0.14
BCS-P10-6v1	0.11	0.11	0.17	0.05	0.06	0.04	0.05	-0.19	-0.44	-0.27	-0.90
BCS-P10-7v1	0.33	0.11	0.11	0.48	0.20	0.10	0.05	0.03	-0.01	-0.21	-0.19
BCS-P10-8v1	0.17	0.10	0.14	0.50	0.43	0.10	0.11	-0.13	0.01	-0.21	-0.33
BCS-P10-9v1	0.27	0.12	0.20	1.34	0.79	0.23	0.16	-0.03	0.85	-0.08	0.74
BCS-P11-1v1	0.36	0.18	0.27	0.53	1.01	0.36	0.73	0.06	0.04	0.05	0.15
BCS-P11-2v1	0.70	0.21	0.33	2.81	2.94	0.56	0.77	0.40	2.32	0.25	2.98
BCS-P11-3v1	0.33	0.12	0.14	1.44	0.64	0.35	0.17	0.03	0.95	0.04	1.02
BCS-P11-4V1	0.32	0.15	0.17	0.24	0.14	0.03	0.03	0.02	-0.25	-0.28	-0.51
BCS-P11-5v1	0.17	0.11	0.16	2.03	1.69	0.22	0.20	-0.13	1.54	-0.09	1.32
BCS-P11-6v1	0.19	0.10	0.13	0.19	0.32	0.19	0.32	-0.11	-0.30	-0.12	-0.54
BCS-P11-7v1	0.48	0.13	0.15	5.84	2.12	0.50	0.21	0.18	5.35	0.19	5.73
BCS-P11-8v1	0.19	0.08	0.09	1.17	0.71	0.15	0.11	-0.11	0.68	-0.16	0.40
BCS-P11-9v1	0.21	0.09	0.13	1.64	0.86	0.13	0.08	-0.09	1.15	-0.18	0.88
BCS-P12-1v1	0.18	0.10	0.14	0.74	0.78	0.15	0.20	-0.12	0.25	-0.16	-0.04
[redacted]S-P12-2v1	0.28	0.20	0.32	1.48	1.51	0.28	0.34	-0.02	0.99	-0.03	0.94
BCS-P12-3v1	0.45	0.15	0.17	0.40	0.26	0.10	0.10	0.15	-0.09	-0.21	-0.15
BCS-P12-4v1	0.36	0.26	0.34	0.97	0.87	0.34	0.33	0.06	0.48	0.03	0.58

Table A3

Final Verification Soil Concentrations – VA-I

Sample Name	^{232}Th (pCi/G)	Error (2σ)	MDA (pCi/G)	^{230}Th (pCi/g)	Error (2σ)	^{228}Th (pCi/g)	Error (2σ)	^{232}Th (Net) (pCi/G)	^{230}Th (Net) (pCi/g)	^{228}Th (Net) (pCi/g)	TOTAL Thorium
BCS-P12-5v1	0.13	0.12	0.16	0.58	0.55	0.14	0.14	-0.17	0.09	-0.17	-0.24
BCS-P12-6v1	0.60	0.21	0.19	5.47	2.14	0.63	0.26	0.30	4.98	0.32	5.60
BCS-P12-7v1	0.23	0.21	0.32	1.06	1.14	0.23	0.26	-0.08	0.57	-0.09	0.41
BCS-P12-8v1	0.26	0.17	0.24	0.71	0.64	0.41	0.39	-0.04	0.22	0.10	0.28
BCS-P12-9v1	0.32	0.15	0.29	1.87	1.09	0.35	0.23	0.02	1.38	0.04	1.43
BCS-P13-1v1	0.23	0.10	0.13	1.01	1.09	0.18	0.26	-0.07	0.52	-0.13	0.32
BCS-P13-2v1	0.28	0.13	0.21	0.27	0.17	0.09	0.07	-0.02	-0.22	-0.22	-0.46
BCS-P13-3v1	0.16	0.15	0.16	0.20	0.23	0.16	0.18	-0.14	-0.29	-0.15	-0.59
BCS-P13-4v1	0.25	0.19	0.29	1.59	1.52	0.29	0.30	-0.05	1.10	-0.02	1.03
BCS-P13-5v1	0.39	0.11	0.15	1.89	1.07	0.38	0.25	0.09	1.50	0.07	1.66
BCS-P13-6v1	0.23	0.15	0.19	0.34	0.29	0.22	0.20	-0.07	-0.15	-0.09	-0.31
BCS-P14-1v1	0.42	0.27	0.38	0.87	0.71	0.35	0.31	0.12	0.38	0.04	0.53
BCS-P14-2v1	0.18	0.11	0.15	0.57	0.52	0.26	0.25	-0.12	0.08	-0.05	-0.09
BCS-P14-3v1	0.11	0.10	0.15	0.99	1.24	0.17	0.23	-0.20	0.50	-0.15	0.16
BCS-P14-4v1	0.31	0.14	0.18	1.45	1.06	0.33	0.29	0.01	0.96	0.02	1.00
BCS-P14-5v1	0.19	0.14	0.19	0.63	0.49	0.19	0.15	-0.11	0.14	-0.12	-0.09
BCS-P14-6v1	0.33	0.12	0.14	1.38	0.82	0.34	0.24	0.03	0.69	0.03	0.95
BCS-P15-1v1	0.52	0.25	0.32	2.85	1.53	0.50	0.29	0.22	2.36	0.19	2.77
BCS-P15-4v1	0.20	0.13	0.18	0.52	0.44	0.12	0.12	-0.10	0.03	-0.19	-0.26
BCS-P6-1v1	0.34	0.13	0.18	0.72	0.49	0.58	0.40	0.04	0.23	0.27	0.54
BCS-P6-2v1	0.23	0.13	0.17	0.35	0.25	0.20	0.15	-0.07	-0.14	-0.11	-0.32
[redacted]S-P6-3v1	0.33	0.28		0.39	0.39	0.31	0.32	0.03	-0.10	0.00	-0.07
BCS-P6-5v1	0.31	0.15	0.17	0.58	0.39	0.36	0.26	0.01	0.09	0.05	0.16
BCS-P6-6v1	0.58	0.16	0.13	0.38	0.31	0.67	0.47	0.28	-0.11	0.36	0.54
BCS-P6-8v1	0.29	0.16	0.23	0.30	0.26	0.23	0.20	-0.01	-0.19	-0.08	-0.28
BCS-P6-9v1	0.38	0.18	0.26	0.27	0.17	0.27	0.17	0.08	-0.22	-0.04	-0.18
BCS-P7-1v1	0.25	0.14	0.19	0.38	0.32	0.19	0.18	-0.05	-0.11	-0.12	-0.28
BCS-P7-2V1	0.33	0.20	0.28	1.12	0.93	0.39	0.35	0.03	0.63	0.08	0.73
BCS-P7-3v1	0.34	0.14	0.19	0.58	0.38	0.28	0.20	0.04	0.09	-0.03	0.09
BCS-P7-4v1	0.47	0.18	0.22	0.53	0.33	0.41	0.27	0.17	0.04	0.10	0.32
BCS-P7-5v1	0.71	0.19	0.27	0.58	0.34	0.83	0.45	0.41	0.09	0.52	1.02
BCS-P7-6v1	0.48	0.21	0.22	0.44	0.39	0.61	0.51	0.18	-0.05	0.30	0.43
BCS-P7-7v1	0.33	0.14	0.17	0.57	0.39	0.49	0.34	0.03	0.08	0.18	0.29
BCS-P7-8v1	0.34	0.15	0.24	1.18	0.80	0.47	0.35	0.04	0.70	0.16	0.90
BCS-P7-9v1	1.11	0.22	0.22	6.84	2.13	0.84	0.33	0.81	6.35	0.53	7.69
BCS-P8-1v1	0.56	0.34	0.41	0.49	0.41	0.43	0.36	0.26	0.00	0.12	0.38
BCS-P8-2v1	0.64	0.16	0.20	0.28	0.14	0.64	0.26	0.34	-0.21	0.33	0.46
BCS-P8-4v1	0.35	0.11	0.13	1.93	0.79	0.31	0.15	0.05	1.44	0.00	1.49
BCS-P8-4v1-R	0.38	0.20	0.36	1.55	1.25	0.67	0.58	0.08	1.06	0.36	1.50
BCS-P8-5v1	0.19	0.10	0.13	0.36	0.25	0.21	0.15	-0.11	-0.13	-0.10	-0.34
BCS-P8-6v1	0.31	0.10	0.23	0.00	0.00	0.00	0.00	0.01	-0.49	-0.31	-0.79
BCS-P8-7v1	0.12	0.10	0.06	0.00	0.00	0.00	0.00	-0.18	-0.49	-0.31	-0.98
BCS-P8-8v1	0.22	0.14	0.28	0.22	0.65	0.00	0.00	-0.08	-0.27	-0.31	-0.66
BCS-P8-9v1	0.10	0.10	0.12	0.20	0.39	0.10	0.22	-0.20	-0.29	-0.21	-0.70
BCS-P9-4v1	0.15	0.15		0.00	0.00	0.29	0.78	-0.15	-0.49	-0.02	-0.66
BCS-P9-4v1-R	0.33	0.17	0.24	0.33	0.28	0.31	0.27	0.03	-0.16	0.00	-0.13
BCS-P9-5v1	0.49	0.26	0.15	1.06	0.67	0.18	0.14	0.19	0.57	-0.13	0.63
[redacted]S-P9-6v1	0.20	0.14	0.28	0.27	0.28	0.32	0.32	-0.10	-0.22	0.01	-0.31
BCS-P9-7v1-R	0.06	0.05	0.08	0.12	0.31	0.06	0.17	-0.24	-0.37	-0.25	-0.86
BCS-P9-7v1-R	0.18	0.26		0.42	0.83	0.18	0.39	-0.12	-0.07	-0.13	-0.32

Table A3

Final Verification Soil Concentrations – VA-I

Sample	^{232}Th	Error	MDA	^{230}Th	Error	^{228}Th	Error	^{232}Th (Net)	^{230}Th (Net)	^{228}Th (Net)	TOTAL
Name	(pCi/G)	(2σ)	(pCi/G)	(pCi/g)	(2σ)	(pCi/g)	(2σ)	(pCi/G)	(pCi/g)	(pCi/g)	Thorium
BCS-P9-8v1	0.21	0.10	0.12	1.27	0.90	0.48	0.36	-0.09	0.78	0.17	0.86
BCS-P9-9v1	0.22	0.08	0.13	0.22	0.45	0.22	0.45	-0.08	-0.27	-0.09	-0.44
BCS-Q6-8v1	0.38	0.19	0.20	0.51	0.41	0.46	0.38	0.08	0.02	0.15	0.25
BCS-Q7-3V1	0.32	0.16	0.18	0.53	0.38	0.34	0.25	0.02	0.04	0.03	0.09
BCS-Q7-3v1-R	0.28	0.35	0.17	0.53	0.73	0.25	0.36	-0.02	0.04	-0.06	-0.04
BCS-Q7-6v1	0.67	0.17	0.16	0.61	0.27	0.54	0.25	0.37	0.12	0.23	0.72
BCS-Q7-6v1-R	0.98	0.20	0.19	0.54	0.21	0.74	0.27	0.66	0.05	0.43	1.15
BCS-Q7-8v1	0.31	0.17	0.19	0.81	0.70	0.60	0.53	0.01	0.32	0.29	0.61
BCS-Q7-9v1	0.44	0.18	0.20	0.87	0.49	0.46	0.28	0.14	0.38	0.15	0.67
BCS-Q8-1v1	0.11	0.10	0.15	0.32	0.31	0.10	0.10	-0.19	-0.17	-0.21	-0.58
BCS-Q8-1v1-R	0.72	0.40	0.37	0.41	0.33	0.14	0.14	0.42	-0.08	-0.17	0.17
BCS-Q8-2v1	0.23	0.22	0.33	0.39	0.41	0.23	0.25	-0.07	-0.10	-0.08	-0.25
BCS-Q8-3v1	0.52	0.20	0.22	0.75	0.51	0.40	0.30	0.22	0.26	0.09	0.56
BCS-Q8-4v1	0.16	0.08	0.10	0.04	0.09	0.08	0.14	-0.14	-0.45	-0.23	-0.82
BCS-Q8-5v1	0.53	0.40		0.80	0.78	0.50	0.52	0.23	0.31	0.19	0.73
BCS-Q8-6v1	0.16	0.11	0.20	0.00	0.00	0.05	0.13	-0.14	-0.49	-0.26	-0.88
BCS-Q8-7v1	0.14	0.11	0.16	0.32	0.34	0.04	0.05	-0.16	-0.17	-0.27	-0.60
BCS-Q8-8v1	0.22	0.12	0.16	0.30	0.30	0.22	0.23	-0.08	-0.19	-0.09	-0.37
BCS-Q8-8v1-R	0.62	0.22	0.20	0.67	0.37	0.14	0.11	0.32	0.18	-0.17	0.32
BCS-Q8-9v1	0.59	0.22	0.14	0.31	0.16	0.53	0.25	0.29	-0.18	0.22	0.33
BCS-R10-1v1	0.28	0.15	0.20	1.03	0.79	0.20	0.18	-0.02	0.54	-0.11	0.41
BCS-R10-2v1	0.54	0.15	0.12	0.50	0.26	0.07	0.06	0.24	0.01	-0.24	0.01
BCS-R10-3v1	0.44	0.16	0.19	2.83	1.65	0.64	0.42	0.14	2.34	0.33	2.80
BCS-R10-4v1	0.51	0.18	0.31	3.03	1.60	0.78	0.46	0.21	2.54	0.48	3.23
BCS-R10-5v1	0.48	0.16	0.32	3.00	1.51	0.50	0.30	0.18	2.51	0.19	2.88
BCS-R10-6v1	0.34	0.12	0.13	2.75	2.76	1.37	1.45	0.04	2.26	1.06	3.36
BCS-R10-7v1	0.45	0.26	0.22	1.49	1.00	0.27	0.21	0.15	1.00	-0.04	1.11
BCS-R11-1v1	0.58	0.21	0.21	0.55	0.39	0.39	0.30	0.28	0.06	0.08	0.42
BCS-R11-2v1	0.21	0.12	0.17	0.48	0.48	0.00	0.00	-0.09	-0.03	-0.31	-0.44
BCS-R11-3v1	0.28	0.10	0.14	0.35	0.49	0.35	0.49	-0.02	-0.14	0.04	-0.11
BCS-R11-4v1	0.36	0.11	0.16	1.05	0.59	0.24	0.17	0.06	0.56	-0.07	0.56
BCS-R11-4v1-R	0.35	0.19	0.33	1.20	0.84	0.41	0.31	0.05	0.71	0.10	0.86
BCS-R11-4v1-R	0.60	0.25	0.37	0.60	0.38	0.44	0.30	0.30	0.11	0.13	0.53
BCS-R11-5v1	0.44	0.21	0.28	1.39	0.88	0.41	0.29	0.14	0.90	0.10	1.13
BCS-R11-6v1	0.42	0.24	0.37	0.63	0.48	0.41	0.32	0.12	0.14	0.10	0.36
BCS-R11-8v1	0.17	0.22	0.34	0.22	0.33	0.14	0.22	-0.13	-0.27	-0.17	-0.57
BCS-R11-9v1	0.37	0.25	0.35	0.85	0.92	0.41	0.43	0.07	0.46	0.10	0.63
BCS-R12-1v1	0.27	0.19	0.31	0.36	0.30	0.31	0.26	-0.03	-0.13	0.00	-0.16
BCS-R12-2v1	0.24	0.11	0.15	0.70	0.63	0.40	0.39	-0.06	0.21	0.09	0.25
BCS-R12-3v1	0.27	0.11	0.18	0.36	0.26	0.24	0.19	-0.03	-0.13	-0.07	-0.24
BCS-R12-4v1	0.39	0.21	0.30	0.95	0.60	0.35	0.24	0.09	0.46	0.04	0.59
BCS-R12-5v1	0.24	0.11	0.11	0.30	0.21	0.22	0.16	-0.06	-0.19	-0.09	-0.34
BCS-R12-6v1	0.35	0.20	0.38	0.59	0.43	0.28	0.22	0.05	0.10	-0.03	0.12
BCS-R12-6v1-R	0.54	0.51		0.89	0.99	0.75	0.85	0.24	0.40	0.44	1.08
BCS-R12-7v1	0.37	0.13	0.18	2.57	1.85	0.34	0.31	0.07	2.06	0.03	2.18
BCS-R12-8v1	0.16	0.10	0.14	0.81	0.63	0.15	0.13	-0.14	0.32	-0.16	0.01
BCS-R12-9v1	0.11	0.08	0.11	0.36	0.32	0.12	0.12	-0.19	-0.13	-0.19	-0.51
BCS-R12-9v1-R	0.22	0.19	0.24	0.49	0.56	0.22	0.27	-0.08	0.00	-0.09	-0.17
BCS-R13-1v1	0.28	0.24	0.34	0.72	0.78	0.42	0.48	-0.02	0.23	0.11	0.32
BCS-R13-2v1	0.13	0.11	0.16	0.22	0.22	0.12	0.13	-0.17	-0.27	-0.19	-0.63

Table A3

Final Verification Soil Concentrations – VA-I

Sample	^{232}Th	Error	MDA	^{230}Th	Error	^{228}Th	Error	^{232}Th (Net)	^{230}Th (Net)	^{228}Th (Net)	TOTAL
Name	(pCi/G)	(2σ)	(pCi/G)	(pCi/g)	(2σ)	(pCi/g)	(2σ)	(pCi/G)	(pCi/g)	(pCi/g)	Thorium
BCS-R13-3v1	0.27	0.22	0.33	0.26	0.28	0.26	0.28	-0.03	-0.23	-0.05	-0.31
BCS-R13-4v1	0.60	0.18	0.32	0.51	0.59	0.26	0.36	0.30	0.02	-0.05	0.27
BCS-R13-5v1	0.40	0.18	0.30	0.80	0.52	0.37	0.26	0.10	0.31	0.06	0.47
BCS-R13-6v1	0.62	0.20	0.27	2.67	1.21	0.55	0.27	0.32	2.38	0.24	2.95
BCS-R13-7v1	0.34	0.15	0.18	1.44	0.93	0.23	0.19	0.04	0.95	-0.08	0.91
BCS-R13-8v1	0.12	0.13	0.20	0.53	0.72	0.24	0.34	-0.18	0.04	-0.07	-0.21
BCS-R13-9v1	0.16	0.12	0.19	0.26	0.25	0.15	0.15	-0.14	-0.23	-0.16	-0.54
BCS-R13-9v1-R	0.23	0.15	0.21	1.09	1.03	0.14	0.17	-0.07	0.60	-0.17	0.35
BCS-R14-1v1	0.07	0.08	0.12	0.40	0.53	0.09	0.12	-0.23	-0.09	-0.22	-0.54
BCS-R14-1v1-R	0.19	0.09	0.10	0.79	0.47	0.18	0.12	-0.11	0.30	-0.13	0.06
BCS-R14-2v1	0.16	0.09	0.12	0.64	0.54	0.20	0.14	-0.14	0.35	-0.11	0.10
BCS-R14-3v1	0.36	0.20	0.12	1.72	1.12	0.25	0.19	0.06	1.23	-0.06	1.23
BCS-R14-4v1	0.55	0.20	0.25	1.24	0.87	0.48	0.39	0.25	0.75	0.17	1.18
BCS-R14-5v1	0.16	0.08	0.10	0.70	0.40	0.13	0.08	-0.14	0.21	-0.18	-0.11
BCS-R14-6v1	0.17	0.11	0.15	0.79	0.55	0.15	0.12	-0.13	0.30	-0.16	0.01
BCS-R14-7v1	0.43	0.18	0.33	2.34	1.20	0.31	0.18	0.13	1.85	0.00	1.98
BCS-R14-7v1-R	0.36	0.17	0.23	2.26	1.55	0.51	0.39	0.06	1.77	0.20	2.03
BCS-R14-8v1	0.38	0.23	0.32	1.31	0.93	0.29	0.22	0.08	0.82	-0.02	0.87
BCS-R14-8v1-R	0.42	0.17	0.25	1.04	0.69	0.42	0.31	0.12	0.55	0.11	0.77
BCS-R14-8v1-R	0.36	0.30		1.11	1.02	0.35	0.34	0.06	0.62	0.04	0.72
[redacted]S-R15-4v1	0.42	0.14	0.22	1.69	0.84	0.30	0.18	0.12	1.20	-0.01	1.31
[redacted]S-R6-4v1	0.31	0.14	0.11	0.33	0.23	0.41	0.28	0.01	-0.16	0.10	-0.05
BCS-R7-6v1	0.45	0.22	0.26	0.69	0.48	0.27	0.21	0.15	0.20	-0.04	0.31
BCS-R7-9v1	0.55	0.17	0.20	0.96	0.63	0.43	0.33	0.25	0.47	0.12	0.84
BCS-R7-9v1-R	0.75	0.21	0.25	1.70	0.93	0.46	0.32	0.45	1.21	0.15	1.80
BCS-R8-1v1	0.31	0.16	0.26	1.41	0.93	0.32	0.24	0.01	0.92	0.01	0.94
BCS-R8-2v1	0.34	0.15	0.18	2.07	1.19	0.30	0.20	0.04	1.58	-0.01	1.61
BCS-R8-3v1	0.42	0.16	0.26	5.99	6.60	0.74	0.96	0.12	5.50	0.43	6.04
BCS-R8-4v1	0.36	0.14	0.17	0.38	0.30	0.29	0.24	0.06	-0.11	-0.02	-0.07
BCS-R8-5v1	0.18	0.13	0.19	0.42	0.35	0.11	0.10	-0.12	-0.07	-0.20	-0.39
BCS-R8-6v1	0.27	0.10	0.12	0.71	0.51	0.14	0.14	-0.03	0.22	-0.17	0.02
BCS-R8-7v1	0.17	0.10	0.18	0.19	0.13	0.14	0.10	-0.13	-0.30	-0.17	-0.60
BCS-R8-8v1	0.31	0.14	0.31	0.68	0.35	0.46	0.24	0.01	0.19	0.15	0.35
BCS-R8-9v1	0.09	0.08	0.14	0.21	0.19	0.09	0.08	-0.21	-0.28	-0.22	-0.71
BCS-R8-9v1-R	0.10	0.10	0.16	0.23	0.25	0.09	0.11	-0.20	-0.26	-0.22	-0.67
BCS-R9-1v1	0.29	0.15	0.19	2.66	1.64	0.23	0.16	-0.01	2.17	-0.08	2.08
BCS-R9-2v1	0.06	0.10	0.16	0.15	0.26	0.09	0.16	-0.24	-0.34	-0.22	-0.79
BCS-R9-3v1	0.13	0.11	0.16	0.13	0.14	0.05	0.06	-0.17	-0.36	-0.26	-0.78
BCS-R9-4v1	0.07	0.12	0.19	0.39	0.65	0.07	0.11	-0.23	-0.10	-0.24	-0.57
BCS-R9-5v1	0.40	0.21	0.28	0.98	0.67	0.45	0.33	0.10	0.49	0.14	0.73
BCS-R9-6v1	0.16	0.12	0.18	0.52	0.71	0.24	0.36	-0.14	0.03	-0.07	-0.19
BCS-R9-7v1	0.15	0.11	0.17	0.16	0.17	0.05	0.06	-0.15	-0.33	-0.26	-0.74
BCS-R9-8v1	0.41	0.21	0.34	0.88	0.72	0.70	0.59	0.11	0.39	0.39	0.89
BCS-R9-9v1	0.16	0.10	0.15	0.35	0.32	0.02	0.04	-0.14	-0.14	-0.29	-0.56
BCS-R9-9v1-R	0.32	0.24	0.15	0.43	0.38	0.31	0.28	0.02	-0.06	0.00	-0.05
BCS-S10-4v1	0.43	0.33	0.25	1.31	1.14	0.52	0.47	0.13	0.82	0.21	1.16
[redacted]S-S10-5v1	0.26	0.23	0.26	1.88	2.15	0.50	0.61	-0.04	1.39	0.19	1.55
[redacted]S-S10-6v1	0.28	0.15	0.16	2.12	1.35	0.34	0.24	-0.02	1.63	0.03	1.63
BCS-S10-6v1-R	0.70	0.26	0.25	3.96	2.09	1.26	0.72	0.40	3.47	0.95	4.83
BCS-S10-7v1	0.33	0.20	0.26	1.08	0.73	0.23	0.17	0.03	0.59	-0.08	0.54

Table A5

Final Gamma Exposure Rates – VA-I

Grid No.	Gross Exposure (μR/hr)	Net Exposure (μR/hr)	Grid No.	Gross Exposure (μR/hr)	Net Exposure (μR/hr)
N7-1	5	0	Q8-3	5	0
N7-2	5	0	Q8-4	5	0
N8-2	5	0	Q8-5	5	0
N9-1	6	1	Q8-6	5	0
N9-4	4	-1	Q8-7	5	0
07-1	5	0	Q8-8	7	2
07-2	5	0	Q8-9	4	-1
07-3	5	0	R8-2	3	-2
07-4	5	0	R8-3	5	0
07-5	5	0	R8-4	5	0
07-6	4	-1	R8-5	5	0
07-7	5	0	R8-6	6	1
07-8	5	0	R8-7	5	0
07-9	4	-1	R8-8	5	0
08-1	4	-1	R8-9	4	-1
08-2	5	0	R9-2	5	0
08-3	5	0	R9-3	6	1
08-4	5	0	R9-4	6	1
08-5	6	1	R9-5	6	1
08-6	6	1	R9-6	6	1
08-7	4	-1	R10-1	6	1
08-8	5	0	R10-2	6	1
08-9	5	0	R10-3	6	1
09-1	6	1	R10-4	6	1

Table A5

Final Gamma Exposure Rates – VA-I

Grid No.	Gross Exposure (μR/hr)	Net Exposure (μR/hr)	Grid No.	Gross Exposure (μR/hr)	Net Exposure (μR/hr)
09-2	6	1	R10-5	6	1
09-3	6	1	R10-6	6	1
09-4	5	0	R10-7	7	2
09-5	6	1	R11-1	7	2
09-6	5	0	R11-2	7	2
09-7	6	1	R11-3	7	2
09-8	4	-1	R11-4	6	1
010-1	4	-1	R11-5	6	1
P8-1	4	-1	R11-6	4	-1
P7-2	5	0	R12-1	6	1
P7-3	4	-1	R12-2	6	1
P7-4	5	0	R12-3	6	1
P7-5	4	-1	R12-4	5	0
P7-6	5	0	R12-5	5	0
P7-7	5	0	R12-6	5	0
P7-8	6	1	R13-1	6	1
P7-9	5	0	R13-2	5	0
P8-1	5	0	R13-3	5	0
P8-2	5	0	R13-4	5	0
P8-4	5	0	R13-5	6	1
P8-5	6	1	R13-6	6	1
P8-6	5	0	R13-8	4	-1
P8-7	4	-1	R13-9	5	0
P8-8	6	1	R14-1	5	0

Table A5

Final Gamma Exposure Rates – VA-I

Grid No.	Gross Exposure (μR/hr)	Net Exposure (μR/hr)	Grid No.	Gross Exposure (μR/hr)	Net Exposure (μR/hr)
P8-9	4	-1	R14-2	4	-1
P9-4	5	0	R14-4	5	0
P9-5	4	-1	R14-5	5	0
P9-6	6	1	R14-6	4	-1
P9-7	5	0	R14-7	5	0
P9-8	6	1	R14-8	6	1
P9-9	6	1	R14-9	4	-1
P10-3	6	1	S8-9	3	-2
P10-4	7	2	S9-5	5	0
P10-5	5	0	S9-6	5	0
P10-6	7	2	S9-7	5	0
P11-4	4	-1	S9-8	5	0
P11-5	4	-1	S10-1	5	0
P11-6	4	-1	S10-2	5	0
P11-7	5	0	S10-3	6	1
P11-8	5	0	S10-4	6	1
P11-9	4	-1	S10-5	5	0
P12-1	6	1	S10-6	6	1
P12-2	5	0	S10-7	6	1
P12-3	5	0	S10-8	6	1
P12-4	5	0	S10-9	6	1
P12-5	5	0	S11-1	6	1
P12-6	5	0	S11-2	5	0
P12-7	4	-1	S11-3	4	-1

Table A5

Final Gamma Exposure Rates – VA-I

Grid No.	Gross Exposure (μR/hr)	Net Exposure (μR/hr)	Grid No.	Gross Exposure (μR/hr)	Net Exposure (μR/hr)
P13-1	6	1	S11-4	6	1
P13-2	4	-1	S11-5	7	2
P13-3	4	-1	S11-6	5	0
P13-4	5	0	S11-7	8	3
P13-5	4	-1	S11-8	7	2
P13-6	5	0	S11-9	7	2
P14-1	4	-1	S12-4	5	0
P14-2	4	-1	S12-7	6	1
P14-4	5	0	S12-8	6	1
P14-5	5	0	S12-9	6	1
P14-6	5	0	S13-7	6	1
P15-4	4	-1	S13-8	5	0
Q7-3	5	0	S13-9	4	-1
Q7-6	6	1	S14-7	5	0
Q7-9	6	1	T10-9	5	0
Q8-1	7	2	T11-7	5	0
Q8-2	5	0			

no. measurements - 183
average 0.2 μR/hr (=0 μR/hr)
Standard Deviation 0.9 μR/hr (=0 μR/hr)

Notes

1. Net value is gross value less background of 5 μR/hr.

2. Where rising waters have covered a subgrid where final verification soil samples were collected, gamma measurements were not taken.

Table A6

Final Status Survey: Statistical Analysis

The following statistical relations were used to assess the database for the Bay City survey unit:

Survey Data Average ($\bar{x}$):

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

Standard Deviation (S_x):

$$S_x = \sqrt{\frac{\sum_{i=1}^{n}(\bar{x} - x_i)^2}{n-1}}$$

Determination of Number of Background data points (n_B):

$$n_B = \left[\frac{t_{95.5\%,df} S_x}{0.2 \bullet \bar{x}_B}\right]^2$$

Comparison of statistical mean ($\mu\alpha$) with guideline values:

$$\mu_\alpha = \bar{x} + t_{1-\alpha,df}\frac{S_x}{\sqrt{n}}$$

Identifying additional measurement/sampling needs:

$$\text{Estimating Factor} = \frac{C_G - \bar{x}}{S_x}$$

(Tables B-2 in NUREG/CR-5849)

Note: See chapter 8.0 of NUREG/CR-5849 for detailed discussion of above-listed statistical analyses.

Where:

X_i = measurement (analysis) at point i
n = number of measurements (analyses)
t_i - α, df = 95% confidence level from Table B-1 of Appendix B of NUREG/CR-5849
C_G = Guideline Value

Table A7

Final Status Survey: Summary Statistics

Exposure Rates							
Section	n	X (μR/h)	Sx (μR/h)	μα (μR/h)	C_G (μR/h)	Estimating Factor	No. Verification Samples Needed
VA-I	183	0.2	0.9	0.31	5.0	5.3	<9
Th-232 Soil Concentrations							
Section	n	X (pCi/g)	Sx (pCi/g)	μα (pCi/g)	C_G (pCi/g)	Estimating Factor	No. Verification Samples Needed
VA-I	237	0.06	0.22	0.08	3.2	14.9	<9

Final Status Survey Report for VA-II
Magnesium-Thorium Slag Storage Area
The Dow Chemical Company's
Bay City, Michigan Facility

DOW U.S.A.

The Dow Chemical Company
Midland, Michigan 48674

Revision 1
March 2003

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TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

1.0 BACKGROUND INFORMATION

The radioactive material at the Dow Chemical Company's Bay City site consisted primarily of foundry slag containing Thorium. This material, and similar material originally stored at Dow's Midland site, was produced in the period from 1940 to 1970 as the residual from the production of a magnesium-thorium alloy. This lightweight alloy was used for defense purposes, including aircraft engines and aeronautical structural components.

A single license (STB-527) was originally granted by the NRC in 1973 for the Bay City and Midland sites to store up to 200,000 pounds of thorium slag. The license expired in 1978, but has remained in effect under timely renewal.

The Midland site was decontaminated with the material removed and transported to Bay City for consolidation with the Bay City material and subsequent transport to the Envirocare facility in Clive, Utah. A final survey was conducted at the Midland site by Dow with the results documented in a Final Status Survey Report of March, 1997, showing that the residual contamination criteria had been met. The NRC subsequently conducted an independent survey of the Midland site and verified that the residual contamination criteria had been met.

The material transported from the Midland site to the Bay City site originally consisted of magnesium with up to two percent thorium. Portions of this process slag were mixed with soil or limited amounts of construction debris. As a result of this mixing, the thorium concentrations, as determined by Dow characterization soil sampling, varied from 2-7000 pCi/g at the Bay City Site (with an average concentration of 188 pCi/g) . A total activity of 9.7 Ci of Th-232 was originally distributed throughout approximately 52,000 cubic yards of soil, slag, and construction debris.

Initial remedial action support surveys, performed in 1996, identified wide spread areas of elevated contamination. The gamma scan surveys were conducted using a sodium iodide detector. Readings were generally higher the closer the proximity to the original thorium pile but several hot spots in the 300,000 to 600,000 cpm range were identified. Construction debris, such as drums, were removed from these areas along with the contaminated soil.

Decontamination of the Bay City site is ongoing. In accordance with NRC and Dow discussions, as confirmed in Dow's letter of June 12, 1997, verification that residual contamination criteria have been achieved on this large site is being performed in sections. This Final Status Survey Report (FSR) provides the descriptive text on the site and the parameters of the survey program and includes the analyzed verification data for Verification Area (VA) II. As the database is acquired for subsequent VAs addendums to the Final Survey Report will be submitted to the NRC containing the analyzed database.

Supporting information on the Bay City site and decommissioning project is presented in the October, 1993 Decommissioning Work Plan, the December, 1995 Supplement to the Decommissioning Work Plan, and the March, 1996 Response to Comments.

This document is a revision to the original Final Status Survey Report for VA-I and VA-II dated July, 1997. For the purposes of this revised report, only changes to the original report pertinent to VA-II are addressed. Changes to the VA-I portion of the original report will be addressed in a separate revised report.

On July 24th and 25th of 1997, after the original report submittal, the NRC Region III conducted an inspection of the VA-I and VA-II portions of the Dow Bay City facility. The primary purpose of the inspection was to conduct an independent confirmatory survey of VA-I and VA-II. This revision to the original report is provided to include the findings of the NRC confirmatory surveys documented in NRC Report No. 040-00017/97002 (DNMS) dated August 14, 1997.

Additionally, this revision to the original report is provided to address deficiencies identified by NRC staff in a letter to Dow dated August 16, 2002 (Review of Final Status Survey Reports for the Previously Remediated Areas VA-I through VA-VI, Dow Chemical Company's Bay City, MI, SDMP Site (TAC# L60463)).

2.0 SITE INFORMATION

2.1 SITE DESCRIPTION

The Bay City thoriated material storage site is on a Dow facility near the Town of Bay City, Michigan about one-mile south of Saginaw Bay. The Bay City site (pile) is shown on Figure 2-1 in relation to adjacent land features and other facilities.

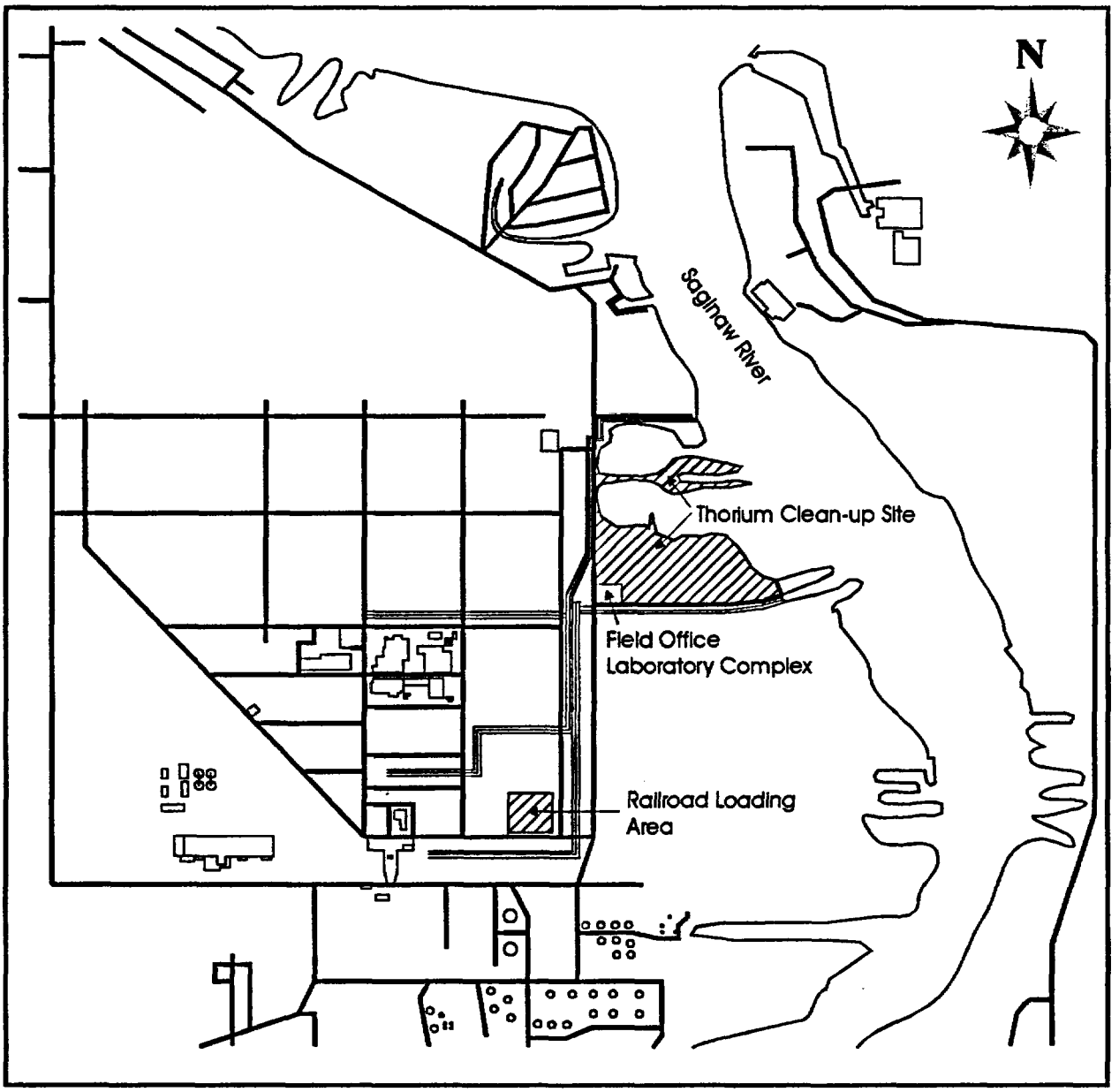
The thoriated material site is located adjacent to and north of an inlet canal, which enters the Saginaw River to the east. The Saginaw River is located to the north and east of the material. Access to the Dow manufacturing facility is restricted to authorized personnel. The storage site within the facility is posted as a radiation control area and delineated with a fence.

The area surrounding the material is relatively level, with some marshy areas and ponds. Any sediments containing elevated levels of thorium are being excavated as part of the decontamination program.

The affected area of the Bay City storage site was initially based on knowledge of the operating history, and subsequently on radiological characterization surveys. While areas immediately surrounding the Bay City storage area were included in the affected area, some further outward adjustment of the affected area boundary was required during site remediation to encompass surface and subsurface contamination uncovered during remedial operations.

Figure 2-1

Bay City Thorium Disposal Site



2.2 SITE CONDITIONS AT TIME OF FINAL SURVEY

The decommissioning activities at the Bay City site involve excavation of the contaminated soil, loading on to trucks, onsite transportation of the material to the stockpile at the railhead, loading on to the rail cars, and transport of the material to the Envirocare burial site in Clive, Utah. Soil removal is to varying depths continuing until sample analysis showed residual concentrations to be within NRC defined limits. Final verification samples were taken in the VA and analyzed on site through gamma spectroscopy. When the gamma spectral analysis results showed the Th-232 levels to be less than the guideline value, the final verification samples were then sent to the Freeport, Texas laboratory for gamma and alpha spectral analysis and confirmation that residual contamination limits have been met. Ten percent of all final verification samples were then sent to an outside contract laboratory for independent QC verification. Dow conducted QA/QC programs which were monitored by the Dow QA coordinator.

2.3 IDENTITY OF POTENTIAL CONTAMINANTS AND RELEASE GUIDELINES

Based on the knowledge of the process that generated the slag material, and the results of the characterization survey, the significant radiological contaminants were determined to be Th-232, Th-230, and Th-228. The above background residual soil concentration measurements used as a basis for the final verification for all the verification samples analyzed to date at Bay City provided the average soil activity ratios at Bay City of approximately:

Th-232	-	22%
Th-230	-	60%
Th-228	-	18%

Using the approach described in Section 3.1 ("Release Criteria") of the December, 1995 Supplement to the Decommissioning Work Plan and response No. 8 of the Response to Comments (on the Work Plan) of March, 1996, in conjunction with the methodology in Appendix A of NUREG/CR 5849 gives a residual soil gross activity guideline of 14.5 pCi/g total

thorium. The site-specific guideline levels for each of the contributory radionuclides is thus 3.2 pCi/g for Th-232, 2.6 pCi/g for Th-228, and 8.7 pCi/g for Th-230.

The gross activity guideline is determined as follows:

$$\textit{Gross Activity Guideline} = \frac{1}{\frac{0.22}{10} + \frac{0.18}{10} + \frac{0.60}{21}} = 14.5\ pCi/g$$

where Th-232, Th-230, and Th-228 are present in net activity ratios of 0.22, 0.60. and 0.18 respectively in the residual soil. The guideline concentrations for Th-232 plus Th-228 are 10 pCi/g and 21 pCi/g for Th-230 (see March, 1996 Response to Comments).

3.0 FINAL STATUS SURVEY OVERVIEW

3.1 SURVEY OBJECTIVES

The purpose of the final status survey was to demonstrate that the residual radiological concentrations in the soil at the Bay City thorium storage site satisfy the NRC guidelines (see 2.3 above) and that the storage site can, therefore, be released for future use without radiological controls. Specifically, the final status survey soil database should show that:

- Average residual radionuclide concentrations are at or below the soil guideline values defined in Section 2.3. Averaging is based on a 100 m^2 (10m x 10m) grid area. Note an actual grid size of 33.3 ft. x 33.3 ft. was used for convenience in measuring rather than 10m x 10m (32.8 ft. x 32.8 ft.).

- Reasonable efforts have been made to identify, evaluate, and remove, if necessary, areas of residual activity exceeding the guideline values. Areas of residual activity exceeding the guideline value (elevated areas) may be acceptable provided they do not exceed the guideline value by greater than a factor of $(100/A)^{1/2}$, where A is the area of residual

activity in m^2, and provided the activity level at any location does not exceed three times the guideline values.

In addition, exposure rates should not exceed 5 μR/h above background at 1 m above the soil surface. Exposure rates may be averaged over a 100 m^2 grid area. Maximum exposure rates over any discrete area may not exceed 10 μR/h above background.

A 95% minimum level of confidence that the above conditions have been met was to be demonstrated. The entire Section II of the Bay City storage area (affected area) is treated as a single survey unit, and the 95% level of confidence was to be applied to the entire survey unit.

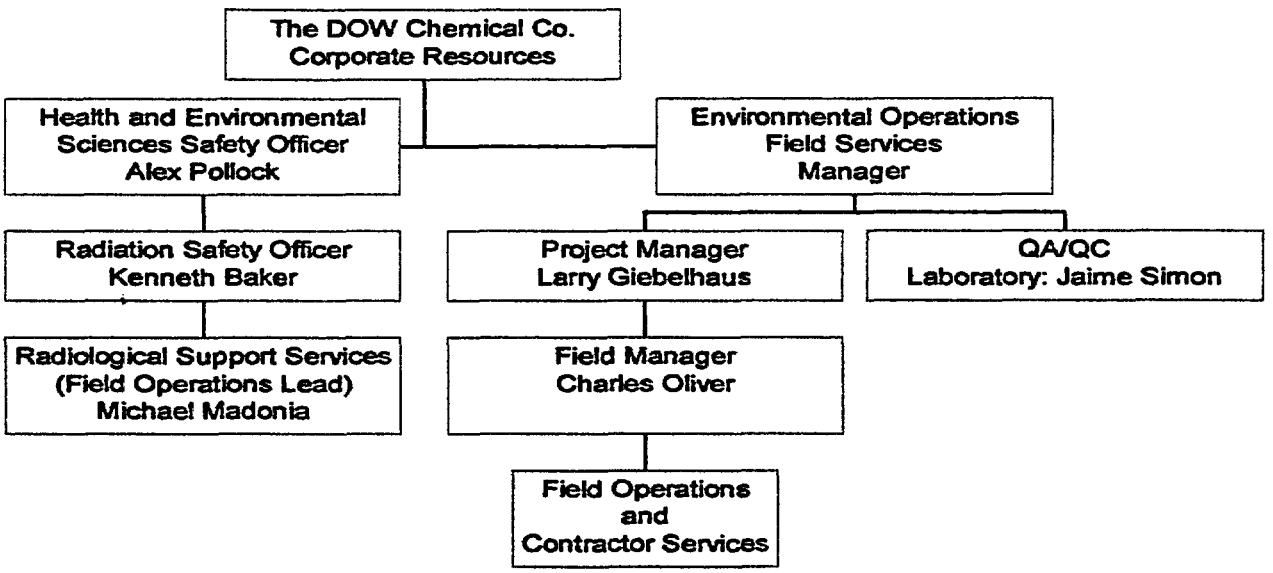
3.2 ORGANIZATION AND RESPONSIBILITIES

The final status survey was conducted by the same qualified Dow and subcontractor personnel who had conducted the characterization survey, and remediation control survey. The Project Organization is shown in Figure 3-1.

The sampling and analysis methods to be used during the remediation control survey was designed to achieve the sampling sensitivity and elevated activity guidelines defined in NUREG/CR-5849 relative to the site specific residual contamination criteria. The approach consisted of first performing a gamma scan survey of the remediated area to determine if any localized areas of elevated activity remained. Elevated areas of activity identified by the scan survey were remediated. If no areas of elevated activity were identified, composite soil samples were then collected and analyzed in the field laboratory using a NaI crystal coupled to the MCA to provide rapid turnaround on the Th-232 levels. If the Th-232 level exceeded the guideline value, further remediation was performed. The soil sample results of the analysis of the final samples collected, that demonstrated that the administrative cleanup level had been achieved, were then used as input into the final status survey.

Figure 3-1

Project Organization for Remediation of the Midland and Bay City Storage Sites



3.3 INSTRUMENTATION

Table 3-1 describes the laboratory instrumentation used for soil analyses along with the detection sensitivities for the instrumentation. The detection sensitivity for both the gamma and alpha spectrometer analyses are less than 25% of the residual concentration guideline values. The laboratory instrumentation calibration procedures and schedule are provided in Appendix D-2 of the March, 1996 Response to Comments.

Table 3-1

Laboratory Radiometric Analyses

Dow Chemical Freeport, Texas

Sample Type	Radionuclide Measured	Instrument	Analytical Procedures	Approx. Sensitivity
250 ml soil sample (polypropylene beaker w/ lid	Th-232 daughters in equilibrium with Th-232 (Ac-228, Bi-212, Pb-212, Ti-208)	Canberra Gamma Spectrometer system. The components include a 51.5 mm closed ended coaxial germanium detector, crystal, pre-amplifier, amplifier, power supply, multi-channel analyzer and computer.	Dow Central Research Index Report: CRI-TSP-92-076	0.2 pCi/g
0.6 sample from 250 ml soil sample	Th-232, Th-228, Th-230	Canberra Model 7404 four channel alpha spectrometer with built-in power supply, vacuum guage, detector bias supply, generator, pre-amplifier/amplifiers, multi-channel analyzer having a mixer-router input. The detectors are four passively implanted planar silicon (PIPS).	Dow Central Research Index Report: CRI-TSP-92-076	0.2 pCi/g

Table 3-2 lists the field radiological monitoring instrumentation used on the project inclusive of the specific use of each instrumentation and detection sensitivities. Each instrument was initially calibrated to NIST-traceable standards prior to use on the project, and then checked for radiation response and efficiency prior to daily use.

Table 3-2

Field Radiological Monitoring Instrumentation

Instrument	Measures	Detector Efficiency*	LLD/MDA
Ludlum Model 43-5 w/ Ludlum Model 12	Alpha Surface	15%	22 dpm
Ludlum Model 43-90 w/ Ludlum Model 2221	Alpha Surface	22%	12 dpm
Ludlum Model 44-9 w/ Ludlum Model 12	Alpha, Beta, Gamma	12% alpha 15% beta 1% gamma	
Ludlum Model 43-10 w/ Ludlum 1000	Alpha (air filters, smears)	43%	0.04 dpm
Ludlum Model 19	Exposure Rate		1 microR/h
Air Particulate			
Eberline RAS-1 Air Pump	Flow Rate = 40-100 lpm		
MSA Escort Lapel Sampler	Flow Rate = 2-3 lpm		
General Metal Works-2000 High Vol Sampler	Flow Rate = 30-60 cfm		
Test/Calibration Equipment			
Ludlum Model 500 Pulser	NIST Traceable		
AFC-85L Air Flow Calibrator	NIST Traceable		
GMW-Calibrator Orifice for High Vol Sampler	NIST Traceable		
MSA Optiflow 660 Air Flow Calibrator	NIST Traceable		
Field Laboratory Equipment			
Canberra Gamma Spectrometer	Soil Th-232 Concentration		0.8 pCi/g

* Detector efficiencies are approximate and appropriate for Th-230, Tc-99, and Co-60

3.4 SURVEY PROCEDURES

Survey planning and procedures are consistent with the methods described in the Decommissioning Plan. The soil survey procedures are summarized in this section and can be found in greater detail in Appendices D-2 and D-3 of the March, 1996 Response to Comments.

3.4.1 Area Classification

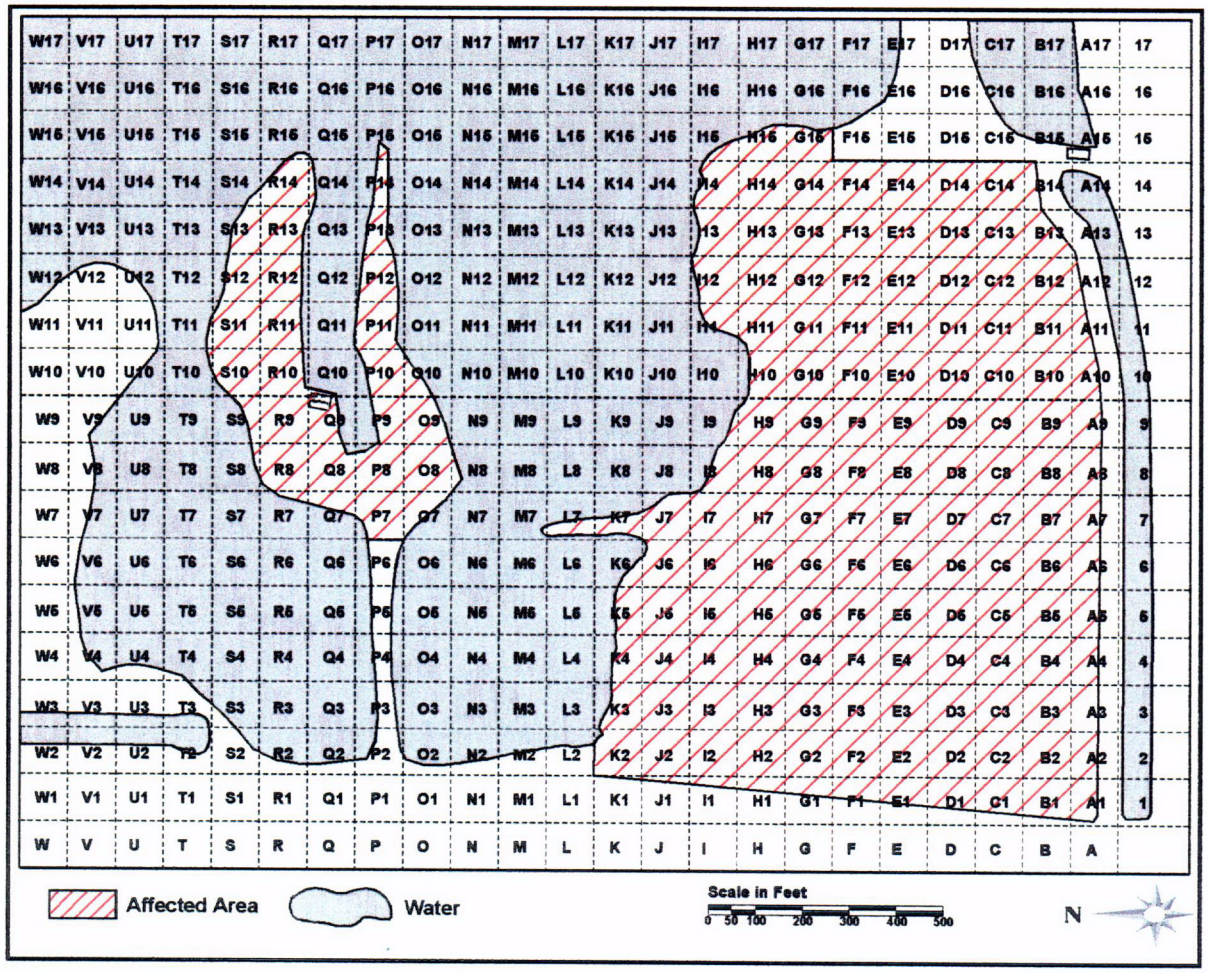
The Bay City storage site was divided into affected and unaffected areas to establish the sampling pattern and frequency. The basis for the affected and unaffected classification, as applied to the Bay City site are:

- **Affected Area** – As shown in Figure 3-2, the thorium material storage area and region immediately surrounding the storage area was defined as the affected area based on both historical records and prior characterization surveys. This location had known thorium contamination in the soil that had been placed there via backfill operations and storage.

- **Unaffected Area** – The region surrounding the affected area (see Figure 3-2) was treated as unaffected since it did not contain residual radioactivity.

Figure 3-2

Bay City Site Affected Areas



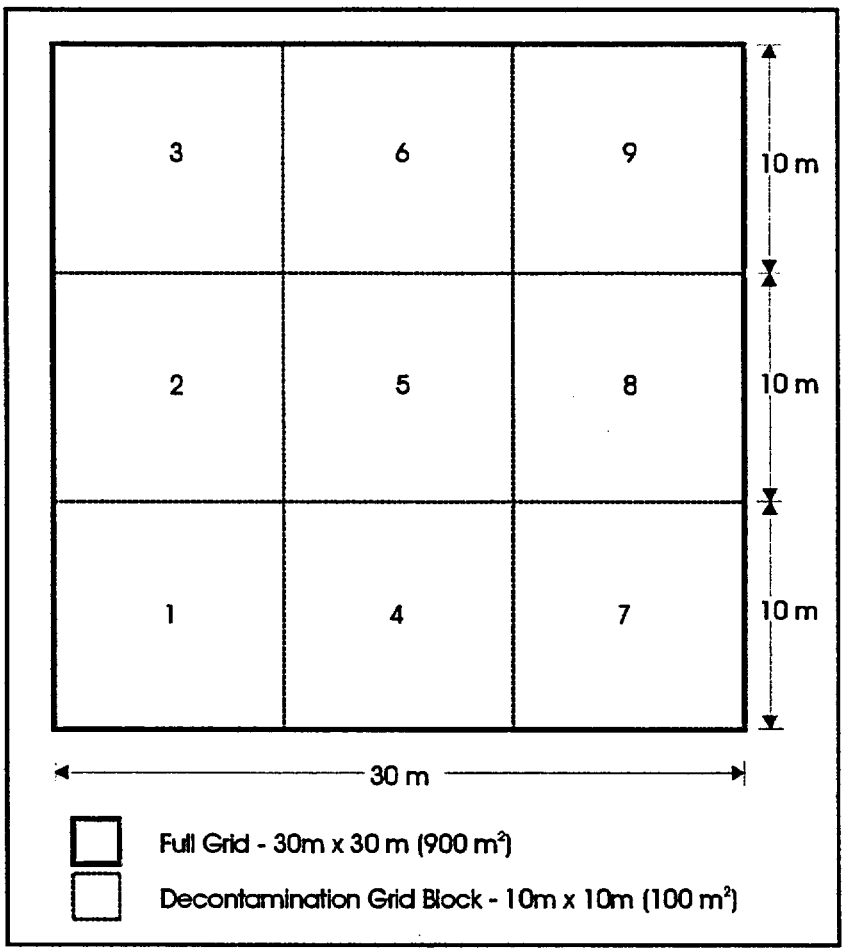
3.4.2 Reference Grid

A grid was established over the affected area upon completion of material excavation for the purpose of referencing locations of samples and measurements (see Figure 3-2). These full grids were 30m x 30m (900 m^2) in size. Each full grid was then divided into nine 10m x 10m sub-grids (100 m^2 each). Each sub-grid was marked into 2.5m increments to establish the nine individual soil sample locations taken to obtain one composite sample per sub-grid. Figure 3-3 depicts the breakdown of the reference grid system. As previously noted, the entire Section II (affected area) constituted the survey unit.

C04

Figure 3-3

Reference Grid System



3.4.3 Surface Scans

One hundred percent of the soil surface was initially scanned to identify locations of elevated activity. The gamma scans were conducted in accordance with procedure SOP 1.5, Measurement of Gamma-Ray Fields using a Sodium Iodide (NaI) Detector. As soil was removed, additional gamma scans were conducted to identify remaining locations of contaminated soil. After completion of contaminated soil removal, a final scan was performed of the soil surface prior to obtaining final verification soil samples.

3.4.4 Soil sampling

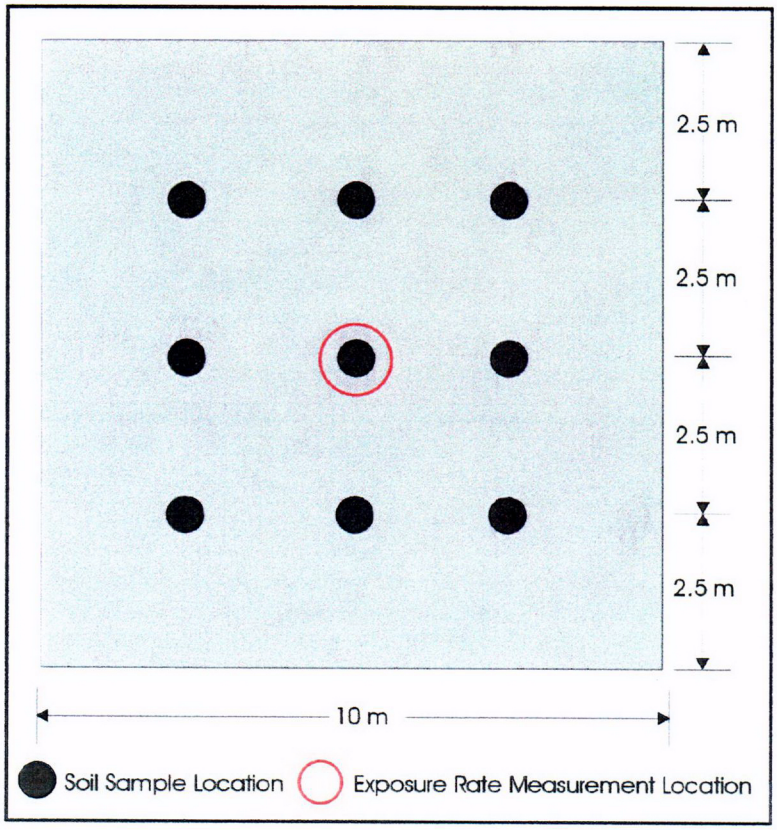
Final survey soil samples consisted of one composite sample obtained from nine individual samples (approximately 1 kg each) from each sub-grid (see Figure 3-4). The samples were collected after gamma levels were measured to preliminarily determine that all contaminated soil had been removed. Each of the nine locations where the individual samples were collected was scanned prior to soil sampling to validate that elevated levels did not exist (>3 times background). These final verification soil samples were analyzed on site through gamma spectroscopy. When the gamma spectral analysis results showed the Th-232 levels to be less than the guideline value, the final verification samples were then sent to the Freeport, Texas laboratory for gamma and alpha spectral analysis and confirmation that residual contamination limits have been met. Ten percent of the samples were split for QA analysis by three outside certified laboratories (Paragon Analytics, American Radiation Services and SRC Analytical). Soil sample collection was performed in accordance with procedure SOP 1.8, Guide to the Handling, Packaging and Shipping of Samples, and SOP 1.9, Sample Control and Documentation.

3.4.5 Exposure Rate Measurements

Gamma exposure rates were measured in the affected area at 1 meter above the soil surface at the midpoint of each sub-grid (see Figure 3-4). Exposure rate measurements were obtained using a Ludlum Model 19 MicroR meter.

Figure 3-4

Sampling Pattern for Composite Preparation Within Decontaminated Grid Block



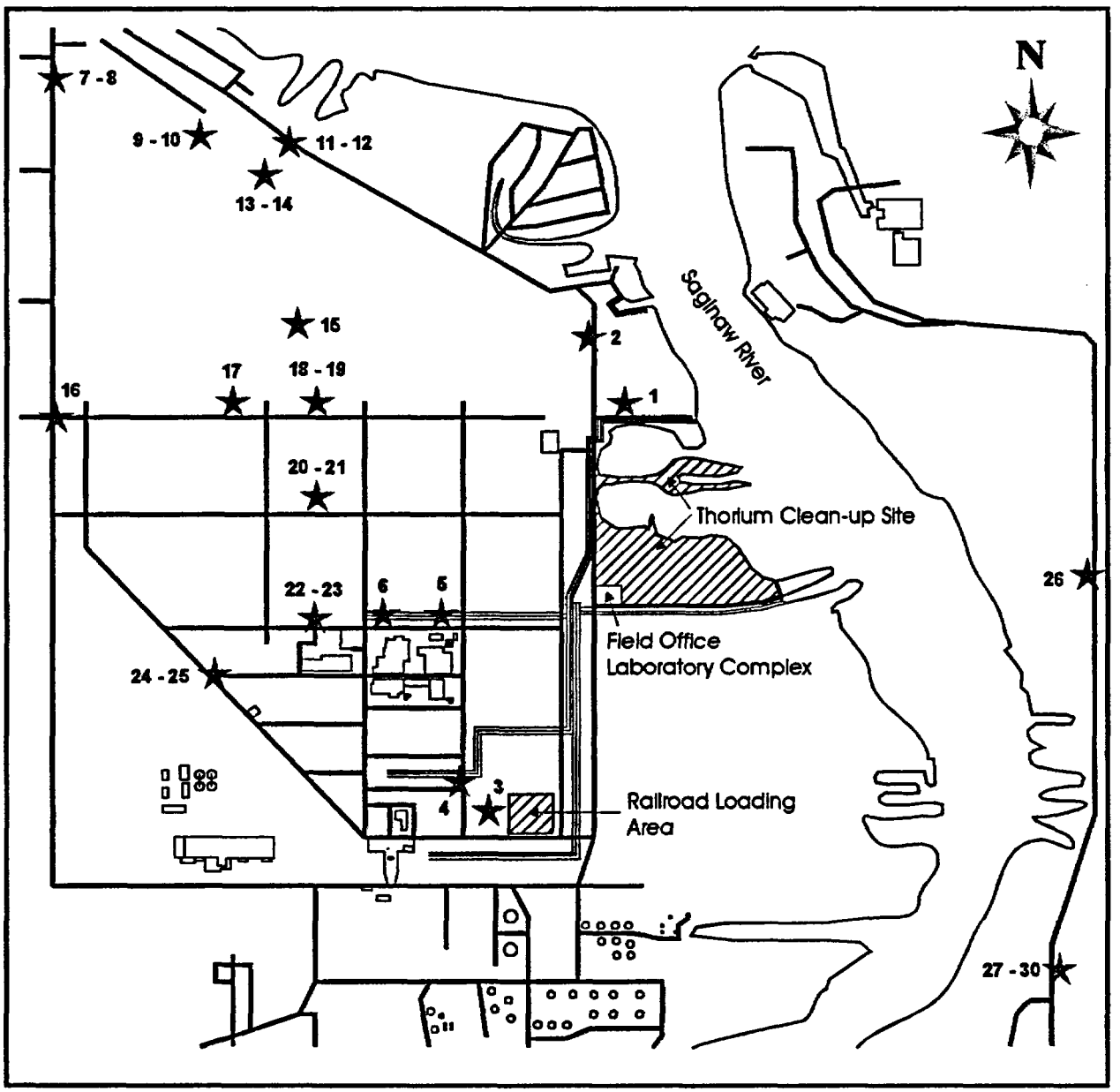
3.5 BACKGROUND LEVEL DETERMINATION

Background soil samples were collected from 30 locations in the unaffected area (Figure 3-5), and 29 samples analyzed for Th-230, Th-232, and Th-228 concentrations in the Freeport Laboratory (sample no. 14 was lost in transit). Sample numbers 1-25 were collected from locations on Dow property that were not impacted by site operations. Sample numbers 26-30 were collected from locations east of the Dow property, across the Saginaw River. Background exposure rates were measured at the same locations as the soil samples. Statistical procedures described in NUREG/CR-5849 (see Table A6) were used to assure that the average thorium concentrations determined were representative of true average background levels.

C05

Figure 3-5

Background Sample Locations



3.6 SAMPLE ANALYSIS

Final survey soil samples were analyzed for Th-232 in the field laboratory using the NaI detector coupled to the MCA. Soil samples were analyzed in accordance with "Procedure for Counting

Soil Samples for EOP Characterization". The final verification samples were analyzed for Th-232, Th-230, and Th-228 using gamma and alpha spectroscopy in the Freeport Laboratory.

3.7 DATA INTERPRETATION

Soil sample locations and survey results for fixed measurements were recorded on data sheets. The data conversion and statistical analysis techniques in NUREG/CR-5849 (Chapter 8.0) were used to convert the reported data into a form that permitted a direct comparison with residual contamination guidelines and thus assess if remediation goals were met. The statistical relationships are shown with the analyzed data in Appendix A (Tables A6, A7). Soil concentrations were converted into units of pCi/g and exposure rates to μR/h. The reported affected area data in Appendix A has been adjusted by subtracting the natural background levels.

Additional soil removal was performed when the remediation control survey measurements showed that residual contamination guidelines were not being met. As a result, there were no remaining "hot spots" and "hot spot" averaging criteria were not applied.

3.8 RECORDS

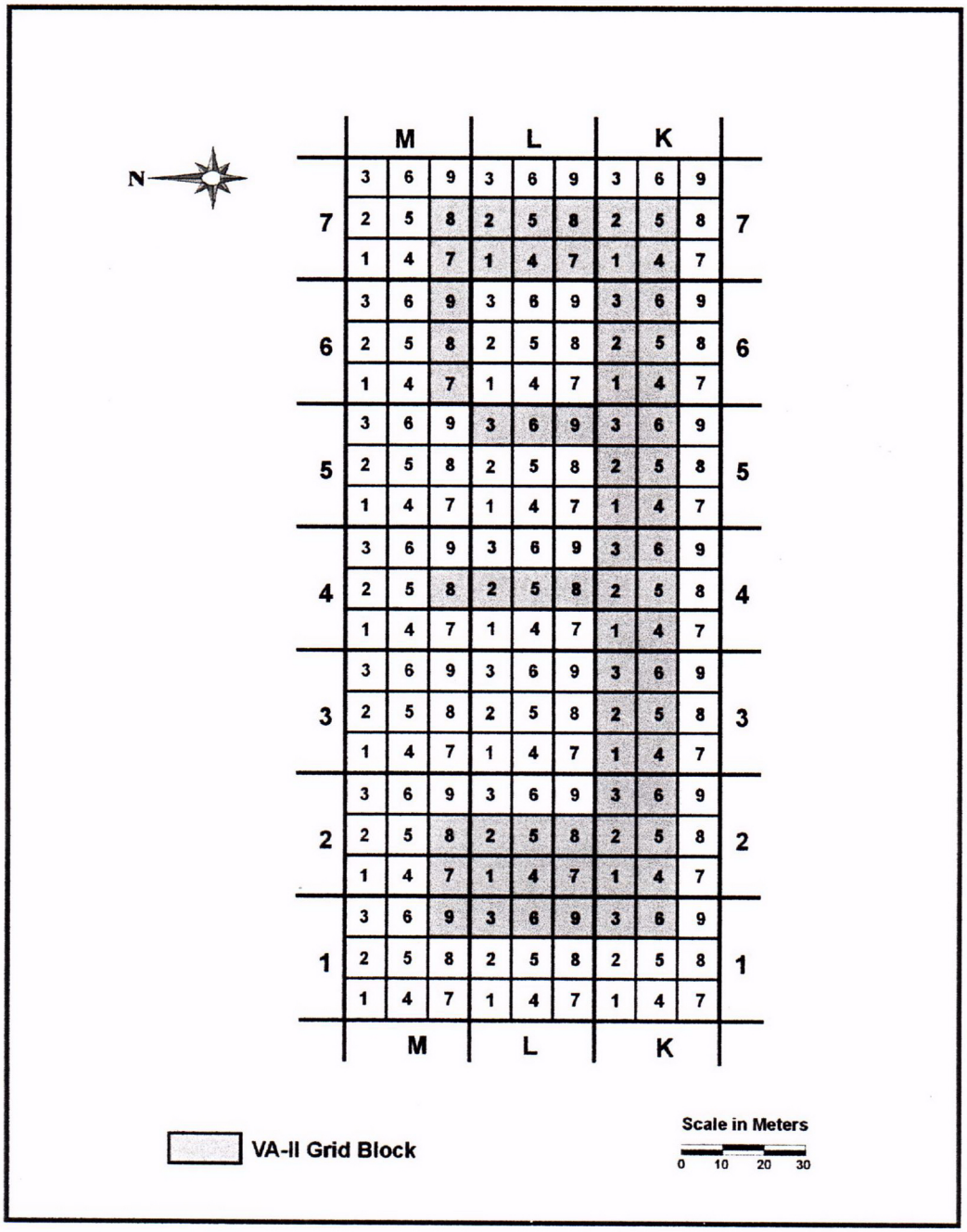
All soil samples, original survey data records, and log-books have been archived at the Dow Bay City facility and will be held until after license termination.

4.0 SURVEY FINDINGS AND RESULTS

Appendix A contains the radiological database collected during the final status survey for VA-II (as defined in Figure 4-1) that provides the basis for verifying that the residual contamination objectives have been achieved for this area at the Bay City thorium site. Summary Tables, data interpretations and statistical comparisons with residual contamination guidelines in VA-II are included in Appendix A.

Figure 4-1

Grid locations for VA-II



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4.1 BACKGROUND LEVELS

Background soil concentrations (Table A1) averaged 0.30 pCi/g for Th-232, 0.49 pCi/g for Th-230, and 0.31 pCi/g for Th-228. Background exterior exposure rates averaged 5 μR/h (Table A2). Both the number of data points collected to obtain the average background soil concentrations and exposure rates are more than sufficient to meet the test for demonstrating that the measured average background is within ± 20% of the true average at the 95% confidence level.

4.2 GROUND SURVEYS

4.2.1 Scans

Surface scans were used during the remediation control survey to identify locations of elevated gamma radiation to guide the excavation of the material and locate remaining hot spots. A total of 11 discreet areas of elevated activity were identified during the verification scan survey. These areas were remediated and re-scanned with satisfactory results. Areas covered by water were not scanned, however, sediment samples were obtained.

4.2.2 Thorium Concentrations in Soil

The results of the analyses of the verification soil samples from VA-II are provided in table A3, and related to the grid locations shown in Figure 4-1. QA soil analyses, performed by the outside laboratories on splits of 10 percent of the background and verification samples, are shown in Table A3 together with the analyses of the same soil performed at Dow's Freeport Laboratory. None of the verification or QA samples contained total thorium concentrations in excess of the soil residual activity guideline (see Section 2.3). Analysis of the mean concentration of Th-232 shows that the concentration meets the guideline value at the 95% confidence level (Tables A6, A7). The number of samples collected (84 in VA-II) is much greater than the number (<9) statistically required to demonstrate that the concentrations satisfies the guideline value at the 95% confidence level Table A7).

The maximum total residual thorium concentrations (above background) as measured in sample BCS-K5-3Av1 was 13.98 pCi/g which is less than the residual guideline of 14.5 pCi/g.

Since none of the verification soil sample concentrations in VA-II exceeded the guideline value (no hot spots) it was not necessary to apply averaging techniques in any of the grids.

All of the verification soil samples in VA-II (Table A3) meet the criteria that the sum of the ratios of the concentration of each radionuclide to its respective guideline must not exceed 1 (Appendix A of NUREG/CR-5849).

4.2.3 Exposure Rates

Exposure rate measurements of the remediated VA-II areas (Figure 4-1) and for each grid block are provided in Table A5. All individual values are within the guideline levels of 5 μR/h above background with the single exception of sub-grid K2-8 where the exposure rate was 7 μR/h. The average exposure rate for the K-2 grid is 4.5 μR/h meeting the criteria of 5 μR/h. Analysis of the statistical mean also shows that the exposure rates in VA-II meet the guideline at the 95% confidence level. The number of measurements (16) is in excess of the number required (<9) to demonstrate that the exposure rate satisfies the guideline value at the 95% confidence level Tables A6, A7).

4.2.4 NRC Confirmatory Surveys

The NRC performed an inspection of VA-II on July 24th and 25th of 1997. This inspection included the performance of a confirmatory survey. Approximately 20% of VA-II was scanned using a sodium iodide detector. Numerous areas were identified which exceeded the "three times background" criteria in the K3 grid. Dow personnel collected 2 soil samples, per NRC staff direction, at the areas of highest gamma scan readings within the K3 grid. The soil samples were analyzed for Th-232 at the Bay City field laboratory, under inspector observation, following QA/QC and calibration checks of the counting systems. Both sample results had Th-232

concentrations (8.0 pCi/g and 12 pCi/g) in excess of the site guideline value (6.2 pCi/g). Exposure rate measurements obtained at the soil sample locations were found to be three to five times the acceptable ranges. Additionally, the eastern portion of the VA could not be accessed to due to the high growth of vegetation.

Grid K3 was subsequently remediated by Dow and the grid, as well as the immediately adjacent grids, were re-scanned. Three areas of elevated activity were identified by the gamma scan survey (K2-1, K3-4 and K3-5). These areas were further remediated and re-scanned with satisfactory results. Soil samples were collected in the three locations as part of the re-survey effort. The Th-232 concentrations for these sub-grids were below the guideline value (K2 = 2.72 pCi/g, K3-4 = 3.19 pCi/g, and K3-5 = 1.08 pCi/g). The previously inaccessible areas to the east were subsequently cleared of all overgrowth.

The NRC performed another inspection of VA-II on October 28th and 29th of 1997 (as well as VA-III). Approximately 20% of VA-II was scanned with a sodium iodide detector with no elevated areas of activity identified. Exposure rate measurements were within acceptable ranges. No detectable activity was found in any of the soil samples collected in VA-II.

Since the most recent confirmatory survey did not identify any areas of elevated activity, no further remediation was performed and no additional final status surveys were required.

5.0 SUMMARY

Decontamination of the affected area by soil removal at Dow's Bay City facility is an ongoing process. Since the affected area is quite large it is more efficient for Dow to verify that residual contamination criteria have been met in sections, and for the NRC to subsequently validate each section. Thus area VA-II has been verified and the evaluated database from the final status survey provided in the Appendix. Remediation control surveys were performed to guide the decontamination effort, and a final status survey conducted of VA-II during June, 1997. Independent QA analysis of soil samples was performed. Results of the final status survey demonstrate that the decontamination program successfully reduced residual activity in VA-II to within the NRC limits for unrestricted use. As each subsequent VA is surveyed, a FSSR will be submitted to NRC.

6.0 REFERENCES

6.1 Dow Decommissioning Work Plan, October 1993

6.2 Supplement to the Decommissioning Work Plan, December 1995

6.3 Letter from Dow to NRC, Response to Comments, March 1996

6.4 NUREG/CR-5849, Manual for Conducting Radiological Surveys in Support of License Termination (Draft for Comment), December 1993

6.5 NRC Inspection Report No. 040-00017/97002 (DNMS), August 14, 1997

6.6 Letter from NRC to Dow, Review of Final Status Survey Reports for the Previously Remediated Areas VA-I through VA-VI, Dow Chemical Company's Bay City, MI, SDMP Site (TAC# L60463), August 16, 2002

6.7 Dow "Background Radiological Survey", October 11-13, 1989

6.8 Dow Bay City Site Procedures

- 6.8.1 SOP 1.1, Access Control Procedures
- 6.8.2 SOP 1.2, Total Alpha Surface Contamination Measurements
- 6.8.3 SOP 1.3, External Dosimetry Procedure
- 6.8.4 SOP 1.4, Beta-Gamma Radiation Measurements using a Geiger-Muller Detector
- 6.8.5 SOP 1.5, Measurement of Gamma-Ray Fields using a Sodium Iodide (NaI) Detector
- 6.8.6 SOP 1.6, Intermediate Volume Air Particulate Sampling
- 6.8.7 SOP 1.7, Sampling for Removable Alpha Contamination
- 6.8.8 SOP 1.8, Guide to the Handling, Packaging and Shipping of Samples
- 6.8.9 SOP 1.9, Sample Control and Documentation
- 6.8.10 SOP 1.10, Radiation Work Permits
- 6.8.11 SOP 1.11, Respiratory Protection Program
- 6.8.12 "Procedure for Counting Soil Samples for EOP Characterization"
- 6.8.13 Dow Central Research Index Report, CRI-TSP-92-076, "Radiological Analysis of Soil Samples from the Madison, Illinois Storage Facility Utilizing a Revised Alpha Spectroscopic Method"

Appendix A

Final Status Survey

Verification Measurements / Analyses

Table A1

BACKGROUND SOIL CONCENTRATIONS							
Bay City							
Sample Name	^{232}Th (pCi/G)	Error (2σ)	MDA (pCi/G)	^{230}Th (pCi/G)	Error (2σ)	^{228}Th (pCi/G)	Error (2σ)
BCBKG01	0.39	0.08	0.13	1.04	0.84	0.48	0.44
BCBKG02	0.36	0.07	0.14	0.46	0.34	0.41	0.31
BCBKG03	0.28	0.08	0.11	0.38	0.31	0.35	0.29
BCBKG04	0.44	0.10	0.13	0.80	0.91	0.62	0.74
BCBKG05	0.43	0.10	0.15	0.70	0.51	0.52	0.40
BCBKG06	0.51	0.18	0.13	0.68	0.47	0.48	0.35
BCBKG07	0.38	0.19	0.13	2.30	3.69	0.77	1.38
BCBKG08	0.16	0.08	0.11	0.37	0.48	0.12	0.20
BCBKG09	0.13	0.07	0.10	0.21	0.25	0.09	0.12
BCBKG10	0.26	0.09	0.13	0.38	0.39	0.23	0.26
BCBKG11	0.19	0.07	0.11	0.04	0.04	0.14	0.10
BCBKG12	0.18	0.08	0.14	0.18	0.14	0.11	0.09
BCBKG13	0.18	0.08	0.14	0.21	0.12	0.19	0.11
BCBKG15	0.23	0.07	0.11	0.12	0.15	0.32	0.31
BCBKG16	0.56	0.12	0.16	0.76	0.51	0.66	0.46
BCBKG17	0.41	0.10	0.16	0.30	0.47	0.30	0.47
BCBKG18	0.10	0.08	0.12	0.18	0.21	0.16	0.19
BCBKG19	0.12	0.06	0.10	0.15	0.14	0.06	0.07
BCBKG20	0.14	0.07	0.11	0.29	0.25	0.09	0.09
BCBKG21	0.19	0.07	0.15	0.23	0.17	0.13	0.11
BCBKG22	0.20	0.07	0.10	0.36	0.39	0.13	0.18
BCBKG23	0.15	0.06	0.11	0.24	0.24	0.30	0.29
BCBKG24	0.12	0.08	0.11	0.13	0.16	0.05	0.08
BCBKG25	0.22	0.07	0.08	0.93	0.89	0.72	0.70
BCBKG26	0.32	0.09	0.13	0.27	0.23	0.16	0.15
BCBKG27	0.56	0.20	0.20	0.93	0.69	0.90	0.67
BCBKG28	0.68	0.24	0.20	0.41	0.45	0.07	0.14
BCBKG29	0.43	0.19	0.21	0.65	1.22	0.43	0.89
BCBKG30	0.34	0.08	0.15	0.44	0.45	0.10	0.16
AVERAGE	0.30			0.49		0.31	
St. Dev.	0.16			0.44		0.24	

Table A2

Background Exposure Rates – Bay City

Sample	Value (μR/hr)
BCBKG1	5
BCBKG2	7
BCBKG3	5
BCBKG4	6
BCBKG5	4
BCBKG6	4
BCBKG7	5
BCBKG8	5
BCBKG9	5
BCBKG10	6
BCBKG11	5
BCBKG12	6
BCBKG13	5
BCBKG14	5
BCBKG15	7
BCBKG16	5
BCBKG17	4
BCBKG18	5
BCBKG19	5
BCBKG20	4
BCBKG21	4
BCBKG22	4
BCBKG23	4
BCBKG24	3
BCBKG25	3
ACROSS THE RIVER	
BCBKG26(1)	3
BCBKG27(2)	5
BCBKG28(3)	5
BCBKG29(4)	4
BCBKG30(5)	5

Number of measurements: 30
Average: 5 μR/hr
Standard Deviation: 1.3 μR/hr (≅ 1.0 μR/hr)

Table A3

Final Verification Soil Concentrations – VA-II

Sample Name	^{232}Th (pCi/G)	Error (2σ)	MDA (pCi/G)	^{230}Th (pCi/g)	Error (2σ)	^{228}Th (pCi/g)	Error (2σ)	^{232}Th (Net) (pCi/G)	^{230}Th (Net) (pCi/g)	^{228}Th (Net) (pCi/g)	TOTAL Thorium
BCS-K7-1Av1	0.86	0.23	0.20	0.31	0.12	0.80	0.27	0.56	-0.18	0.49	0.87
BCS-K7-1Bv1	0.30	0.12	0.16	0.15	0.12	0.27	0.18	0.00	-0.34	-0.04	-0.38
BCS-K7-2v1	0.89	0.23	0.28	0.40	0.33	0.65	0.46	0.59	-0.09	0.34	0.84
BCS-K7-4Av1	0.53	0.14	0.15	0.63	0.21	0.47	0.17	0.23	0.14	0.16	0.53
BCS-K7-4Bv1	0.21	0.12	0.16	0.19	0.14	0.26	0.19	-0.09	-0.30	-0.05	-0.44
BCS-K7-5v1	2.31	0.35	0.37	0.57	0.23	2.23	0.64	2.01	0.08	1.92	4.01
BCS-L4-2Av1	1.27	0.32	0.31	2.71	0.78	1.07	0.33	0.97	2.22	0.76	3.95
BCS-L4-2Bv1	0.48	0.16	0.20	0.87	0.38	0.54	0.25	0.18	0.38	0.23	0.78
BCS-L4-5Av1	1.78	0.48	0.29	4.00	1.35	1.51	0.55	1.49	3.51	1.20	6.19
BCS-L4-5Bv1	0.24	0.20	0.28	0.48	0.93	0.24	0.52	-0.06	-0.01	-0.07	-0.13
BCS-L4-8Bv1	0.30	0.14	0.17	0.15	0.11	0.07	0.06	0.00	-0.34	-0.24	-0.59
BCS-L5-3Av1	1.63	0.39	0.27	3.82	1.08	1.35	0.41	1.33	3.33	1.04	5.70
BCS-L5-3Bv1	0.22	0.16	0.28	0.17	0.15	0.15	0.14	-0.08	-0.32	-0.16	-0.56
BCS-L5-3Bv1-R	0.30	0.13	0.24	0.43	0.32	0.21	0.17	0.00	-0.06	-0.10	-0.17
BCS-L5-6Av1	1.35	0.33	0.35	1.29	0.45	0.63	0.25	1.05	0.80	0.32	2.17
BCS-L5-6Bv1	0.20	0.12	0.25	0.24	0.21	0.16	0.15	-0.10	-0.25	-0.15	-0.50
BCS-L5-9Bv1	0.40	0.19	0.33	0.67	0.36	0.36	0.20	0.10	0.18	0.05	0.33
BCS-L7-1Bv1	1.52	0.26	0.19	1.21	0.37	1.02	0.33	1.22	0.72	0.71	2.65
BCS-L7-2v1	0.92	0.19	0.20	0.50	0.31	0.86	0.47	0.62	0.01	0.55	1.18
BCS-L7-4Av1	0.69	0.23	0.15	0.39	0.19	0.63	0.29	0.39	-0.10	0.32	0.61
BCS-L7-4Av1-R	0.61	0.13	0.15	0.45	0.20	0.46	0.20	0.31	-0.04	0.15	0.42
BCS-L7-4Bv1	0.52	0.20	0.23	0.18	0.10	0.62	0.30	0.22	-0.31	0.31	0.22
BCS-L7-5v1	0.64	0.19	0.15	0.49	0.28	0.64	0.36	0.34	0.00	0.33	0.67
BCS-L7-7Av1	0.18	0.16	0.23	0.11	0.10	0.02	0.02	-0.12	-0.38	-0.29	-0.79
BCS-L7-7Bv1	0.64	0.19	0.20	0.33	0.14	0.60	0.23	0.34	-0.16	0.29	0.47
BCS-L7-8v1	0.71	0.17	0.20	0.42	0.30	0.45	0.31	0.41	-0.07	0.14	0.49
BCS-M4-8Av1	0.57	0.24	0.27	1.12	0.51	0.56	0.26	0.27	0.63	0.25	1.15
BCS-M4-8Bv1	0.34	0.16	0.21	0.54	0.35	0.26	0.19	0.04	0.05	-0.05	0.04
BCS-M5-7Av1	0.56	0.33	0.23	0.86	0.57	0.64	0.43	0.26	0.37	0.33	0.95
BCS-M5-7Bv1	1.68	0.33	0.30	3.59	0.92	1.38	0.39	1.38	3.10	1.07	5.54
BCS-M5-8Av1	0.35	0.24		0.48	0.42	0.35	0.31	0.05	-0.01	0.04	0.07
BCS-M5-8Bv1	1.11	0.38	0.32	2.31	0.87	1.08	0.42	0.81	1.82	0.77	3.39
BCS-M5-9Av1	0.92	0.32	0.41	2.18	0.92	0.98	0.44	0.62	1.69	0.67	2.98
BCS-M5-9Bv1	0.26	0.16	0.21	0.38	0.24	0.21	0.15	-0.04	-0.13	-0.10	-0.28
AVERAGE	0.84			1.45		0.76		0.64	0.96	0.45	1.95
St. Dev.	0.71			1.60		0.63		0.71	1.60	0.63	2.62
Maximum	3.44			8.51		3.13		3.14	8.02	2.82	13.98
Note: Net concentrations are gross values less background (Table A1)											

Table A3

Final Verification Soil Concentrations – VA-II

Sample Name	^{232}Th (pCi/G)	Error (2σ)	MDA (pCi/G)	^{230}Th (pCi/g)	Error (2σ)	^{228}Th (pCi/g)	Error (2σ)	^{232}Th (Net) (pCi/G)	^{230}Th (Net) (pCi/g)	^{228}Th (Net) (pCi/g)	TOTAL Thorium
BCS-K2-1V1	0.25	0.12	0.15	0.33	0.30	0.17	0.17	-0.05	-0.16	-0.14	-0.35
BCS-K2-2v1	0.46	0.19	0.23	0.84	0.62	0.41	0.33	0.16	0.35	0.10	0.61
BCS-K2-3Av1	0.38	0.16	0.20	0.68	0.35	0.52	0.28	0.08	0.19	0.21	0.48
BCS-K2-3Bv1	0.11	0.10	0.15	0.19	0.19	0.12	0.12	-0.19	-0.30	-0.18	-0.69
BCS-K2-4v1	0.22	0.15	0.22	0.65	0.56	0.48	0.42	-0.08	0.16	0.17	0.25
BCS-K2-5v1	0.37	0.15	0.17	0.98	1.01	0.85	0.80	0.07	0.49	0.54	1.10
BCS-K2-6v1	0.56	0.17	0.19	2.14	1.11	0.74	0.43	0.26	1.65	0.43	2.33
BCS-K3-1Av1	0.72	0.18	0.31	1.53	0.56	0.81	0.32	0.42	1.04	0.50	1.97
BCS-K3-1Bv1	0.35	0.12	0.16	0.74	0.34	0.46	0.22	0.05	0.25	0.15	0.45
BCS-K3-2Av1	1.22	0.39	0.27	2.66	0.98	0.72	0.29	0.92	2.17	0.41	3.50
BCS-K3-2Bv1	0.14	0.13	0.19	0.22	0.22	0.15	0.15	-0.16	-0.27	-0.16	-0.58
BCS-K3-3Av1	2.28	0.36	0.35	4.68	1.05	2.08	0.51	1.98	4.19	1.77	7.95
BCS-K3-3Bv1	0.51	0.16	0.19	0.89	0.31	0.47	0.17	0.21	0.40	0.16	0.77
BCS-K3-4v1	0.58	0.18	0.22	0.67	0.28	0.39	0.17	0.28	0.18	0.08	0.54
BCS-K3-5v1	1.36	0.26	0.30	1.56	0.55	1.02	0.39	1.06	1.07	0.71	2.84
BCS-K3-6Av1	1.71	0.27	0.24	2.95	0.80	1.72	0.50	1.41	2.46	1.41	5.27
BCS-K3-6Bv1	1.09	0.21	0.20	1.78	0.41	1.00	0.24	0.79	1.29	0.69	2.76
BCS-K4-1Av1	2.01	0.37	0.34	4.82	1.11	1.68	0.42	1.71	4.33	1.37	7.41
BCS-K4-1Bv1	0.64	0.22	0.23	1.48	0.58	0.59	0.24	0.34	0.99	0.28	1.61
BCS-K4-2Av1	2.31	0.35	0.30	4.82	0.92	1.91	0.40	2.01	4.33	1.60	7.94
BCS-K4-2Bv1	0.52	0.16	0.18	1.06	0.47	0.66	0.30	0.22	0.57	0.35	1.14
BCS-K4-3Av1	2.10	0.39	0.40	6.64	1.68	1.77	0.51	1.80	6.15	1.46	9.40
BCS-K4-3Bv1	0.62	0.17	0.14	0.74	0.31	0.39	0.18	0.32	0.25	0.08	0.65
BCS-K4-4v2	0.53	0.27	0.41	0.78	0.51	0.41	0.29	0.23	0.29	0.10	0.63
BCS-K4-5Bv1	0.86	0.54	0.19	3.10	2.07	0.56	0.40	0.56	2.61	0.25	3.42
BCS-K4-5v2	0.46	0.14	0.27	0.56	0.29	0.33	0.18	0.16	0.07	0.02	0.25
BCS-K4-6v2	1.23	0.30	0.40	1.99	0.79	1.21	0.52	0.93	1.50	0.90	3.33
BCS-K4-6v2-R	0.96	0.24	0.31	2.56	1.07	1.30	0.58	0.66	2.07	0.99	3.72
BCS-K4-6v2-R	1.05	0.35	0.42	1.41	0.77	1.18	0.66	0.75	0.92	0.88	2.55
BCS-K5-1Av1	2.18	0.58	0.37	4.48	1.33	1.86	0.57	1.88	3.99	1.55	7.42
BCS-K5-1Bv1	0.59	0.39	0.24	1.15	0.82	0.53	0.39	0.29	0.66	0.22	1.17
BCS-K5-2Bv1	0.16	0.17	0.22	0.28	0.30	0.20	0.22	-0.14	-0.21	-0.11	-0.46
BCS-K5-3Av1	3.44	0.54	0.39	8.51	1.89	3.13	0.78	3.14	8.02	2.82	13.98
BCS-K5-3Bv1	0.49	0.17	0.27	1.11	0.46	0.47	0.20	0.19	0.62	0.16	0.97
BCS-K5-4v2	2.46	0.36	0.46	3.88	1.02	2.46	0.69	2.16	3.39	2.15	7.70
BCS-K5-5v2	0.59	0.21	0.35	1.06	0.48	0.51	0.25	0.29	0.57	0.20	1.06
BCS-K5-6v2	0.50	0.25	0.33	1.30	0.85	0.43	0.32	0.20	0.81	0.12	1.13
BCS-K6-1Av1	2.37	0.36	0.39	1.41	0.33	2.02	0.45	2.07	0.92	1.71	4.71
BCS-K6-1Bv1	0.21	0.16	0.23	0.61	0.49	0.30	0.24	-0.09	0.12	-0.01	0.01
BCS-K6-2Av1	1.96	0.28	0.27	3.28	0.73	1.64	0.41	1.66	2.79	1.33	5.78
BCS-K6-2Bv1	0.15	0.12	0.05	0.15	0.13	0.10	0.09	-0.15	-0.34	-0.21	-0.70
BCS-K6-3Av1	0.79	0.29	0.25	2.14	0.92	0.81	0.37	0.49	1.65	0.50	2.64
BCS-K6-3Bv1	0.11	0.11	0.16	0.04	0.04	0.07	0.07	-0.19	-0.45	-0.24	-0.88
BCS-K6-3v1	0.31	0.26	0.38	0.36	0.34	0.25	0.25	0.01	-0.13	-0.06	-0.18
BCS-K6-4v2	0.41	0.23	0.28	0.92	0.60	0.43	0.29	0.11	0.43	0.12	0.67
BCS-K6-5Bv1	0.23	0.20	0.00	0.26	0.26	0.21	0.21	-0.07	-0.23	-0.10	-0.41
BCS-K6-5v2	0.29	0.19	0.28	0.44	0.35	0.32	0.26	-0.01	-0.06	0.01	-0.06
BCS-K6-6Av1	1.64	0.37	0.29	3.75	1.04	1.75	0.52	1.34	3.26	1.44	6.05
BCS-K6-6Bv1	0.30	0.12	0.24	0.54	0.29	0.31	0.17	0.00	0.05	0.00	0.04
BCS-K6-6Bv1-	0.21	0.16	0.25	0.30	0.25	0.18	0.15	-0.09	-0.19	-0.13	-0.41

Table A5

Final Gamma Exposure Rates – VA-II

Grid No.	Gross Exposure (μR/hr)	Net Exposure (μR/hr)
K1-9	8	3
K2-6	8	3
K2-7	8	3
K2-8	12	7[3]
K2-9	10	5
K3-4	7	2
K3-7	7	2
K3-8	7	2
K3-9	8	3
K4-7	9	4
K4-8	7	2
K7-2	7	2
K7-5	9	4
K7-8	9	4
L7-5	7	2
L7-8	7	2

no. measurements 16
Average 3 μR/hr
Standard deviation 1.4 μR/hr (≈ 1.0 μR/hr)

Notes:

1. Net value is gross value less background of 5 μR/hr

2. Where rising waters have covered a subgrid where final verifcation soil samples were collected, gamma measurements were not taken.

3. Average exposure rate over the K2 grid is 4.5 μR/hr (< 5 μR/hr)

Table A6

Final Status Survey: Statistical Analysis

The following statistical relations were used to assess the database for the Bay City survey unit:

Survey Data Average ($\bar{x}$):

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

Standard Deviation (S_x):

$$S_x = \sqrt{\frac{\sum_{i=1}^{n}(\bar{x} - x_i)^2}{n-1}}$$

Determination of Number of Background data points (n_B):

$$n_B = \left[\frac{t_{95.5\%,df} S_x}{0.2 \bullet \bar{x}_B}\right]^2$$

Comparison of statistical mean ($\mu\alpha$) with guideline values:

$$\mu_\alpha = \bar{x} + t_{1-\alpha,df}\frac{S_x}{\sqrt{n}}$$

Identifying additional measurement/sampling needs:

$$\text{Estimating Factor} = \frac{C_G - \bar{x}}{S_x}$$

(Tables B-2 in NUREG/CR-5849)

Note: See chapter 8.0 of NUREG/CR-5849 for detailed discussion of above-listed statistical analyses.

Where:

X_i = measurement (analysis) at point i
n = number of measurements (analyses)
t_i - α, df = 95% confidence level from Table B-1 of Appendix B of NUREG/CR-5849
C_G = Guideline Value

Table A7

Final Status Survey: Summary Statistics

Exposure Rates							
Section	n	X (μR/h)	Sx (μR/h)	μα (μR/h)	C_G (μR/h)	Estimating Factor	No. Verification Samples Needed
VA-II	16	3.0	1.4	3.61	5.0	1.4	<9
Th-232 Soil Concentrations							
Section	n	X (pCi/g)	Sx (pCi/g)	μα (pCi/g)	C_G (pCi/g)	Estimating Factor	No. Verification Samples Needed
VA-II	84	0.54	0.71	0.67	3.2	3.8	<9

Final Status Survey Report for VA-III

Magnesium-Thorium Slag Storage Area
The Dow Chemical Company's
Bay City, Michigan Facility

Dow U.S.A.

The Dow Chemical Company
Midland, Michigan 48674

Revision 1
March 2003

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TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

1.0 BACKGROUND INFORMATION

The radioactive material at the Dow Chemical Company's Bay City site consisted primarily of foundry slag containing Thorium. This material, and similar material originally stored at Dow's Midland site, was produced in the period from 1940 to 1970 as the residual from the production of a magnesium-thorium alloy. This lightweight alloy was used for defense purposes, including aircraft engines and aeronautical structural components.

A single license (STB-527) was originally granted by the NRC in 1973 for the Bay City and Midland sites to store up to 200,000 pounds of thorium slag. The license expired in 1978, but has remained in effect under timely renewal.

The Midland site was decontaminated with the material removed and transported to Bay City for consolidation with the Bay City material and subsequent transport to the Envirocare facility in Clive, Utah. A final survey was conducted at the Midland site by Dow with the results documented in a Final Status Survey Report of March, 1997, showing that the residual contamination criteria had been met. The NRC subsequently conducted an independent survey of the Midland site and verified that the residual contamination criteria had been met.

The material transported from the Midland site to the Bay City site originally consisted of magnesium with up to two percent thorium. Portions of this process slag were mixed with soil or limited amounts of construction debris. As a result of this mixing, the thorium concentrations, as determined by Dow characterization soil sampling, varied from 2-7000 pCi/g at the Bay City Site (with an average concentration of 188 pCi/g) . A total activity of 9.7 Ci of Th-232 was originally distributed throughout approximately 52,000 cubic yards of soil, slag, and construction debris.

Initial remedial action support surveys, performed in 1996, identified wide spread areas of elevated contamination. The gamma scan surveys were conducted using a sodium iodide detector. Readings were generally higher the closer the proximity to the original thorium pile but several hot spots in the 300,000 to 600,000 cpm range were identified. Construction debris, such as drums, were removed from these areas along with the contaminated soil.

Decontamination of the Bay City site is ongoing. In accordance with NRC and Dow discussions, as confirmed in Dow's letter of June 12, 1997, verification that residual contamination criteria have been achieved on this large site is being performed in sections. This Final Status Survey Report (FSR) provides the descriptive text on the site and the parameters of the survey program and includes the analyzed verification data for Verification Area (VA) III. As the database is acquired for subsequent VAs addendums to the Final Survey Report will be submitted to the NRC containing the analyzed database.

Supporting information on the Bay City site and decommissioning project is presented in the October, 1993 Decommissioning Work Plan, the December, 1995 Supplement to the Decommissioning Work Plan, and the March, 1996 Response to Comments.

This document is a revision to the original Final Status Survey Report for VA-III dated October 1997 as well as the amended report dated November 1997 which addressed sub-grids that were incorrectly labeled in the October report.

On October 28th and 29th of 1997, after the original report submittal, the NRC Region III conducted an inspection of the VA-III portion of the Dow Bay City facility. The primary purpose of the inspection was to conduct an independent confirmatory survey of VA-III. This revision to the original report is provided to include the findings of the NRC confirmatory surveys documented in NRC Report No. 040-00017/97003 (DNMS) dated January 7, 1998.

Additionally, this revision to the original report is provided to address deficiencies identified by NRC staff in a letter to Dow dated August 16, 2002 (Review of Final Status Survey Reports for the Previously Remediated Areas VA-I through VA-VI, Dow Chemical Company's Bay City, MI, SDMP Site (TAC# L60463)).

2.0 SITE INFORMATION

2.1 SITE DESCRIPTION

The Bay City thoriated material storage site is on a Dow facility near the Town of Bay City, Michigan about one-mile south of Saginaw Bay. The Bay City site (pile) is shown on Figure 2-1 in relation to adjacent land features and other facilities.

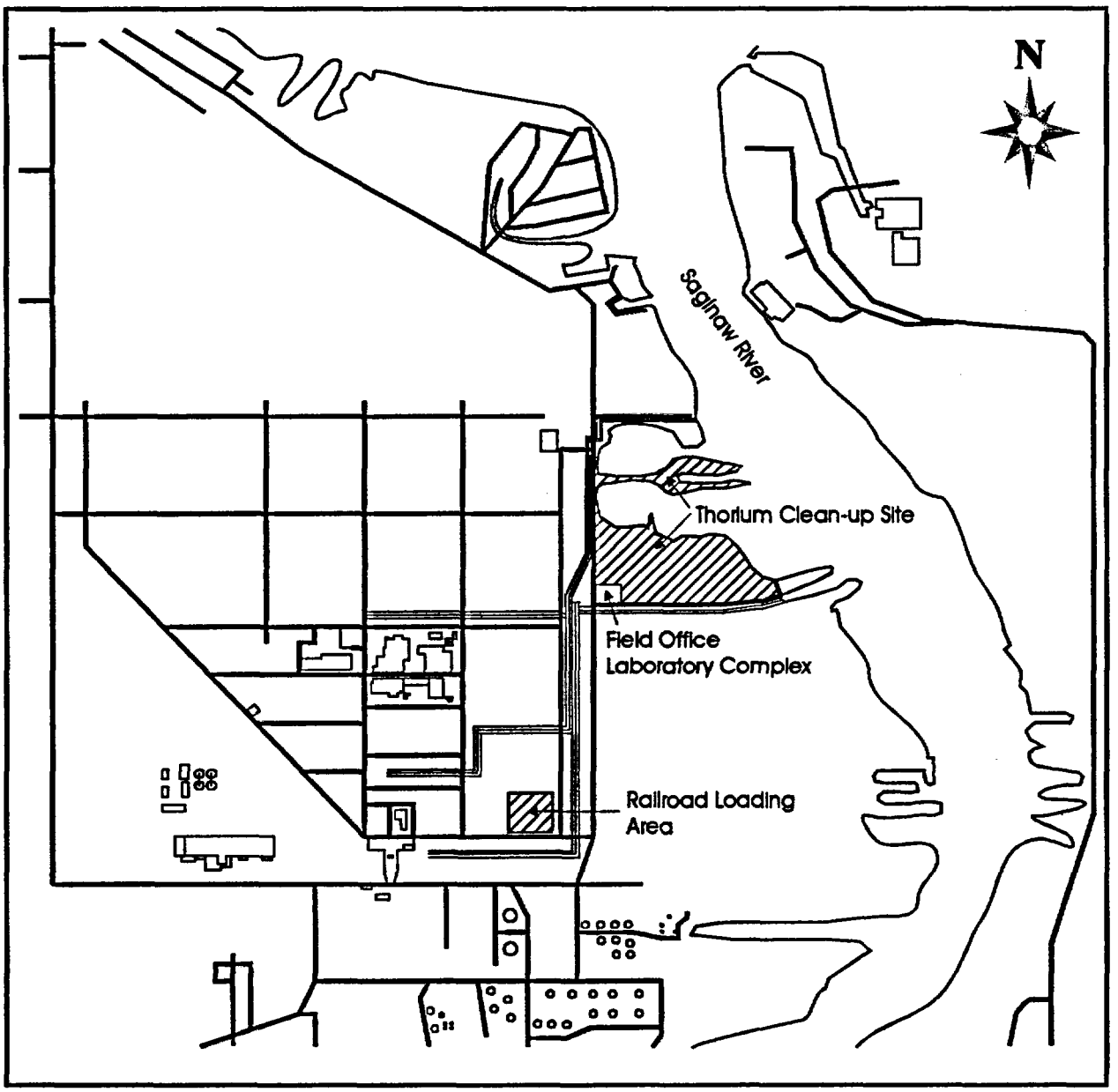
The thoriated material site is located adjacent to and north of an inlet canal, which enters the Saginaw River to the east. The Saginaw River is located to the north and east of the material. Access to the Dow manufacturing facility is restricted to authorized personnel. The storage site within the facility is posted as a radiation control area and delineated with a fence.

The area surrounding the material is relatively level, with some marshy areas and ponds. Any sediments containing elevated levels of thorium are being excavated as part of the decontamination program.

The affected area of the Bay City storage site was initially based on knowledge of the operating history, and subsequently on radiological characterization surveys. While areas immediately surrounding the Bay City storage area were included in the affected area, some further outward adjustment of the affected area boundary was required during site remediation to encompass surface and subsurface contamination uncovered during remedial operations.

Figure 2-1

Bay City Thorium Disposal Site



2.2 SITE CONDITIONS AT TIME OF FINAL SURVEY

The decommissioning activities at the Bay City site involve excavation of the contaminated soil, loading on to trucks, onsite transportation of the material to the stockpile at the railhead, loading on to the rail cars, and transport of the material to the Envirocare burial site in Clive, Utah. Soil removal is to varying depths continuing until sample analysis showed residual concentrations to be within NRC defined limits. Final verification samples were taken in the VA and analyzed on site through gamma spectroscopy. When the gamma spectral analysis results showed the Th-232 levels to be less than the guideline value, the final verification samples were then sent to the Freeport, Texas laboratory for gamma and alpha spectral analysis and confirmation that residual contamination limits have been met. Ten percent of all final verification samples were then sent to an outside contract laboratory for independent QC verification. Dow conducted QA/QC programs which were monitored by the Dow QA coordinator.

2.3 IDENTITY OF POTENTIAL CONTAMINANTS AND RELEASE GUIDELINES

Based on the knowledge of the process that generated the slag material, and the results of the characterization survey, the significant radiological contaminants were determined to be Th-232, Th-230, and Th-228. The above background residual soil concentration measurements used as a basis for the final verification for all the verification samples analyzed to date at Bay City provided the average soil activity ratios at Bay City of approximately:

Th-232	-	22%
Th-230	-	60%
Th-228	-	18%

Using the approach described in Section 3.1 ("Release Criteria") of the December, 1995 Supplement to the Decommissioning Work Plan and response No. 8 of the Response to Comments (on the Work Plan) of March, 1996, in conjunction with the methodology in Appendix A of NUREG/CR 5849 gives a residual soil gross activity guideline of 14.5 pCi/g total

thorium. The site-specific guideline levels for each of the contributory radionuclides is thus 3.2 pCi/g for Th-232, 2.6 pCi/g for Th-228, and 8.7 pCi/g for Th-230.

The gross activity guideline is determined as follows:

$$\textit{Gross Activity Guideline} = \frac{1}{\frac{0.22}{10} + \frac{0.18}{10} + \frac{0.60}{21}} = 14.5\ pCi/g$$

where Th-232, Th-230, and Th-228 are present in net activity ratios of 0.22, 0.60. and 0.18 respectively in the residual soil. The guideline concentrations for Th-232 plus Th-228 are 10 pCi/g and 21 pCi/g for Th-230 (see March, 1996 Response to Comments).

3.0 FINAL STATUS SURVEY OVERVIEW

3.1 SURVEY OBJECTIVES

The purpose of the final status survey was to demonstrate that the residual radiological concentrations in the soil at the Bay City thorium storage site satisfy the NRC guidelines (see 2.3 above) and that the storage site can, therefore, be released for future use without radiological controls. Specifically, the final status survey soil database should show that:

- Average residual radionuclide concentrations are at or below the soil guideline values defined in Section 2.3. Averaging is based on a 100 m^2 (10m x 10m) grid area. Note an actual grid size of 33.3 ft. x 33.3 ft. was used for convenience in measuring rather than 10m x 10m (32.8 ft. x 32.8 ft.).

- Reasonable efforts have been made to identify, evaluate, and remove, if necessary, areas of residual activity exceeding the guideline values. Areas of residual activity exceeding the guideline value (elevated areas) may be acceptable provided they do not exceed the guideline value by greater than a factor of $(100/A)^{1/2}$, where A is the area of residual

activity in m^2, and provided the activity level at any location does not exceed three times the guideline values.

In addition, exposure rates should not exceed 5 μR/h above background at 1 m above the soil surface. Exposure rates may be averaged over a 100 m^2 grid area. Maximum exposure rates over any discrete area may not exceed 10 μR/h above background.

A 95% minimum level of confidence that the above conditions have been met was to be demonstrated. The entire Section III of the Bay City storage area (affected area) is treated as a single survey unit, and the 95% level of confidence was to be applied to the entire survey unit.

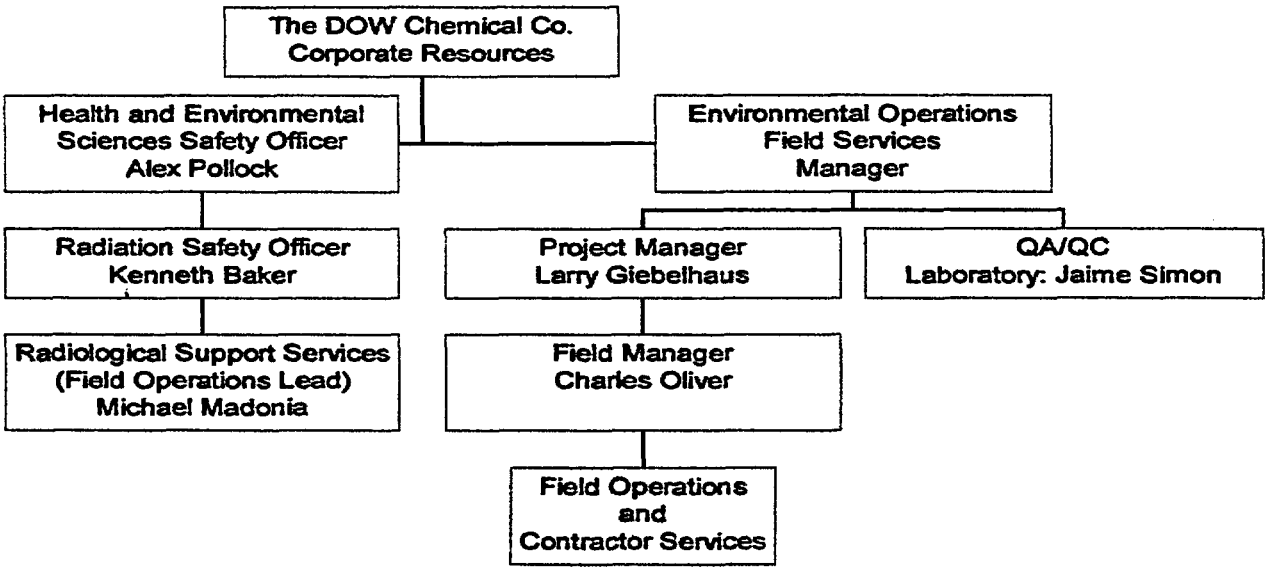
3.2 ORGANIZATION AND RESPONSIBILITIES

The final status survey was conducted by the same qualified Dow and subcontractor personnel who had conducted the characterization survey, and remediation control survey. The Project Organization is shown in Figure 3-1.

The sampling and analysis methods to be used during the remediation control survey was designed to achieve the sampling sensitivity and elevated activity guidelines defined in NUREG/CR-5849 relative to the site specific residual contamination criteria. The approach consisted of first performing a gamma scan survey of the remediated area to determine if any localized areas of elevated activity remained. Elevated areas of activity identified by the scan survey were remediated. If no areas of elevated activity were identified, composite soil samples were then collected and analyzed in the field laboratory using a NaI crystal coupled to the MCA to provide rapid turnaround on the Th-232 levels. If the Th-232 level exceeded the guideline value, further remediation was performed. The soil sample results of the analysis of the final samples collected, that demonstrated that the administrative cleanup level had been achieved, were then used as input into the final status survey.

Figure 3-1

Project Organization for Remediation of the Midland and Bay City Storage Sites



3.3 INSTRUMENTATION

Table 3-1 describes the laboratory instrumentation used for soil analyses along with the detection sensitivities for the instrumentation. The detection sensitivity for both the gamma and alpha spectrometer analyses are less than 25% of the residual concentration guideline values. The laboratory instrumentation calibration procedures and schedule are provided in Appendix D-2 of the March, 1996 Response to Comments.

Table 3-1

Laboratory Radiometric Analyses

Dow Chemical Freeport, Texas

Sample Type	Radionuclide Measured	Instrument	Analytical Procedures	Approx. Sensitivity
250 ml soil sample (polypropylene beaker w/ lid	Th-232 daughters in equilibrium with Th-232 (Ac-228, Bi-212, Pb-212, Ti-208)	Canberra Gamma Spectrometer system. The components include a 51.5 mm closed ended coaxial germanium detector, crystal, pre-amplifier, amplifier, power supply, multi-channel analyzer and computer.	Dow Central Research Index Report: CRI-TSP-92-076	0.2 pCi/g
0.6 sample from 250 ml soil sample	Th-232, Th-228, Th-230	Canberra Model 7404 four channel alpha spectrometer with built-in power supply, vacuum guage, detector bias supply, generator, pre-amplifier/amplifiers, multi-channel analyzer having a mixer-router input. The detectors are four passively implanted planar silicon (PIPS).	Dow Central Research Index Report: CRI-TSP-92-076	0.2 pCi/g

Table 3-2 lists the field radiological monitoring instrumentation used on the project inclusive of the specific use of each instrumentation and detection sensitivities. Each instrument was initially calibrated to NIST-traceable standards prior to use on the project, and then checked for radiation response and efficiency prior to daily use.

Table 3-2

Field Radiological Monitoring Instrumentation

Instrument	Measures	Detector Efficiency*	LLD/MDA
Ludlum Model 43-5 w/ Ludlum Model 12	Alpha Surface	15%	22 dpm
Ludlum Model 43-90 w/ Ludlum Model 2221	Alpha Surface	22%	12 dpm
Ludlum Model 44-9 w/ Ludlum Model 12	Alpha, Beta, Gamma	12% alpha 15% beta 1% gamma	
Ludlum Model 43-10 w/ Ludlum 1000	Alpha (air filters, smears)	43%	0.04 dpm
Ludlum Model 19	Exposure Rate		1 microR/h
Air Particulate			
Eberline RAS-1 Air Pump	Flow Rate = 40-100 lpm		
MSA Escort Lapel Sampler	Flow Rate = 2-3 lpm		
General Metal Works–2000 High Vol Sampler	Flow Rate = 30-60 cfm		
Test/Calibration Equipment			
Ludlum Model 500 Pulser	NIST Traceable		
AFC-85L Air Flow Calibrator	NIST Traceable		
GMW-Calibrator Orifice for High Vol Sampler	NIST Traceable		
MSA Optiflow 660 Air Flow Calibrator	NIST Traceable		
Field Laboratory Equipment			
Canberra Gamma Spectrometer	Soil Th-232 Concentration		0.8 pCi/g

* Detector efficiencies are approximate and appropriate for Th-230, Tc-99, and Co-60

3.4 SURVEY PROCEDURES

Survey planning and procedures are consistent with the methods described in the Decommissioning Plan. The soil survey procedures are summarized in this section and can be found in greater detail in Appendices D-2 and D-3 of the March, 1996 Response to Comments.

3.4.1 Area Classification

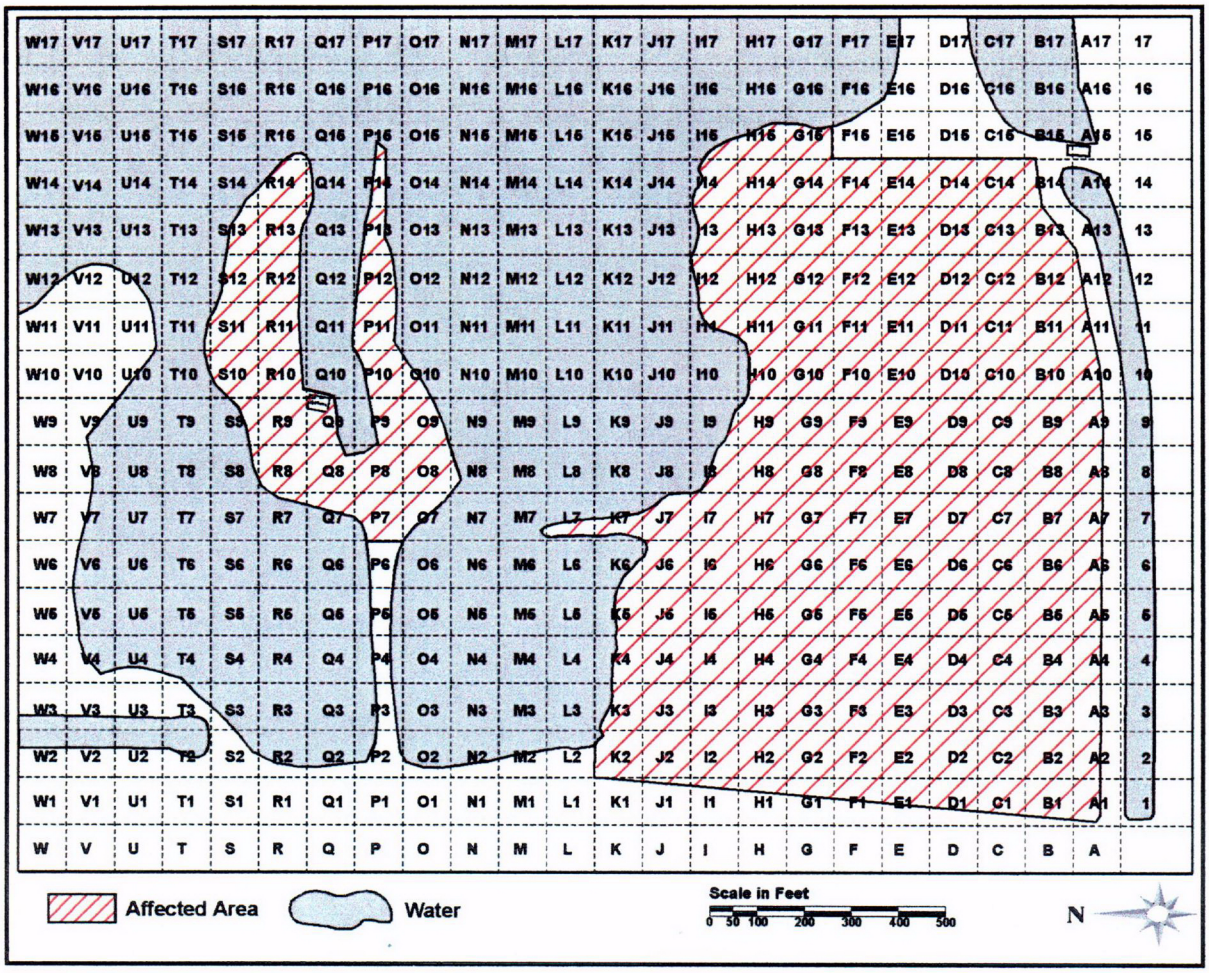
The Bay City storage site was divided into affected and unaffected areas to establish the sampling pattern and frequency. The basis for the affected and unaffected classification, as applied to the Bay City site are:

- **Affected Area** – As shown in Figure 3-2, the thorium material storage area and region immediately surrounding the storage area was defined as the affected area based on both historical records and prior characterization surveys. This location had known thorium contamination in the soil that had been placed there via backfill operations and storage.

- **Unaffected Area** – The region surrounding the affected area (see Figure 3-2) was treated as unaffected since it did not contain residual radioactivity.

Figure 3-2

Bay City Site Affected Areas



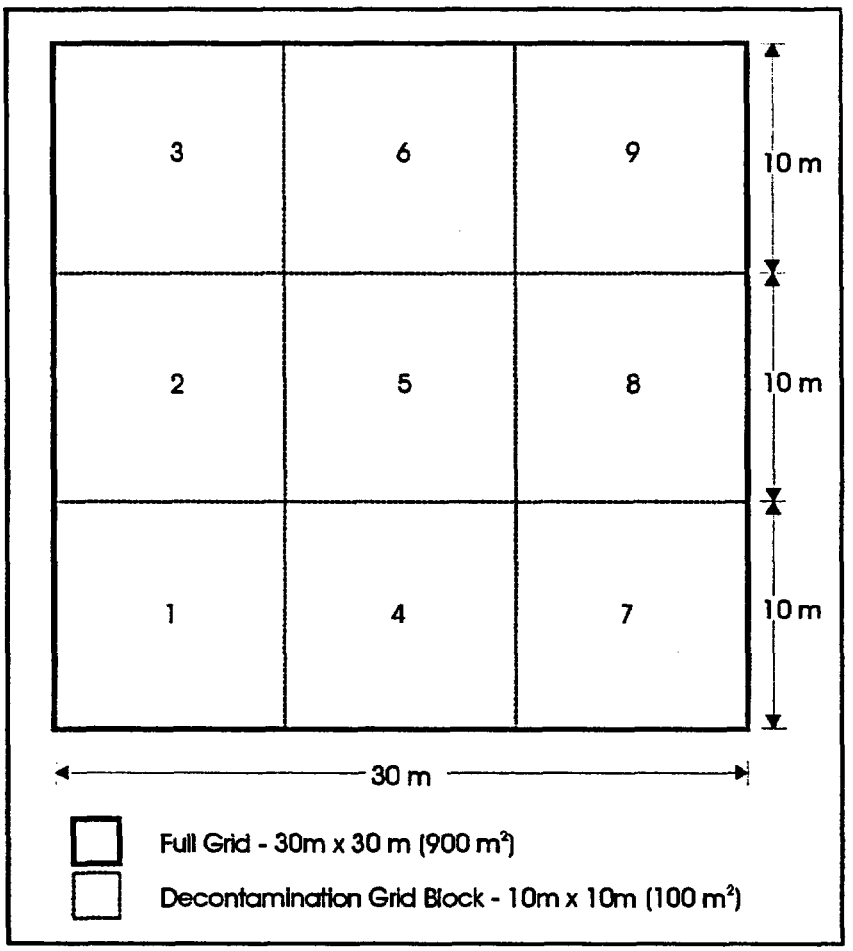
3.4.2 Reference Grid

A grid was established over the affected area upon completion of material excavation for the purpose of referencing locations of samples and measurements (see Figure 3-2). These full grids were 30m x 30m (900 m^2) in size. Each full grid was then divided into nine 10m x 10m sub-grids (100 m^2 each). Each sub-grid was marked into 2.5m increments to establish the nine individual soil sample locations taken to obtain one composite sample per sub-grid. Figure 3-3 depicts the breakdown of the reference grid system. As previously noted, the entire Section III (affected area) constituted the survey unit.

C07

Figure 3-3

Reference Grid System



3.4.3 Surface Scans

One hundred percent of the soil surface was initially scanned to identify locations of elevated activity. The gamma scans were conducted in accordance with procedure SOP 1.5, Measurement of Gamma-Ray Fields using a Sodium Iodide (NaI) Detector. As soil was removed, additional gamma scans were conducted to identify remaining locations of contaminated soil. After completion of contaminated soil removal, a final scan was performed of the soil surface prior to obtaining final verification soil samples.

3.4.4 Soil sampling

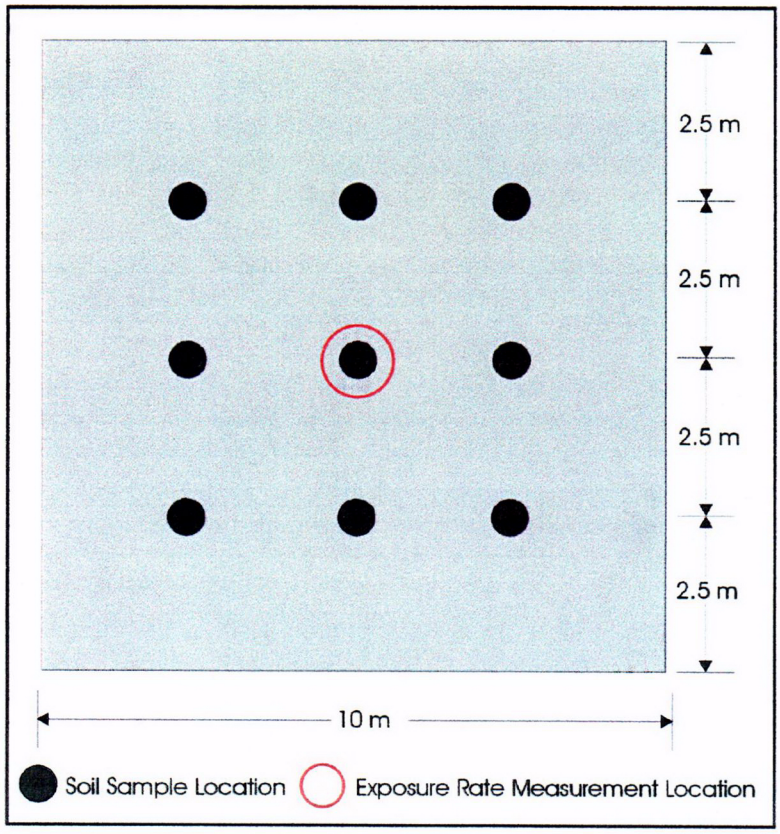
Final survey soil samples consisted of one composite sample obtained from nine individual samples (approximately 1 kg each) from each sub-grid (see Figure 3-4). The samples were collected after gamma levels were measured to preliminarily determine that all contaminated soil had been removed. Each of the nine locations where the individual samples were collected was scanned prior to soil sampling to validate that elevated levels did not exist (>3 times background). These final verification soil samples were analyzed on site through gamma spectroscopy. When the gamma spectral analysis results showed the Th-232 levels to be less than the guideline value, the final verification samples were then sent to the Freeport, Texas laboratory for gamma and alpha spectral analysis and confirmation that residual contamination limits have been met. Ten percent of the samples were split for QA analysis by three outside certified laboratories (Paragon Analytics, American Radiation Services and SRC Analytical). Soil sample collection was performed in accordance with procedure SOP 1.8, Guide to the Handling, Packaging and Shipping of Samples, and SOP 1.9, Sample Control and Documentation.

3.4.5 Exposure Rate Measurements

Gamma exposure rates were measured in the affected area at 1 meter above the soil surface at the midpoint of each sub-grid (see Figure 3-4). Exposure rate measurements were obtained using a Ludlum Model 19 MicroR meter.

Figure 3-4

Sampling Pattern for Composite Preparation Within Decontaminated Grid Block



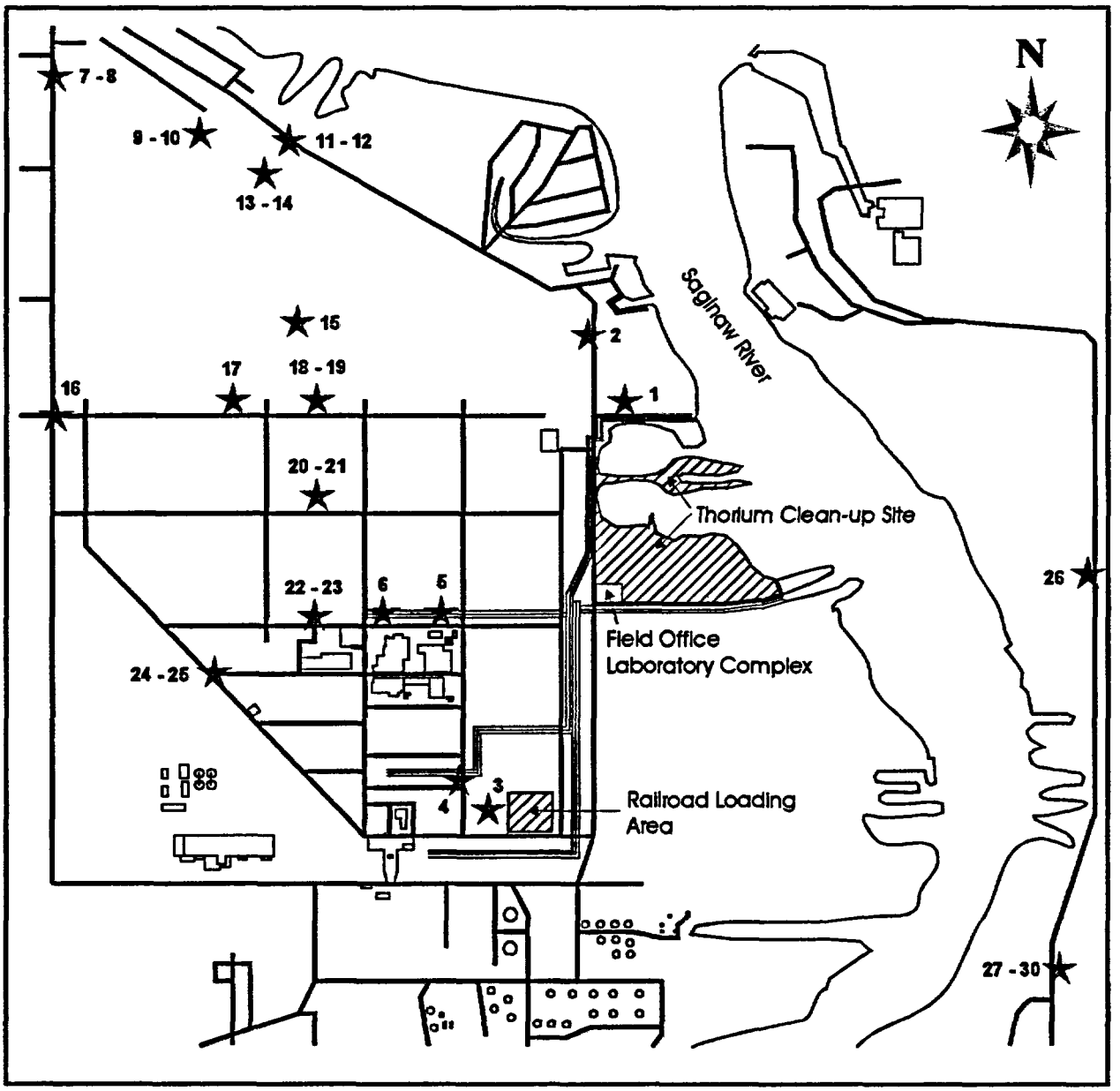
3.5 BACKGROUND LEVEL DETERMINATION

Background soil samples were collected from 30 locations in the unaffected area (Figure 3-5), and 29 samples analyzed for Th-230, Th-232, and Th-228 concentrations in the Freeport Laboratory (sample no. 14 was lost in transit). Sample numbers 1-25 were collected from locations on Dow property that were not impacted by site operations. Sample numbers 26-30 were collected from locations east of the Dow property, across the Saginaw River. Background exposure rates were measured at the same locations as the soil samples. Statistical procedures described in NUREG/CR-5849 (see Table A6) were used to assure that the average thorium concentrations determined were representative of true average background levels.

C08

Figure 3-5

Background Sample Locations



3.6 SAMPLE ANALYSIS

Final survey soil samples were analyzed for Th-232 in the field laboratory using the NaI detector coupled to the MCA. Soil samples were analyzed in accordance with "Procedure for Counting

Soil Samples for EOP Characterization". The final verification samples were analyzed for Th-232, Th-230, and Th-228 using gamma and alpha spectroscopy in the Freeport Laboratory.

3.7 DATA INTERPRETATION

Soil sample locations and survey results for fixed measurements were recorded on data sheets. The data conversion and statistical analysis techniques in NUREG/CR-5849 (Chapter 8.0) were used to convert the reported data into a form that permitted a direct comparison with residual contamination guidelines and thus assess if remediation goals were met. The statistical relationships are shown with the analyzed data in Appendix A (Tables A6, A7). Soil concentrations were converted into units of pCi/g and exposure rates to μR/h. The reported affected area data in Appendix A has been adjusted by subtracting the natural background levels.

Additional soil removal was performed when the remediation control survey measurements showed that residual contamination guidelines were not being met. As a result, there were no remaining "hot spots" and "hot spot" averaging criteria were not applied.

3.8 RECORDS

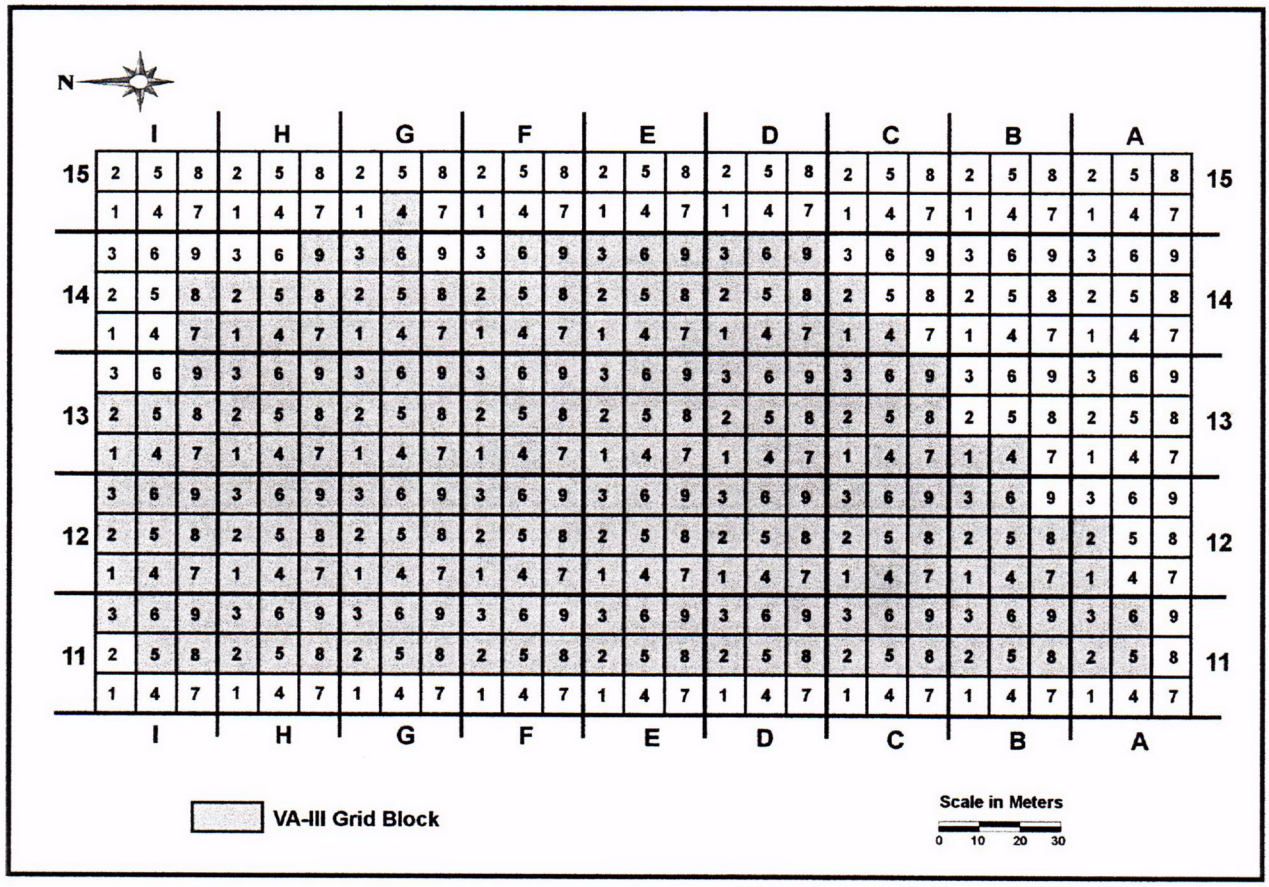
All soil samples, original survey data records, and log-books have been archived at the Dow Bay City facility and will be held until after license termination.

4.0 SURVEY FINDINGS AND RESULTS

Appendix A contains the radiological database collected during the final status survey for VA-III (as defined in Figure 4-1) that provides the basis for verifying that the residual contamination objectives have been achieved for this area at the Bay City thorium site. Summary Tables, data interpretations and statistical comparisons with residual contamination guidelines in VA-III are included in Appendix A.

Figure 4-1

Grid Locations for VA-III



4.1 BACKGROUND LEVELS

Background soil concentrations (Table A1) averaged 0.30 pCi/g for Th-232, 0.49 pCi/g for Th-230, and 0.31 pCi/g for Th-228. Background exterior exposure rates averaged 5 μR/h (Table A2). Both the number of data points collected to obtain the average background soil concentrations and exposure rates are more than sufficient to meet the test for demonstrating that the measured average background is within ± 20% of the true average at the 95% confidence level.

C09

4.2 GROUND SURVEYS

4.2.1 Scans

Surface scans were used during the remediation control survey to identify locations of elevated gamma radiation to guide the excavation of the material and locate remaining hot spots. A total of 10 discreet areas of elevated activity were identified during the verification scan survey. These areas were remediated and re-scanned with satisfactory results.

4.2.2 Thorium Concentrations in Soil

The results of the analyses of the verification soil samples from VA-III are provided in Table A3, and related to the grid locations shown in Figure 4-1. QA soil analyses, performed by the outside laboratories on splits of 10 percent of the FSS samples, are shown in Table A3 together with the analyses of the same soil performed at Dow's Freeport Laboratory. None of the verification or QA samples contained total thorium concentrations in excess of the soil residual activity guideline (see Section 2.3). Analysis of the mean concentration of Th-232 shows that the concentration meets the guideline value at the 95% confidence level (Tables A6, A7). The number of samples collected (265 in VA-III) is much greater than the number (<9) statistically required to demonstrate that the concentrations satisfies the guideline value at the 95% confidence level (Table A7).

The maximum total residual thorium concentrations (above background) as measured in sample BCS-F13-3v1 was 12.21 pCi/g which is less than the residual guideline of 14.5 pCi/g.

Since none of the verification soil sample concentrations in VA-III exceeded the guideline value (no hot spots) it was not necessary to apply averaging techniques in any of the grids.

All of the verification soil samples in VA-III (Table A3) meet the criteria that the sum of the ratios of the concentration of each radionuclide to its respective guideline must not exceed 1 (Appendix A of NUREG/CR-5849).

4.2.3 Exposure Rates

Exposure rate measurements of the remediated VA-III areas (Figure 4-1) and for each grid block are provided in Table A5. All individual values are within the guideline levels of 5 μR/h above background with the exception of sub-grids C11-2 and D11-8 where the exposure rate was 6 μR/h. The average exposure rate for the C11 grid is 4.7 μR/h and 5.0 μR/h for the D11 grid, thus meeting the criteria of 5 μR/h for both grids. Analysis of the statistical mean also shows that the exposure rates in VA-III meet the guideline at the 95% confidence level (Tables A6, A7). The number of measurements (207) is far in excess of the number required (<9) to demonstrate that the exposure rate satisfies the guideline value at the 95% confidence level (Table A7).

4.2.4 NRC Confirmatory Surveys

The NRC performed an inspection of VA-III on October 28th and 29th of 1997. This inspection included the performance of a confirmatory survey. Approximately 20% of VA-III was scanned using a sodium iodide detector. One "hot spot" was identified that was determined to be a piece of slag. The slag was immediately removed and the area re-scanned with satisfactory results. Dow personnel collected 25 soil samples, per NRC staff direction, at random areas throughout the survey unit. The soil samples were analyzed for Th-232 at the Bay City field laboratory, under inspector observation, following QA/QC and calibration checks of the counting systems. When analyzed, no detectable activity above release guidelines was found in any of the samples. Exposure rate measurements were also conducted with all readings in the acceptable ranges.

Since the confirmatory survey did not identify any areas of elevated activity, no further remediation was performed and no additional final status surveys were required. Although a piece of slag was identified during the inspection, it was immediately removed and disposed of. Although it is unknown if additional soil samples were collected at the location of the slag, it is reasonable to assume that the slag was the source of the elevated measurement since the re-scan of the area showed no elevated activity, and therefore, no additional sampling was necessary.

5.0 SUMMARY

Decontamination of the affected area by soil removal at Dow's Bay City facility is an ongoing process. Since the affected area is quite large it is more efficient for Dow to verify that residual contamination criteria have been met in sections, and for the NRC to subsequently validate each section. Thus area VA-III has been verified and the evaluated database from the final status survey provided in the Appendix. Remediation control surveys were performed to guide the decontamination effort, and a final status survey conducted of VA-III during September, 1997. Independent QA analysis of soil samples was performed. Results of the final status survey demonstrate that the decontamination program successfully reduced residual activity in VA-III to within the NRC limits for unrestricted use. As each subsequent VA is surveyed, a FSSR will be submitted to NRC.

6.0 REFERENCES

6.1 Dow Decommissioning Work Plan, October 1993

6.2 Supplement to the Decommissioning Work Plan, December 1995

6.3 Letter from Dow to NRC, Response to Comments, March 1996

6.4 NUREG/CR-5849, Manual for Conducting Radiological Surveys in Support of License Termination (Draft for Comment), December 1993

6.5 NRC Inspection Report No. 040-00017/97003 (DNMS), January 7, 1998

6.6 Letter from NRC to Dow, Review of Final Status Survey Reports for the Previously Remediated Areas VA-I through VA-VI, Dow Chemical Company's Bay City, MI, SDMP Site (TAC# L60463), August 16, 2002

6.7 Dow "Background Radiological Survey", October 11-13, 1989

6.8 Dow Bay City Site Procedures

- 6.8.1 SOP 1.1, Access Control Procedures
- 6.8.2 SOP 1.2, Total Alpha Surface Contamination Measurements
- 6.8.3 SOP 1.3, External Dosimetry Procedure
- 6.8.4 SOP 1.4, Beta-Gamma Radiation Measurements using a Geiger-Muller Detector
- 6.8.5 SOP 1.5, Measurement of Gamma-Ray Fields using a Sodium Iodide (NaI) Detector
- 6.8.6 SOP 1.6, Intermediate Volume Air Particulate Sampling
- 6.8.7 SOP 1.7, Sampling for Removable Alpha Contamination
- 6.8.8 SOP 1.8, Guide to the Handling, Packaging and Shipping of Samples
- 6.8.9 SOP 1.9, Sample Control and Documentation
- 6.8.10 SOP 1.10, Radiation Work Permits
- 6.8.11 SOP 1.11, Respiratory Protection Program
- 6.8.12 "Procedure for Counting Soil Samples for EOP Characterization"
- 6.8.13 Dow Central Research Index Report, CRI-TSP-92-076, "Radiological Analysis of Soil Samples from the Madison, Illinois Storage Facility Utilizing a Revised Alpha Spectroscopic Method"

Appendix A

Final Status Survey

Verification Measurements / Analyses

Table A1

BACKGROUND SOIL CONCENTRATIONS							
Bay City							
Sample Name	^{232}Th (pCi/G)	Error (2σ)	MDA (pCi/G)	^{230}Th (pCi/G)	Error (2σ)	^{228}Th (pCi/G)	Error (2σ)
BCBKG01	0.39	0.08	0.13	1.04	0.84	0.48	0.44
BCBKG02	0.36	0.07	0.14	0.46	0.34	0.41	0.31
BCBKG03	0.28	0.08	0.11	0.38	0.31	0.35	0.29
BCBKG04	0.44	0.10	0.13	0.80	0.91	0.62	0.74
BCBKG05	0.43	0.10	0.15	0.70	0.51	0.52	0.40
BCBKG06	0.51	0.18	0.13	0.68	0.47	0.48	0.35
BCBKG07	0.38	0.19	0.13	2.30	3.69	0.77	1.38
BCBKG08	0.16	0.08	0.11	0.37	0.48	0.12	0.20
BCBKG09	0.13	0.07	0.10	0.21	0.25	0.09	0.12
BCBKG10	0.26	0.09	0.13	0.38	0.39	0.23	0.26
BCBKG11	0.19	0.07	0.11	0.04	0.04	0.14	0.10
BCBKG12	0.18	0.08	0.14	0.18	0.14	0.11	0.09
BCBKG13	0.18	0.08	0.14	0.21	0.12	0.19	0.11
BCBKG15	0.23	0.07	0.11	0.12	0.15	0.32	0.31
BCBKG16	0.56	0.12	0.16	0.76	0.51	0.66	0.46
BCBKG17	0.41	0.10	0.16	0.30	0.47	0.30	0.47
BCBKG18	0.10	0.08	0.12	0.18	0.21	0.16	0.19
BCBKG19	0.12	0.06	0.10	0.15	0.14	0.06	0.07
BCBKG20	0.14	0.07	0.11	0.29	0.25	0.09	0.09
BCBKG21	0.19	0.07	0.15	0.23	0.17	0.13	0.11
BCBKG22	0.20	0.07	0.10	0.36	0.39	0.13	0.18
BCBKG23	0.15	0.06	0.11	0.24	0.24	0.30	0.29
BCBKG24	0.12	0.08	0.11	0.13	0.16	0.05	0.08
BCBKG25	0.22	0.07	0.08	0.93	0.89	0.72	0.70
BCBKG26	0.32	0.09	0.13	0.27	0.23	0.16	0.15
BCBKG27	0.56	0.20	0.20	0.93	0.69	0.90	0.67
BCBKG28	0.68	0.24	0.20	0.41	0.45	0.07	0.14
BCBKG29	0.43	0.19	0.21	0.65	1.22	0.43	0.89
BCBKG30	0.34	0.08	0.15	0.44	0.45	0.10	0.16
AVERAGE	0.30			0.49		0.31	
St. Dev.	0.16			0.44		0.24	

Table A2

Background Exposure Rates – Bay City

Sample	Value (μR/hr)
BCBKG1	5
BCBKG2	7
BCBKG3	5
BCBKG4	6
BCBKG5	4
BCBKG6	4
BCBKG7	5
BCBKG8	5
BCBKG9	5
BCBKG10	6
BCBKG11	5
BCBKG12	6
BCBKG13	5
BCBKG14	5
BCBKG15	7
BCBKG16	5
BCBKG17	4
BCBKG18	5
BCBKG19	5
BCBKG20	4
BCBKG21	4
BCBKG22	4
BCBKG23	4
BCBKG24	3
BCBKG25	3
ACROSS THE RIVER	
BCBKG26(1)	3
BCBKG27(2)	5
BCBKG28(3)	5
BCBKG29(4)	4
BCBKG30(5)	5

Number of measurements: 30
Average: 5 μR/hr
Standard Deviation: 1.3 μR/hr (≅ 1.0 μR/hr)

Table A3

Final Verification Soil Concentrations – VA-III

Sample Name	^{232}Th (pCi/G)	Error (2σ)	MDA (^{212}Pb, pCi/G)	^{230}Th (pCi/g)	Error (2σ)	^{228}Th (pCi/g)	Error (2σ)	^{232}Th (Net) (pCi/G)	^{230}Th (Net) (pCi/g)	^{228}Th (Net) (pCi/g)	TOTAL Thonum
BCS-A11-2v1	0.41	0.23	0.19	1.03	1.14	1.03	1.14	0.11	0.54	0.72	1.36
BCS-A11-3v1	0.29	0.20	0.26	0.34	0.27	0.25	0.21	-0.01	-0.15	-0.06	-0.21
BCS-A11-5v1	0.39	0.18	0.29	0.55	0.36	0.35	0.24	0.09	0.06	0.04	0.19
BCS-A11-6v1	0.39	0.20	0.21	0.48	0.35	0.39	0.29	0.09	-0.01	0.08	0.17
BCS-A12-1v1	0.20	0.15	0.22	0.33	0.31	0.25	0.24	-0.10	-0.16	-0.06	-0.32
BCS-A12-1v1-R	0.38	0.21	0.29	0.56	0.38	0.29	0.21	0.08	0.07	-0.02	0.13
BCS-A12-2v1	0.30	0.16	0.22	0.47	0.38	0.40	0.33	0.00	-0.02	0.09	0.07
BCS-B11-2v1	1.01	0.33	1.75	1.43	0.82	1.01	0.61	0.71	0.94	0.70	2.35
BCS-B11-2v2	0.71	0.30	0.39	1.11	0.68	0.81	0.52	0.41	0.62	0.50	1.53
BCS-B11-2v2-R	0.84	0.32	0.41	0.94	0.54	0.77	0.46	0.54	0.45	0.46	1.45
BCS-B11-3v1	0.40	0.17	0.24	0.54	0.27	0.46	0.23	0.10	0.05	0.15	0.30
BCS-B11-3v1-R	0.38	0.19	0.27	0.38	0.43	0.29	0.34	0.08	-0.11	-0.02	-0.05
BCS-B11-3v2	0.78	0.26	0.33	1.17	0.69	0.92	0.56	0.48	0.68	0.61	1.78
BCS-B11-5v1	0.63	0.22	0.29	0.97	0.73	0.85	0.65	0.33	0.48	0.54	1.35
BCS-B11-6v1	0.39	0.18	0.18	0.53	0.39	0.35	0.27	0.09	0.04	0.04	0.16
BCS-B11-8v1	0.13	0.18	0.30	0.25	0.41	0.17	0.28	-0.17	-0.24	-0.15	-0.56
BCS-B11-9v1	0.31	0.18	0.20	1.11	1.30	0.37	0.50	0.01	0.62	0.06	0.69
BCS-B12-1v1	0.42	0.19	0.23	0.72	0.58	0.60	0.50	0.12	0.23	0.29	0.65
BCS-B12-2v1	0.27	0.14	0.15	0.38	0.43	0.57	0.61	-0.03	-0.11	0.26	0.13
BCS-B12-3v1	0.52	0.21	0.14	0.63	0.43	0.58	0.41	0.22	0.14	0.27	0.63
BCS-B12-4v1	0.28	0.13	0.17	0.56	0.67	0.67	0.79	-0.02	0.07	0.36	0.42
BCS-B12-5v1	0.61	0.18	0.19	1.65	0.72	0.59	0.29	0.31	1.16	0.28	1.74
BCS-B12-5v1	1.24	0.32	0.29	1.69	0.77	1.39	0.65	0.94	1.20	1.08	3.21
BCS-B12-6v1	0.51	0.15	0.17	1.24	0.60	0.47	0.26	0.21	0.75	0.16	1.11
BCS-B12-7v1	0.21	0.12	0.19	0.33	0.32	0.33	0.32	-0.09	-0.16	0.02	-0.22
BCS-B12-8v1	1.27	0.25	0.28	2.14	1.06	0.62	0.41	0.97	1.65	0.31	2.93
BCS-B13-1v1	0.61	0.17	0.20	0.59	0.33	0.43	0.26	0.31	0.10	0.12	0.53
BCS-B13-4v1	0.51	0.32		0.58	0.46	0.32	0.28	0.21	0.09	0.01	0.32
BCS-C11-2v1	0.41	0.20	0.25	0.36	0.39	0.09	0.15	0.11	-0.13	-0.22	-0.24
BCS-C11-3v1	0.22	0.14	0.24	0.03	0.07	0.12	0.17	-0.08	-0.46	-0.19	-0.73
BCS-C11-5v1	0.39	0.11	0.15	0.11	0.13	0.11	0.13	0.09	-0.38	-0.20	-0.49
BCS-C11-6v1	0.25	0.16	0.23	0.22	0.15	0.22	0.15	-0.05	-0.27	-0.09	-0.41
BCS-C11-6v1-R	0.30	0.16	0.26	0.43	0.25	0.29	0.17	0.00	-0.06	-0.02	-0.09
BCS-C11-8v1	0.11	0.18	0.29	0.08	0.14	0.07	0.12	-0.19	-0.41	-0.24	-0.84
BCS-C11-8v1-R	0.40	0.19	0.27	1.02	0.81	0.68	0.56	0.10	0.53	0.37	1.01
BCS-C11-9v1	0.32	0.18	0.27	0.47	0.29	0.33	0.21	0.02	-0.02	0.02	0.02
BCS-C12-1v1	0.29	0.16	0.23	0.44	0.62	0.15	0.27	-0.01	-0.05	-0.16	-0.22
BCS-C12-2v1	0.32	0.14	0.19	0.51	0.29	0.38	0.22	0.02	0.02	0.07	0.10
BCS-C12-3v1	0.39	0.23	0.18	0.00	0.00	0.00	0.00	0.09	-0.49	-0.31	-0.71
BCS-C12-4v1	0.42	0.18	0.25	0.65	0.36	0.56	0.32	0.12	0.16	0.25	0.53
BCS-C12-5v1	0.25	0.15	0.28	0.32	0.21	0.28	0.19	-0.05	-0.17	-0.03	-0.26
BCS-C12-6v1	0.28	0.14	0.20	0.56	1.41	0.00	0.00	-0.02	0.07	-0.31	-0.25
BCS-C12-7v1	0.21	0.19	0.23	0.30	0.43	0.13	0.22	-0.09	-0.19	-0.18	-0.47
BCS-C12-8v1	0.34	0.20	0.31	0.53	0.37	0.46	0.32	0.04	0.04	0.15	0.23
BCS-C12-9v1	0.20	0.14	0.20	0.25	0.18	0.18	0.13	-0.10	-0.24	-0.13	-0.47
BCS-C12-9v1-R	0.53	0.21	0.36	0.94	0.67	0.68	0.51	0.23	0.45	0.37	1.05
BCS-C13-1v1	0.36	0.21	0.25	0.36	0.36	0.22	0.24	0.06	-0.13	-0.09	-0.15
BCS-C13-2v1	0.34	0.30	0.21	0.22	0.27	0.12	0.17	0.04	-0.27	-0.19	-0.41
BCS-C13-3v1	0.19	0.11	0.15	0.21	0.16	0.16	0.12	-0.12	-0.28	-0.15	-0.54
BCS-C13-3v1-R	0.13	0.12	0.18	0.13	0.29	0.13	0.29	-0.17	-0.36	-0.18	-0.71
BCS-C13-4v1	0.16	0.15	0.18	0.19	0.21	0.10	0.11	-0.14	-0.30	-0.21	-0.64
BCS-C13-5v1	0.63	0.26		0.57	0.38	0.57	0.38	0.33	0.08	0.26	0.66
BCS-C13-6v1	0.19	0.14	0.20	0.12	0.15	0.15	0.18	-0.12	-0.37	-0.16	-0.64
BCS-C13-7v1	0.28	0.10	0.17	0.19	0.15	0.12	0.11	-0.02	-0.30	-0.19	-0.52

Table A3

Sample	^{232}Th	Error	MDA	^{230}Th	Error	^{228}Th	Error	^{232}Th (Net)	^{230}Th (Net)	^{228}Th (Net)	TOTAL
Name	(pCi/G)	(2σ)	(pCi/G)	(pCi/g)	(2σ)	(pCi/g)	(2σ)	(pCi/G)	(pCi/g)	(pCi/g)	Thorium
BCS-C13-8v1	0.45	0.21	0.29	0.69	0.59	0.80	0.66	0.15	0.20	0.49	0.84
BCS-C13-9v1	0.50	0.21		0.46	0.30	0.37	0.25	0.20	-0.03	0.06	0.23
BCS-C13-9v1-R	0.18	0.17	0.23	0.00	0.00	0.65	1.20	-0.12	-0.49	0.34	-0.27
BCS-C14-1v1	0.21	0.13	0.16	0.19	0.14	0.19	0.14	-0.09	-0.30	-0.12	-0.51
BCS-C14-2v1	0.24	0.11	0.14	0.31	0.22	0.12	0.10	-0.06	-0.18	-0.19	-0.43
BCS-C14-4v1	0.31	0.12	0.11	0.48	0.24	0.40	0.21	0.01	-0.01	0.09	0.09
BCS-D11-2v1	0.68	0.21	0.25	1.14	1.70	0.68	1.14	0.38	0.65	0.37	1.41
BCS-D11-3v1	0.47	0.15	0.17	0.34	0.24	0.27	0.20	0.17	-0.15	-0.04	-0.01
BCS-D11-5v1	0.43	0.16	0.21	0.96	0.45	0.40	0.20	0.13	0.47	0.09	0.69
BCS-D11-6v1	0.27	0.17	0.23	0.27	0.33	0.23	0.29	-0.03	-0.22	-0.08	-0.34
BCS-D11-8v1	0.53	0.34	0.25	0.67	0.47	0.70	0.49	0.23	0.18	0.39	0.80
BCS-D11-9v1	0.18	0.12	0.17	0.27	0.20	0.18	0.13	-0.12	-0.22	-0.13	-0.47
BCS-D12-1v1	0.37	0.21	0.16	0.47	0.32	0.29	0.21	0.07	-0.02	-0.02	0.03
BCS-D12-1v1-R	0.25	0.13	0.17	0.49	0.28	0.28	0.16	-0.05	0.00	-0.03	-0.09
BCS-D12-2v1	0.16	0.12	0.18	0.11	0.21	0.16	0.29	-0.14	-0.38	-0.15	-0.68
BCS-D12-3v1	0.64	0.27	0.46	1.73	1.42	1.33	1.12	0.34	1.24	1.02	2.59
BCS-D12-4v1	0.23	0.18	0.28	0.23	0.19	0.19	0.17	-0.07	-0.26	-0.12	-0.46
BCS-D12-5v1	0.38	0.16	0.21	0.45	0.25	0.42	0.23	0.08	-0.04	0.11	0.15
BCS-D12-5v1-R	0.47	0.14	0.16	0.38	0.52	0.47	0.61	0.17	-0.11	0.16	0.22
BCS-D12-6v1	0.40	0.16	0.27	0.41	0.28	0.33	0.23	0.10	-0.08	0.02	0.04
BCS-D12-7v1	0.56	0.23	0.35	0.66	0.45	0.71	0.47	0.26	0.17	0.40	0.82
BCS-D12-8v1	0.81	0.26	0.23	1.24	0.71	0.81	0.49	0.51	0.75	0.50	1.77
BCS-D12-9v1	0.28	0.14	0.25	0.08	0.08	0.04	0.05	-0.02	-0.41	-0.27	-0.71
BCS-D12-9v1-R	0.28	0.11	0.21	0.33	0.19	0.21	0.13	-0.02	-0.16	-0.10	-0.28
BCS-D13-1v1	0.27	0.16	0.24	0.44	0.30	0.35	0.24	-0.03	-0.05	0.04	-0.03
BCS-D13-2v1	0.23	0.14	0.20	0.35	0.30	0.36	0.31	-0.07	-0.14	0.05	-0.16
BCS-D13-2v1-R	0.26	0.16	0.23	0.00	0.00	0.26	0.75	-0.04	-0.49	-0.05	-0.58
BCS-D13-3v1	0.44	0.18	0.27	0.84	0.54	0.51	0.35	0.14	0.35	0.20	0.69
BCS-D13-4v1	0.68	0.30	0.46	1.75	1.75	0.49	0.61	0.38	1.25	0.18	1.82
BCS-D13-4v1-R	0.68	0.30	0.46	0.89	0.58	0.75	0.50	0.38	0.40	0.44	1.21
BCS-D13-5v1	0.14	0.16	0.25	0.18	0.22	0.12	0.15	-0.16	-0.31	-0.19	-0.65
BCS-D13-6v1	0.27	0.15	0.20	0.34	0.21	0.26	0.17	-0.03	-0.15	-0.05	-0.23
BCS-D13-7v1	0.10	0.12	0.19	0.18	0.23	0.11	0.14	-0.20	-0.31	-0.20	-0.72
BCS-D13-7v1-R	0.45	0.16	0.19	0.79	0.46	0.59	0.36	0.15	0.30	0.28	0.74
BCS-D13-8v1	0.27	0.11	0.15	0.50	0.26	0.29	0.16	-0.03	0.01	-0.02	-0.03
BCS-D13-9v1	0.35	0.15	0.18	0.52	0.28	0.46	0.25	0.05	0.03	0.15	0.24
BCS-D14-1v1	0.37	0.16	0.21	0.41	0.32	0.35	0.28	0.07	-0.08	0.04	0.04
BCS-D14-2v1	0.24	0.15	1.14	0.15	0.11	0.10	0.08	-0.06	-0.34	-0.21	-0.61
BCS-D14-3v1	0.20	0.14	0.21	0.16	0.16	0.08	0.08	-0.10	-0.33	-0.23	-0.66
BCS-D14-4v1	0.06	0.11	0.17	0.10	0.18	0.09	0.17	-0.24	-0.39	-0.22	-0.85
BCS-D14-5v1	0.14	0.11	0.15	0.17	0.14	0.15	0.12	-0.16	-0.32	-0.16	-0.65
BCS-D14-6v1	0.51	0.22	0.15	0.45	0.38	0.57	0.47	0.21	-0.04	0.26	0.43
BCS-D14-7v1	0.10	0.12	0.18	0.08	0.11	0.12	0.15	-0.20	-0.41	-0.19	-0.80
BCS-D14-7v1-R	0.19	0.15	0.23	0.12	0.25	0.00	0.00	-0.12	-0.37	-0.31	-0.79
BCS-D14-7v1-R	0.17	0.14	0.20	0.27	0.23	0.15	0.12	-0.13	-0.22	-0.16	-0.51
BCS-D14-8v1	0.16	0.13	0.19	0.21	0.19	0.21	0.19	-0.14	-0.28	-0.10	-0.52
BCS-D14-9v1	0.14	0.11	0.22	0.19	0.16	0.17	0.14	-0.16	-0.30	-0.14	-0.60
BCS-D14-9v1-R	0.11	0.14	0.22	0.08	0.12	0.05	0.08	-0.20	-0.41	-0.25	-0.86
BCS-E11-2v1	0.44	0.16	0.24	0.22	0.16	0.36	0.23	0.14	-0.27	0.05	-0.07
BCS-E11-3v1	0.74	0.18	0.20	0.39	0.27	0.77	0.46	0.44	-0.10	0.46	0.80
BCS-E11-5v1	0.53	0.25	0.28	1.08	0.79	0.53	0.42	0.23	0.59	0.22	1.04
BCS-E11-5v2	0.43	0.16	0.12	0.57	0.41	0.38	0.30	0.13	0.08	0.07	0.28
BCS-E11-6v1	0.21	0.12	0.18	0.43	1.07	0.85	1.97	-0.09	-0.06	0.54	0.39
BCS-E11-8v1	0.49	0.19	0.13	0.55	0.39	0.55	0.39	0.19	0.06	0.24	0.49
BCS-E11-9v1-R	0.50	0.17	0.20	0.73	0.31	0.54	0.24	0.20	0.24	0.23	0.67
BCS-E11-9v1-R	0.92	0.30	0.35	1.62	1.12	1.02	0.76	0.62	1.13	0.71	2.46
BCS-E12-1v1	1.11	0.33	0.29	2.37	0.80	1.31	0.45	0.81	1.38	1.00	3.69
BCS-E12-1v1-R	0.82	0.25	0.29	1.04	0.44	0.66	0.37	0.52	0.85	0.85	1.82
BCS-E12-3v1	1.04	0.28	0.28	1.93	0.54	1.07	0.45	0.84	0.84	0.76	2.25

Table A3

Sample Name	^{232}Th (pCi/G)	Error (2σ)	MDA (^{212}Pb pCi/G)	^{230}Th (pCi/g)	Error (2σ)	^{228}Th (pCi/g)	Error (2σ)	^{232}Th (Net) (pCi/G)	^{230}Th (Net) (pCi/g)	^{228}Th (Net) (pCi/g)	TOTAL Thorium
BCS-E12-5v1	0.39	0.24	0.22	0.39	1.12	1.94	4.42	0.09	-0.10	1.63	1.62
BCS-E12-6v1	0.90	0.29	0.41	1.46	1.39	0.79	0.85	0.60	0.97	0.48	2.04
BCS-E12-7v1	0.93	0.30	0.37	1.76	1.56	1.14	1.09	0.63	1.27	0.83	2.73
BCS-E12-7v1-R	1.12	0.35	0.35	1.41	0.64	0.97	0.46	0.82	0.92	0.66	2.40
BCS-E12-8v1	0.65	0.22	0.25	0.85	0.36	0.58	0.26	0.35	0.36	0.27	0.98
BCS-E12-8v2	0.73	0.20	0.22	0.48	0.25	0.47	0.24	0.43	-0.01	0.16	0.59
BCS-E12-9v1	0.44	0.15	0.18	0.72	0.40	0.55	0.32	0.14	0.23	0.24	0.62
BCS-E12-9v1	0.75	0.21	0.25	1.06	0.61	0.97	0.57	0.45	0.57	0.66	1.69
BCS-E13-1v1	0.58	0.19	0.26	1.84	0.91	0.81	0.43	0.28	1.35	0.50	2.12
BCS-E13-2v1	1.16	0.35	0.45	3.06	1.25	1.04	0.48	0.86	2.57	0.73	4.16
BCS-E13-4v1-R	0.39	0.18	0.24	0.57	0.38	0.44	0.30	0.09	0.08	0.13	0.31
BCS-E13-4v1-R	0.77	0.25	0.39	1.30	0.80	1.03	0.66	0.47	0.81	0.72	2.00
BCS-E13-4v1-R	0.59	0.20	0.16	1.45	0.77	0.95	0.53	0.29	0.96	0.64	1.88
BCS-E13-5v1	0.37	0.13	0.26	0.37	1.07	0.00	0.00	0.07	-0.12	-0.31	-0.35
BCS-E13-6v1	0.82	0.25	0.42	0.92	0.48	0.70	0.38	0.52	0.43	0.39	1.34
BCS-E13-7v1	0.40	0.16	0.14	0.57	0.33	0.24	0.16	0.10	0.08	-0.07	0.11
BCS-E13-8v1	0.73	0.28	0.49	1.14	0.67	0.73	0.46	0.43	0.65	0.42	1.51
BCS-E13-9v1	0.43	0.26	0.52	0.86	0.69	0.62	0.52	0.13	0.37	0.31	0.80
BCS-E14-1v1	0.35	0.16	0.23	0.55	0.29	0.66	0.35	0.05	0.06	0.35	0.46
BCS-E14-1v1-R	0.39	0.15	0.20	0.00	0.00	0.00	0.00	0.09	-0.49	-0.31	-0.71
BCS-E14-1v1-R	0.48	0.20	0.12	0.47	0.24	0.30	0.16	0.18	-0.02	-0.01	0.15
BCS-E14-2v1	0.23	0.19	0.28	0.14	0.12	0.14	0.13	-0.07	-0.35	-0.17	-0.60
BCS-E14-3v1	0.41	0.16	0.22	0.64	0.39	0.50	0.32	0.11	0.15	0.19	0.45
BCS-E14-4v1	0.51	0.19	0.26	0.61	0.38	0.48	0.31	0.21	0.12	0.17	0.50
BCS-E14-5v1	0.46	0.31	0.48	0.46	0.72	0.34	0.57	0.16	-0.03	0.03	0.16
BCS-E14-6v1	0.22	0.14	0.25	0.30	0.52	0.22	0.16	-0.08	-0.19	-0.09	-0.36
BCS-E14-7v1	0.44	0.15	0.21	0.44	0.90	0.22	0.55	0.14	-0.05	-0.09	0.01
BCS-E14-8v1	0.32	0.14	0.21	0.25	0.36	0.00	0.00	0.02	-0.24	-0.31	-0.53
BCS-E14-9v1	0.25	0.17	0.24	0.16	0.25	0.10	0.19	-0.04	-0.33	-0.21	-0.58
BCS-F11-2v1	0.37	0.13	0.17	0.46	0.33	0.33	0.24	0.07	0.00	0.02	0.08
BCS-F11-3v1	0.53	0.15	0.19	0.33	0.21	0.51	0.30	0.23	-0.16	0.20	0.27
BCS-F11-5v1	0.35	0.13	0.15	0.50	0.46	0.76	0.64	0.06	0.01	0.45	0.52
BCS-F11-6v1	0.38	0.14	0.18	0.57	0.44	0.49	0.39	0.08	0.08	0.18	0.34
BCS-F11-8v1	0.30	0.11	0.14	0.23	0.21	0.28	0.24	0.00	-0.26	-0.03	-0.29
BCS-F11-9v1	1.00	0.20	0.21	0.34	0.18	0.63	0.29	0.70	-0.15	0.32	0.86
BCS-F12-1v1	0.46	0.14	0.15	3.31	2.08	0.71	0.52	0.16	2.82	0.40	3.39
BCS-F12-2v1	0.50	0.16	0.13	0.55	0.51	0.35	0.36	0.20	0.06	0.04	0.30
BCS-F12-3v1	0.32	0.12	0.16	1.38	1.07	0.22	0.16	0.02	1.39	-0.09	1.32
BCS-F12-4v1	0.43	0.16	0.14	0.31	0.21	0.40	0.26	0.13	-0.18	0.09	0.03
BCS-F12-5v1	0.39	0.14	0.18	0.72	0.77	0.52	0.59	0.09	0.23	0.21	0.53
BCS-F12-6v1	0.27	0.12	0.15	0.12	0.10	0.23	0.17	-0.03	-0.37	-0.08	-0.48
BCS-F12-7v1	0.46	0.14	0.16	0.43	0.41	0.76	0.66	0.18	-0.06	0.45	0.57
BCS-F12-8v1	0.56	0.17	0.17	0.39	0.21	0.47	0.24	0.26	-0.10	0.16	0.32
BCS-F12-9v1	0.36	0.17	0.13	0.30	0.23	0.41	0.30	0.06	-0.19	0.10	-0.03
BCS-F13-1v1	0.30	0.13	0.17	1.37	0.81	0.32	0.21	0.00	0.88	0.01	0.90
BCS-F13-2v1	0.73	0.22	0.23	2.53	0.89	0.70	0.25	0.43	2.14	0.39	2.95
BCS-F13-3v1	1.78	0.49	0.43	9.98	3.66	1.55	0.67	1.48	9.49	1.24	12.21
BCS-F13-4v1	0.48	0.14	0.15	1.35	1.46	0.58	0.72	0.18	0.66	0.27	1.30
BCS-F13-5v1	0.36	0.17	0.17	1.30	0.53	0.42	0.18	0.16	0.81	0.11	1.08
BCS-F14-1v1	0.44	0.16	0.26	0.30	0.17	0.21	0.13	0.14	-0.19	-0.10	-0.15
BCS-F14-1v1-R	0.46	0.17	0.16	0.44	0.32	0.42	0.31	0.16	-0.05	0.11	0.22
BCS-F14-1v2	0.46	0.20	0.14	0.26	0.25	0.19	0.21	0.15	-0.23	-0.12	-0.20
BCS-F14-2v1	0.33	0.11	0.15	0.24	0.19	0.29	0.22	0.03	-0.25	-0.02	-0.24
BCS-F14-4v1	0.43	0.17	0.18	0.76	0.34	0.39	0.18	0.13	0.27	0.08	0.48
BCS-F14-5v1	0.96	0.57	1.01	1.25	0.95	0.67	0.55	0.68	0.76	0.36	1.80
BCS-F14-6v2	1.05	0.22	0.22	0.32	0.18	1.04	0.43	0.75	-0.17	0.13	1.31
BCS-F14-7v1	0.31	0.20	0.26	0.34	0.30	0.17	0.17	0.01	-0.15	-0.14	-0.28
BCS-F14-8v1	0.23	0.16	0.26	0.11	0.09	0.14	0.11	-0.06	-0.38	-0.17	-0.61
BCS-F14-9v1	0.47	0.18	0.27	1.23	0.59	0.63	0.34	0.32	0.64	0.22	1.07

Table A3

Sample Name	^{232}Th (pCi/G)	Error (2σ)	MDA (^{228}Th, pCi/G)	^{230}Th (pCi/g)	Error (2σ)	^{234}Th (pCi/g)	Error (2σ)	^{232}Th (Net) (pCi/G)	^{230}Th (Net) (pCi/g)	^{234}Th (Net) (pCi/g)	TOTAL Thorium
BCS-G11-2v1	0.33	0.19	0.14	0.81	0.64	0.33	0.29	0.03	0.32	0.02	0.38
BCS-G11-3v1	0.30	0.12	0.14	0.85	0.59	0.30	0.23	0.00	0.36	-0.01	0.35
BCS-G11-5v1	0.52	0.16	0.19	0.32	0.20	0.51	0.29	0.22	-0.17	0.20	0.25
BCS-G11-6v1	0.58	0.18	0.11	1.30	1.18	0.65	0.66	0.28	0.81	0.34	1.42
BCS-G11-8v1	0.39	0.18	0.19	0.60	0.46	0.41	0.33	0.09	0.11	0.10	0.29
BCS-G11-9v1	0.24	0.11	0.16	0.27	0.28	0.11	0.14	-0.06	-0.22	-0.20	-0.48
BCS-G12-1v1	0.64	0.16	0.18	2.15	0.95	0.49	0.27	0.34	1.66	0.18	2.17
BCS-G12-2v1	0.45	0.22	0.14	1.50	1.20	0.73	0.63	0.15	1.01	0.42	1.59
BCS-G12-3v1	0.53	0.18	0.15	2.16	1.35	0.53	0.39	0.23	1.67	0.22	2.11
BCS-G12-3v1-R	0.38	0.14	0.20	1.38	0.88	0.45	0.33	0.08	0.89	0.14	1.10
BCS-G12-4v1	0.27	0.11	0.16	0.48	0.32	0.31	0.22	-0.03	-0.01	0.00	-0.04
BCS-G12-5v1	0.84	0.19	0.20	3.69	1.50	0.90	0.43	0.54	3.20	0.59	4.33
BCS-G12-5v1-R	0.73	0.18	0.21	3.62	1.59	0.69	0.37	0.43	3.13	0.38	3.94
BCS-G12-6v1	0.32	0.14	0.20	0.72	0.53	0.32	0.26	0.02	0.23	0.01	0.26
BCS-G12-6v1-R	0.44	0.14	0.14	1.35	0.76	0.51	0.32	0.14	0.86	0.20	1.20
BCS-G12-7v1	0.37	0.13	0.16	0.22	0.15	0.39	0.25	0.07	-0.27	0.08	-0.12
BCS-G12-8v1	0.39	0.15	0.19	1.53	0.79	0.33	0.20	0.09	1.04	0.02	1.16
BCS-G12-8v1-R	0.60	0.16	0.16	0.80	0.45	0.68	0.39	0.30	0.31	0.37	0.98
BCS-G12-9v1	0.37	0.14	0.18	0.87	0.57	0.19	0.16	0.07	0.38	-0.12	0.33
BCS-G12-9v1-R	0.41	0.16	0.23	1.09	0.88	0.34	0.33	0.11	0.60	0.03	0.75
BCS-G13-1v1	0.42	0.15	0.18	1.48	0.77	0.35	0.21	0.12	0.99	0.04	1.16
BCS-G13-1v1-R	0.66	0.17	0.16	2.49	1.09	0.67	0.34	0.36	2.00	0.36	2.72
BCS-G13-2v1	0.62	0.19	0.17	1.78	0.79	0.64	0.32	0.32	1.29	0.33	1.94
BCS-G13-2v1-R	0.89	0.21	0.23	1.72	0.73	0.68	0.34	0.59	1.23	0.37	2.18
BCS-G13-3v1	0.63	0.18	0.20	0.79	0.65	0.85	0.69	0.33	0.30	0.54	1.17
BCS-G13-4v1	0.28	0.13	0.15	0.68	0.49	0.48	0.36	-0.02	0.19	0.17	0.34
BCS-G13-4v1-R	0.20	0.24	0.18	0.48	0.45	0.30	0.29	0.00	-0.01	-0.01	-0.02
BCS-G13-5v1	0.72	0.21	0.21	2.04	0.96	0.64	0.35	0.42	1.55	0.33	2.30
BCS-G13-5v1-R	0.76	0.17	0.20	2.75	1.15	0.82	0.40	0.46	2.26	0.51	3.23
BCS-G13-6v1	0.77	0.22	0.20	2.01	0.98	0.84	0.46	0.47	1.52	0.53	2.52
BCS-G13-7v1	0.73	0.20	0.17	2.82	1.40	0.81	0.47	0.43	2.33	0.50	3.26
BCS-G13-8v1	0.44	0.13	0.13	2.16	1.42	0.59	0.46	0.14	1.67	0.28	2.09
BCS-G13-9v1	0.37	0.13	0.16	1.70	1.24	0.49	0.41	0.07	1.21	0.18	1.46
BCS-G14-1v1	0.62	0.18	0.17	0.58	0.35	0.43	0.28	0.32	0.09	0.12	0.52
BCS-G14-2v1	0.30	0.18	0.16	0.30	0.29	0.37	0.34	0.00	-0.19	0.06	-0.12
BCS-G14-3v1	0.91	0.27	0.26	0.30	0.19	0.81	0.40	0.61	-0.19	0.50	0.92
BCS-G14-4v1	0.58	0.15	0.16	1.04	0.57	0.71	0.41	0.28	0.55	0.40	1.24
BCS-G14-5v1	0.39	0.16	0.17	1.01	1.14	0.54	0.68	0.09	0.52	0.23	0.84
BCS-G14-6V1	0.56	0.20	0.47	0.25	0.19	0.46	0.30	0.26	-0.23	0.15	0.18
BCS-G14-7v1	0.75	0.21	0.20	1.73	1.12	0.58	0.45	0.45	1.24	0.27	1.95
BCS-G14-8v1	0.51	0.15	0.18	0.44	0.31	0.42	0.29	0.21	-0.05	0.11	0.28
BCS-G15-4v1	0.36	0.18	0.25	0.33	0.19	0.32	0.19	0.06	-0.16	0.01	-0.10
BCS-H11-2v1	0.57	0.17	0.18	1.94	1.11	0.70	0.45	0.27	1.45	0.39	2.10
BCS-H11-3v1	1.25	0.30	0.26	9.41	3.47	1.12	0.50	0.95	8.92	0.81	10.68
BCS-H11-5v1	0.72	0.17	0.17	4.52	1.91	0.51	0.28	0.42	4.03	0.20	4.65
BCS-H11-6v1	0.73	0.21	0.20	7.31	4.19	1.18	0.79	0.43	6.82	0.87	8.12
BCS-H11-8v1	0.46	0.15	0.19	1.72	0.81	0.45	0.24	0.16	1.23	0.14	1.52
BCS-H11-9v1	0.48	0.18	0.17	1.40	0.85	0.46	0.32	0.18	0.91	0.15	1.24
BCS-H12-1v1	0.67	0.22	0.22	5.56	2.52	0.70	0.37	0.37	5.07	0.39	5.84
BCS-H12-2v1	0.38	0.15	0.14	1.81	1.38	0.54	0.36	0.08	1.32	0.23	1.64
BCS-H12-3v1	0.46	0.16	0.17	2.56	1.54	0.37	0.27	0.18	2.17	0.06	2.40
BCS-H12-4v1	0.77	0.20	0.24	5.31	2.85	0.84	0.46	0.47	5.82	0.53	6.83
BCS-H12-5v1	0.40	0.16	0.14	2.97	1.79	0.60	0.41	0.10	2.48	0.29	2.97
BCS-H12-6v1	0.25	0.10	0.14	0.22	0.14	0.15	0.10	-0.05	-0.27	-0.16	-0.48
BCS-H12-7v1	0.39	0.13	0.12	1.80	1.07	0.33	0.24	0.09	1.31	0.02	1.41
BCS-H12-7v1-R	0.34	0.15	0.12	1.27	0.89	0.34	0.27	0.04	0.78	0.03	0.85
BCS-H12-8v1	0.22	0.08	0.12	0.55	0.40	0.27	0.21	-0.08	0.06	-0.04	-0.07
BCS-H12-9v1	0.24	0.11	0.16	1.19	0.92	0.30	0.26	-0.06	0.70	-0.01	0.63
BCS-H12-10v1	1.23	0.18	0.21	1.92	1.25	0.32	0.25	0.14	1.43	0.01	1.58

Table A3

Final Verification Soil Concentrations – VA-III

Sample	^{232}Th	Error	MDA	^{230}Th	Error	^{228}Th	Error	^{232}Th (Net)	^{230}Th (Net)	^{228}Th (Net)	TOTAL
Name	pCi/G	(2σ)	[^{212}Pb pCi/G]	(pCi/g)	(2σ)	(pCi/g)	(2σ)	pCi/G	pCi/g	pCi/g	Thorium
BCS-H13-2v1	0.65	0.24	0.19	2.29	1.11	0.43	0.24	0.35	1.80	0.12	2.27
BCS-H13-3v1	0.34	0.17	0.19	1.41	0.90	0.44	0.30	0.04	0.92	0.13	1.09
BCS-H13-4v1	0.33	0.14	0.13	0.61	0.40	0.37	0.27	0.03	0.12	0.06	0.21
BCS-H13-5v1	0.24	0.12	0.14	1.05	0.88	0.37	0.34	-0.06	0.56	0.06	0.56
BCS-H13-5v1-R	0.76	0.17	0.21	1.34	0.63	0.91	0.45	0.46	0.85	0.60	1.91
BCS-H13-6v1	0.17	0.11	0.16	0.17	0.17	0.13	0.14	-0.13	-0.32	-0.18	-0.63
BCS-H13-7v1	0.28	0.14	0.23	1.17	1.01	0.61	0.56	-0.02	0.68	0.30	0.96
BCS-H13-8v1	0.46	0.15	0.20	1.64	0.86	0.51	0.30	0.16	1.15	0.20	1.51
BCS-H13-8v1-R	0.56	0.20	0.19	3.30	1.63	0.62	0.37	0.36	2.81	0.31	3.48
BCS-H13-9v1	0.76	0.20	0.23	1.28	0.87	0.81	0.60	0.46	0.79	0.50	1.74
BCS-H14-1v1	0.47	0.14	0.16	0.83	0.56	0.72	0.49	0.17	0.34	0.41	0.92
BCS-H14-2v1	1.16	0.21	0.19	0.58	0.39	1.45	0.78	0.86	0.09	1.14	2.08
BCS-H14-4v1	0.66	0.11	1.78	1.21	1.24	0.88	0.96	0.36	0.72	0.57	1.64
BCS-H14-5v1	0.43	0.13	0.14	0.21	0.19	0.33	0.26	0.13	-0.28	0.02	-0.12
BCS-H14-7v1	0.31	0.14	0.19	0.48	0.47	0.17	0.21	0.01	-0.01	-0.14	-0.14
BCS-H14-8v1	0.37	0.17	0.15	0.80	0.87	0.74	0.82	0.07	0.31	0.43	0.81
BCS-H14-9v1	0.36	0.21	0.24	0.19	0.16	0.43	0.33	0.06	-0.30	0.12	-0.12
BCS-I11-3v1	0.30	0.13	0.15	0.71	0.55	0.15	0.15	0.00	0.22	-0.16	0.07
BCS-I11-5v1	0.53	0.27	0.29	2.53	2.00	0.49	0.44	0.23	2.14	0.18	2.54
CS-I11-6v1	0.65	0.25	0.29	3.38	2.77	0.86	0.83	0.35	2.89	0.55	3.78
CS-I11-8v1	1.24	0.29	0.35	7.80	3.12	1.19	0.58	0.94	7.31	0.88	9.13
BCS-I11-9v1	1.25	0.27	0.27	9.87	3.52	1.12	0.50	0.95	9.38	0.81	11.14
BCS-I12-1v1	0.30	0.16	0.25	0.56	0.59	0.26	0.31	0.00	0.07	-0.05	0.01
BCS-I12-2v1	0.16	0.12	0.17	0.16	0.18	0.13	0.15	-0.14	-0.33	-0.18	-0.64
BCS-I12-3v1	0.25	0.14	0.18	0.96	0.86	0.37	0.36	-0.05	0.47	0.06	0.47
BCS-I12-4v1	0.14	0.12	0.17	0.37	0.41	0.17	0.20	-0.15	-0.12	-0.14	-0.42
BCS-I12-5v1	0.21	0.14	0.20	0.75	0.63	0.20	0.19	-0.09	0.26	-0.11	0.07
BCS-I12-6v1	0.29	0.13	0.19	0.93	0.63	0.21	0.17	-0.01	0.44	-0.10	0.32
BCS-I12-7v1	0.45	0.22	0.24	1.70	1.08	0.47	0.33	0.15	1.21	0.16	1.52
BCS-I12-8v1	0.27	0.14	0.18	1.14	0.89	0.23	0.22	-0.03	0.65	-0.08	0.55
BCS-I12-9v1	0.21	0.12	0.16	1.00	1.07	0.21	0.27	-0.09	0.51	-0.10	0.31
BCS-I13-1v1	0.26	0.15	0.19	0.53	0.43	0.21	0.19	-0.04	0.04	-0.10	-0.10
BCS-I13-2v1	0.20	0.09	0.12	0.39	0.27	0.19	0.15	-0.10	-0.10	-0.12	-0.33
BCS-I13-4v1	0.39	0.14	0.21	1.40	0.80	0.41	0.27	0.09	0.91	0.10	1.10
BCS-I13-5v1	0.33	0.13	0.15	0.72	0.50	0.24	0.20	0.03	0.23	-0.07	0.20
BCS-I13-7v1	0.61	0.21	0.25	0.46	0.38	0.53	0.42	0.31	-0.03	0.22	0.50
BCS-I13-8v1	0.29	0.12	0.19	0.79	0.55	0.24	0.20	-0.02	0.30	-0.07	0.21
CS-I13-9v1	1.01	0.22	0.26	9.44	7.33	1.76	1.61	0.71	8.95	1.45	11.11
CS-I14-7v1	0.50	0.17	0.22	2.19	1.87	0.44	0.48	0.25	1.70	0.13	2.03
BCS-I14-8v1	0.26	0.13	0.18	1.04	0.98	0.36	0.38	-0.04	0.55	0.05	0.56
AVERAGE	0.47			1.09		0.48		0.17	0.60	0.17	0.93
ST. Deviation	0.26			1.48		0.32		0.25	1.48	0.32	1.88
MAXIMUM	1.76			9.98		1.94		1.46	9.49	1.63	12.21

Note: Net concentrations are gross values less background

Table A5

Final Gamma Exposure Rates – VA-III

Incorrect Grid Identification	Corrected Grid Identification	Gross Exposure Rate (μR/hr)	Net (1) Exposure Rate (μR/hr)
	A11-2*	6	1
	A11-3*	6	1
	A11-5*	6	1
	A12-1*	6	1
A11-1	B11-2	9	4
A11-2	B11-3	9	4
A11-4	B11-5	8	3
A11-5	B11-6	10	5
	B11-8*	7	2
	B11-9*	7	2
A11-3	B12-1	9	4
	B12-4*	8	3
	B12-5*	6	1
	B12-7*	6	1
	B12-8*	6	1
B11-1	C11-2	11	6
B11-2	C11-3	10	5
B11-4	C11-5	9	4
B11-5	C11-6	10	5
B11-7	C11-8	9	4
B11-8	C11-9	9	4
B11-3	C12-1	9	4
B12-1	C12-2	10	5
B12-2	C12-3	9	4
B11-6	C12-4	10	5
B12-4	C12-5	8	3
B12-5	C12-6	7	2
B11-9	C12-7	9	4

Table A5

Incorrect Grid Identification	Corrected Grid Identification	Gross Exposure Rate (μR/hr)	Net (1) Exposure Rate (μR/hr)
B12-7	C12-8	9	4
	C12-9*	7	2
B12-3	C13-1	9	4
	C13-4*	7	2
	C13-7*	8	3
C11-1	D11-2	10	5
C11-2	D11-3	10	5
C11-4	D11-5	10	5
C11-5	D11-6	10	5
C11-7	D11-8	11	6
C11-8	D11-9	9	4
C11-3	D12-1	9	4
C12-1	D12-2	9	4
C12-2	D12-3	10	5
C11-6	D12-4	9	4
C12-4	D12-5	9	4
C12-5	D12-6	9	4
C11-9	D12-7	10	5
C12-7	D12-8	10	5
C12-8	D12-9	9	4
C12-3	D13-1	9	4
C13-1	D13-2	9	4
C13-2	D13-3	8	3
C12-6	D13-4	9	4
C13-4	D13-5	8	3
C13-5	D13-6	8	3
C12-9	D13-7	8	3
C13-7	D13-8	7	2
C13-3	D14-1	8	3
D11-1	E11-2	7	2
D11-2	E11-3	8	3
D11-4	E11-5	9	4
D11-5	E11-6	9	4

Table A5

Incorrect Grid Identification	Corrected Grid Identification	Gross Exposure Rate (μR/hr)	Net (1) Exposure Rate (μR/hr)
D11-7	E11-8	9	4
D11-8	E11-9	8	3
D11-3	E12-1	7	2
D12-1	E12-2	8	3
D12-2	E12-3	6	1
D11-6	E12-4	8	3
D12-4	E12-5	8	3
D12-5	E12-6	8	3
D11-9	E12-7	8	3
D12-7	E12-8	9	4
D12-8	E12-9	8	3
D12-3	E13-1	7	2
D13-1	E13-2	8	3
D13-2	E13-3	9	4
D12-6	E13-4	8	3
D13-4	E13-5	9	4
D13-5	E13-6	9	4
D12-9	E13-7	8	3
D13-7	E13-8	8	3
D13-8	E13-9	8	3
D13-3	E14-1	8	3
D14-1	E14-2	9	4
D13-6	E14-4	8	3
D14-4	E14-5	7	2
D13-9	E14-7	8	3
D14-7	E14-8	8	3
E11-1	F11-2	7	2
E11-2	F11-3	6	1
E11-4	F11-5	7	2
E11-5	F11-6	6	1
E11-7	F11-8	7	2
E11-8	F11-9	6	1
E11-3	F12-1	6	1

Table A5

Incorrect Grid Identification	Corrected Grid Identification	Gross Exposure Rate (μR/hr)	Net (1) Exposure Rate (μR/hr)
E12-1	F12-2	6	1
E12-2	F12-3	7	2
E11-6	F12-4	6	1
E12-4	F12-5	7	2
E12-5	F12-6	6	1
E11-9	F12-7	8	3
E12-7	F12-8	7	2
E12-8	F12-9	7	2
E12-3	F13-1	7	2
E13-1	F13-2	8	3
E13-2	F13-3	7	2
E12-6	F13-4	5	0
E13-4	F13-5	5	0
E13-5	F13-6	7	2
E12-9	F13-7	6	1
E13-7	F13-8	6	1
E13-8	F13-9	8	3
E13-3	F14-1	7	2
E14-1	F14-2	6	1
E13-6	F14-4	8	3
E14-4	F14-5	7	2
E13-9	F14-7	8	3
E14-7	F14-8	8	3
F11-1	G11-2	7	2
F11-2	G11-3	7	2
F11-4	G11-5	7	2
F11-5	G11-6	7	2
F11-7	G11-8	8	3
F11-8	G11-9	7	2
F11-3	G12-1	6	1
F12-1	G12-2	6	1
F12-2	G12-3	7	2
F11-6	G12-4	7	2

Table A5

Incorrect Grid Identification	Corrected Grid Identification	Gross Exposure Rate (μR/hr)	Net (1) Exposure Rate (μR/hr)
F12-4	G12-5	7	2
F12-5	G12-6	6	1
F11-9	G12-7	6	1
F12-7	G12-8	6	1
F12-8	G12-9	6	1
F12-3	G13-1	6	1
F13-1	G13-2	7	2
F13-2	G13-3	6	1
F12-6	G13-4	6	1
F13-4	G13-5	6	1
F13-5	G13-6	6	1
F12-9	G13-7	6	1
F13-7	G13-8	7	2
F13-8	G13-9	8	3
F13-3	G14-1	6	1
F14-1	G14-2	5	0
F14-2	G14-3	5	0
F13-6	G14-4	6	1
	G14-5*	5	0
	G14-6*	6	1
F13-9	G14-7	7	2
F14-7	G14-8	6	1
G11-1	H11-2	8	3
G11-2	H11-3	7	2
G11-4	H11-5	8	3
G11-5	H11-6	8	3
G11-7	H11-8	7	2
G11-8	H11-9	7	2
G11-3	H12-1	7	2
G12-1	H12-2	7	2
G12-2	H12-3	6	1
G11-6	H12-4	8	3
G12-4	H12-5	6	1

Table A5

Incorrect Grid Identification	Corrected Grid Identification	Gross Exposure Rate (μR/hr)	Net (1) Exposure Rate (μR/hr)
G12-5	H12-6	5	0
G11-9	H12-7	6	1
G12-7	H12-8	6	1
G12-8	H12-9	7	2
G12-3	H13-1	5	0
G13-1	H13-2	6	1
G13-2	H13-3	5	0
G12-6	H13-4	5	0
G13-4	H13-5	5	0
G13-5	H13-6	6	1
G12-9	H13-7	5	0
G13-7	H13-8	5	0
G13-8	H13-9	6	1
G13-3	H14-1	5	0
G14-1	H14-2	5	0
G13-6	H14-4	5	0
G14-4	H14-5	4	-1
G13-9	H14-7	6	1
G14-7	H14-8	4	-1
G14-8	H14-9	See note (2)	
H11-2	I11-3	4	-1
H11-4	I11-5	5	0
H11-5	I11-6	5	0
H11-7	I11-8	6	1
H11-8	I11-9	7	2
H11-3	I12-1	4	-1
H12-1	I12-2	4	-1
H12-2	I12-3	4	-1
H11-6	I12-4	4	-1
H12-4	I12-5	4	-1
H12-5	I12-6	4	-1
H11-9	I12-7	6	1
H12-7	I12-8	5	0

Table A5

Final Gamma Exposure Rates – VA-III

Incorrect Grid Identification	Corrected Grid Identification	Gross Exposure Rate (μR/hr)	Net (1) Exposure Rate (μR/hr)
H12-8	I12-9	5	0
H12-3	I13-1	3	-2
H13-1	I13-2	3	-2
H12-6	I13-4	4	-1
H13-4	I13-5	3	-2
H12-9	I13-7	5	0
H13-7	I13-8	4	-1
H13-8	I13-9	5	0
H13-9	I14-7	5	0
H14-7	I14-8	4	-1
I11-9	J12-7	4	-1
I12-7	J12-8	4	-1
I12-8	J12-9	4	-1
I12-9	J13-7	4	-1
AVERAGE			1.96 μR/hr (~2)
ST. DEVIATION			1.74μR/hr (~1.8)

Notes

1. Net Exposure = Gross Exposure - Background Exposure (5uR/hr)
2. Denotes a submerged grid
3. (*) Denotes additional grids due to corrections

Table A6

Final Status Survey: Statistical Analysis

The following statistical relations were used to assess the database for the Bay City survey unit:

Survey Data Average ($\bar{x}$):

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

Standard Deviation (S_x):

$$S_x = \sqrt{\frac{\sum_{i=1}^{n}(\bar{x} - x_i)^2}{n-1}}$$

Determination of Number of Background data points (n_B):

$$n_B = \left[\frac{t_{95.5\%,df} S_x}{0.2 \bullet \bar{x}_B}\right]^2$$

Comparison of statistical mean ($\mu\alpha$) with guideline values:

$$\mu_\alpha = \bar{x} + t_{1-\alpha,df}\frac{S_x}{\sqrt{n}}$$

Identifying additional measurement/sampling needs:

$$\text{Estimating Factor} = \frac{C_G - \bar{x}}{S_x}$$

(Tables B-2 in NUREG/CR-5849)

Note: See chapter 8.0 of NUREG/CR-5849 for detailed discussion of above-listed statistical analyses.

Where:

X_i = measurement (analysis) at point i
n = number of measurements (analyses)
$t_{1-\alpha, df}$ = 95% confidence level from Table B-1 of Appendix B of NUREG/CR-5849
C_G = Guideline Value

Table A7

Final Status Survey: Summary Statistics

Exposure Rates							
Section	n	X (μR/h)	Sx (μR/h)	μα (μR/h)	C_G (μR/h)	Estimating Factor	No. Verification Samples Needed
VA-III	207	2.0	1.8	2.2	5.0	1.7	<9
Th-232 Soil Concentrations							
Section	n	X (pCi/g)	Sx (pCi/g)	μα (pCi/g)	C_G (pCi/g)	Estimating Factor	No. Verification Samples Needed
VA-III	265	0.17	0.26	0.20	3.2	11.7	<9

Final Status Survey Report for VA-IV
Magnesium-Thorium Slag Storage Area
The Dow Chemical Company's
Bay City, Michigan Facility

DOW U.S.A.

The Dow Chemical Company
Midland, Michigan 48674

Revision 1
March 2003

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TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

1.0 BACKGROUND INFORMATION

The radioactive material at the Dow Chemical Company's Bay City site consisted primarily of foundry slag containing Thorium. This material, and similar material originally stored at Dow's Midland site, was produced in the period from 1940 to 1970 as the residual from the production of a magnesium-thorium alloy. This lightweight alloy was used for defense purposes, including aircraft engines and aeronautical structural components.

A single license (STB-527) was originally granted by the NRC in 1973 for the Bay City and Midland sites to store up to 200,000 pounds of thorium slag. The license expired in 1978, but has remained in effect under timely renewal.

The Midland site was decontaminated with the material removed and transported to Bay City for consolidation with the Bay City material and subsequent transport to the Envirocare facility in Clive, Utah. A final survey was conducted at the Midland site by Dow with the results documented in a Final Status Survey Report of March, 1997, showing that the residual contamination criteria had been met. The NRC subsequently conducted an independent survey of the Midland site and verified that the residual contamination criteria had been met.

The material transported from the Midland site to the Bay City site originally consisted of magnesium with up to two percent thorium. Portions of this process slag were mixed with soil or limited amounts of construction debris. As a result of this mixing, the thorium concentrations, as determined by Dow characterization soil sampling, varied from 2-7000 pCi/g at the Bay City Site (with an average concentration of 188 pCi/g) . A total activity of 9.7 Ci of Th-232 was originally distributed throughout approximately 52,000 cubic yards of soil, slag, and construction debris.

Initial remedial action support surveys, performed in 1996, identified wide spread areas of elevated contamination. The gamma scan surveys were conducted using a sodium iodide detector. Readings were generally higher the closer the proximity to the original thorium pile but several hot spots in the 300,000 to 600,000 cpm range were identified. Construction debris, such as drums, were removed from these areas along with the contaminated soil.

Decontamination of the Bay City site is ongoing. In accordance with NRC and Dow discussions, as confirmed in Dow's letter of June 12, 1997, verification that residual contamination criteria have been achieved on this large site is being performed in sections. This Final Status Survey Report (FSR) provides the descriptive text on the site and the parameters of the survey program and includes the analyzed verification data for Verification Area (VA) IV. As the database is acquired for subsequent VAs addendums to the Final Survey Report will be submitted to the NRC containing the analyzed database.

Supporting information on the Bay City site and decommissioning project is presented in the October, 1993 Decommissioning Work Plan, the December, 1995 Supplement to the Decommissioning Work Plan, and the March, 1996 Response to Comments.

This document is a revision to the original Final Status Survey Report for VA-IV dated September 21, 1998.

On September 29th through October 1st of 1997, after the original report submittal, the NRC Region III conducted an inspection of the VA-IV portion of the Dow Bay City facility. The primary purpose of the inspection was to conduct an independent confirmatory survey of VA-IV. This revision to the original report is provided to include the findings of the NRC confirmatory surveys documented in NRC Report No. 040-00017/98001 (DNMS) dated October 20, 1998.

Additionally, this revision to the original report is provided to address deficiencies identified by NRC staff in a letter to Dow dated August 16, 2002 (Review of Final Status Survey Reports for the Previously Remediated Areas VA-I through VA-VI, Dow Chemical Company's Bay City, MI, SDMP Site (TAC# L60463)).

2.0 SITE INFORMATION

2.1 SITE DESCRIPTION

The Bay City thoriated material storage site is on a Dow facility near the Town of Bay City, Michigan about one-mile south of Saginaw Bay. The Bay City site (pile) is shown on Figure 2-1 in relation to adjacent land features and other facilities.

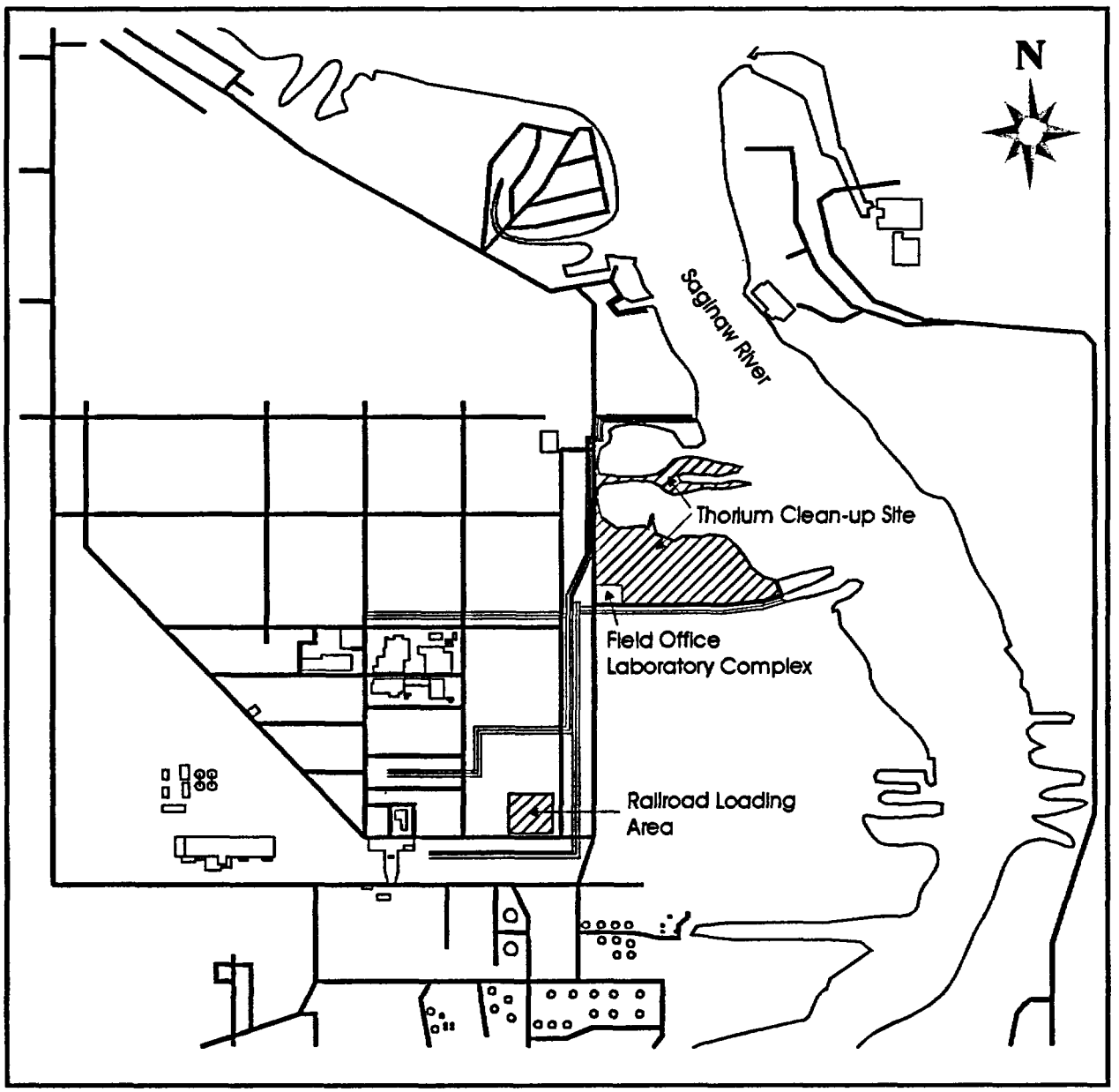
The thoriated material site is located adjacent to and north of an inlet canal, which enters the Saginaw River to the east. The Saginaw River is located to the north and east of the material. Access to the Dow manufacturing facility is restricted to authorized personnel. The storage site within the facility is posted as a radiation control area and delineated with a fence.

The area surrounding the material is relatively level, with some marshy areas and ponds. Any sediments containing elevated levels of thorium are being excavated as part of the decontamination program.

The affected area of the Bay City storage site was initially based on knowledge of the operating history, and subsequently on radiological characterization surveys. While areas immediately surrounding the Bay City storage area were included in the affected area, some further outward adjustment of the affected area boundary was required during site remediation to encompass surface and subsurface contamination uncovered during remedial operations.

Figure 2-1

Bay City Thorium Disposal Site



2.2 SITE CONDITIONS AT TIME OF FINAL SURVEY

The decommissioning activities at the Bay City site involve excavation of the contaminated soil, loading on to trucks, onsite transportation of the material to the stockpile at the railhead, loading on to the rail cars, and transport of the material to the Envirocare burial site in Clive, Utah. Soil removal is to varying depths continuing until sample analysis showed residual concentrations to be within NRC defined limits. Final verification samples were taken in the VA and analyzed on site through gamma spectroscopy. When the gamma spectral analysis results showed the Th-232 levels to be less than the guideline value, a conversion factor was applied to the Th-232 concentration to obtain the Th-230 and Th-228 concentrations. After the net total thorium concentration was determined, five percent of all final verification soil samples were sent to Dow Chemical's radioanalytical laboratory, Freeport, Texas, where the samples were monitored by the Dow Quality Assurance coordinator.

2.3 IDENTITY OF POTENTIAL CONTAMINANTS AND RELEASE GUIDELINES

Based on the knowledge of the process that generated the slag material, and the results of the characterization survey, the significant radiological contaminants were determined to be Th-232, Th-230, and Th-228. The above background residual soil concentration measurements used as a basis for the final verification for all the verification samples analyzed to date at Bay City provided the average soil activity ratios at Bay City of approximately:

Th-232	-	22%
Th-230	-	60%
Th-228	-	18%

Using the approach described in Section 3.1 ("Release Criteria") of the December, 1995 Supplement to the Decommissioning Work Plan and response No. 8 of the Response to Comments (on the Work Plan) of March, 1996, in conjunction with the methodology in Appendix A of NUREG/CR 5849 gives a residual soil gross activity guideline of 14.5 pCi/g total

thorium. The site-specific guideline levels for each of the contributory radionuclides is thus 3.2 pCi/g for Th-232, 2.6 pCi/g for Th-228, and 8.7 pCi/g for Th-230.

The gross activity guideline is determined as follows:

$$\textit{Gross Activity Guideline} = \frac{1}{\frac{0.22}{10} + \frac{0.18}{10} + \frac{0.60}{21}} = 14.5\ pCi/g$$

where Th-232, Th-230, and Th-228 are present in net activity ratios of 0.22, 0.60, and 0.18 respectively in the residual soil. The guideline concentrations for Th-232 plus Th-228 are 10 pCi/g and 21 pCi/g for Th-230 (see March, 1996 Response to Comments).

3.0 FINAL STATUS SURVEY OVERVIEW

3.1 SURVEY OBJECTIVES

The purpose of the final status survey was to demonstrate that the residual radiological concentrations in the soil at the Bay City thorium storage site satisfy the NRC guidelines (see 2.3 above) and that the storage site can, therefore, be released for future use without radiological controls. Specifically, the final status survey soil database should show that:

- Average residual radionuclide concentrations are at or below the soil guideline values defined in Section 2.3. Averaging is based on a 100 m^2 (10m x 10m) grid area. Note an actual grid size of 33.3 ft. x 33.3 ft. was used for convenience in measuring rather than 10m x 10m (32.8 ft. x 32.8 ft.).

- Reasonable efforts have been made to identify, evaluate, and remove, if necessary, areas of residual activity exceeding the guideline values. Areas of residual activity exceeding the guideline value (elevated areas) may be acceptable provided they do not exceed the guideline value by greater than a factor of $(100/A)^{1/2}$, where A is the area of residual

activity in m^2, and provided the activity level at any location does not exceed three times the guideline values.

In addition, exposure rates should not exceed 5 μR/h above background at 1 m above the soil surface. Exposure rates may be averaged over a 100 m^2 grid area. Maximum exposure rates over any discrete area may not exceed 10 μR/h above background.

A 95% minimum level of confidence that the above conditions have been met was to be demonstrated. The entire Section IV of the Bay City storage area (affected area) is treated as a single survey unit, and the 95% level of confidence was applied to the entire survey unit.

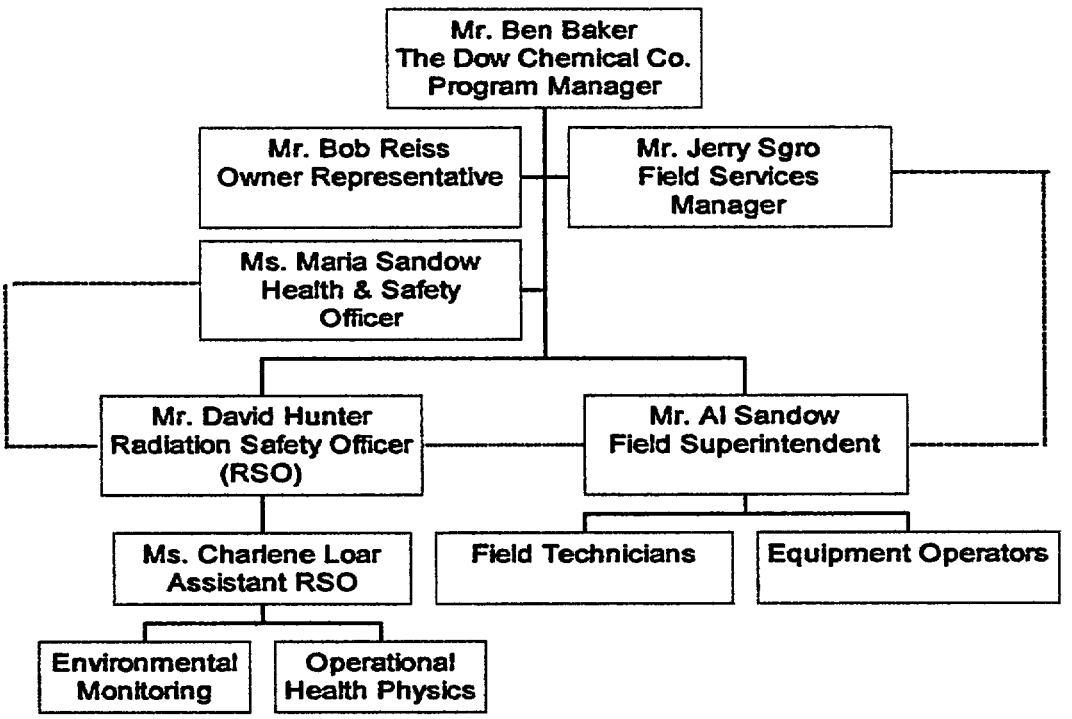
3.2 ORGANIZATION AND RESPONSIBILITIES

The final status survey was conducted by the same qualified Dow and subcontractor personnel who had conducted the characterization survey, and remediation control survey. The Project Organization is shown in Figure 3-1.

The sampling and analysis methods to be used during the remediation control survey was designed to achieve the sampling sensitivity and elevated activity guidelines defined in NUREG/CR-5849 relative to the site specific residual contamination criteria. The approach consisted of first performing a gamma scan survey of the remediated area to determine if any localized areas of elevated activity remained. Elevated areas of activity identified by the scan survey were remediated. If no areas of elevated activity were identified, composite soil samples were then collected and analyzed in the field laboratory using a NaI crystal coupled to the MCA to provide rapid turnaround on the Th-232 levels. If the Th-232 level exceeded the guideline value, further remediation was performed. The soil sample results of the analysis of the final samples collected, that demonstrated that the administrative cleanup level had been achieved, were then used as input into the final status survey.

Figure 3-1

Project Organization for Remediation of the Midland and Bay City Storage Sites



3.3 INSTRUMENTATION

Table 3-1 lists the field radiological monitoring instrumentation used on the project inclusive of the specific use of each instrumentation and detection sensitivities. Each instrument was initially calibrated to NIST-traceable standards prior to use on the project, and then checked for radiation response and efficiency prior to daily use.

Table 3-1

Field Radiological Monitoring Instrumentation

Instrument	Measures	Detector Efficiency*	LLD/MDA
Ludlum Model 43-5 w/ Ludlum Model 12	Alpha Surface	15%	22 dpm
Ludlum Model 43-90 w/ Ludlum Model 2221	Alpha Surface	22%	12 dpm
Ludlum Model 44-9 w/ Ludlum Model 12	Alpha, Beta, Gamma	12% alpha 15% beta 1% gamma	
Ludlum Model 43-10 w/ Ludlum 1000	Alpha (air filters, smears)	43%	0.04 dpm
Ludlum Model 19	Exposure Rate		1 microR/h
Air Particulate			
Eberline RAS-1 Air Pump	Flow Rate = 40-100 lpm		
MSA Escort Lapel Sampler	Flow Rate = 2-3 lpm		
General Metal Works–2000 High Vol Sampler	Flow Rate = 30-60 cfm		
Test/Calibration Equipment			
Ludlum Model 500 Pulser	NIST Traceable		
AFC-85L Air Flow Calibrator	NIST Traceable		
GMW-Calibrator Orifice for High Vol Sampler	NIST Traceable		
MSA Optiflow 660 Air Flow Calibrator	NIST Traceable		
Field Laboratory Equipment			
Canberra Gamma Spectrometer	Soil Th-232 Concentration		0.8 pCi/g

* Detector efficiencies are approximate and appropriate for Th-230, Tc-99, and Co-60

3.4 SURVEY PROCEDURES

Survey planning and procedures are consistent with the methods described in the Decommissioning Plan. The soil survey procedures are summarized in this section and can be found in greater detail in Appendices D-2 and D-3 of the March, 1996 Response to Comments.

3.4.1 Area Classification

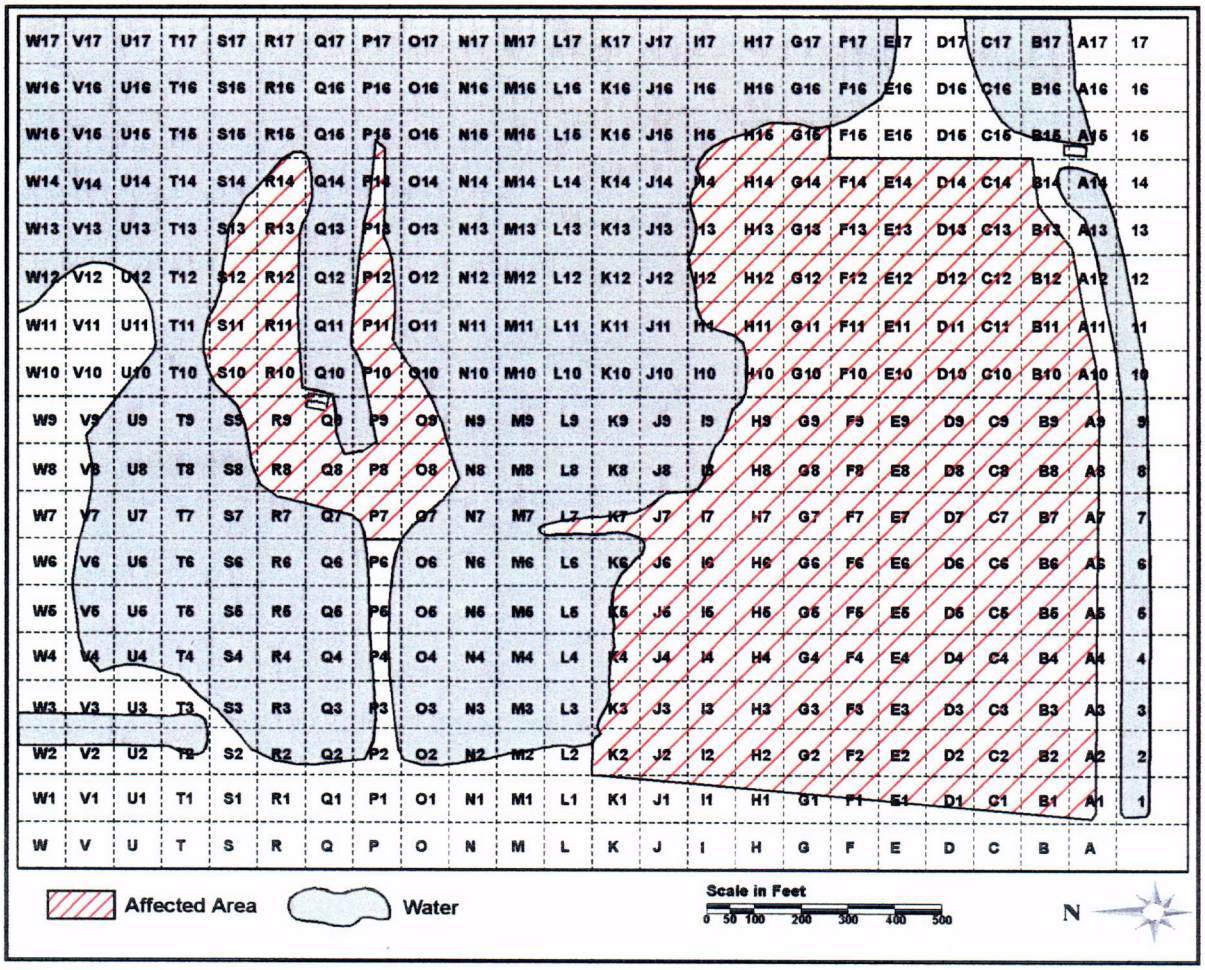
The Bay City storage site was divided into affected and unaffected areas to establish the sampling pattern and frequency. The basis for the affected and unaffected classification, as applied to the Bay City site are:

- **Affected Area** – As shown in Figure 3-2, the thorium material storage area and region immediately surrounding the storage area was defined as the affected area based on both historical records and prior characterization surveys. This location had known thorium contamination in the soil that had been placed there via backfill operations and storage.

- **Unaffected Area** – The region surrounding the affected area (see Figure 3-2) was treated as unaffected since it did not contain residual radioactivity.

Figure 3-2

Bay City Site Affected Areas



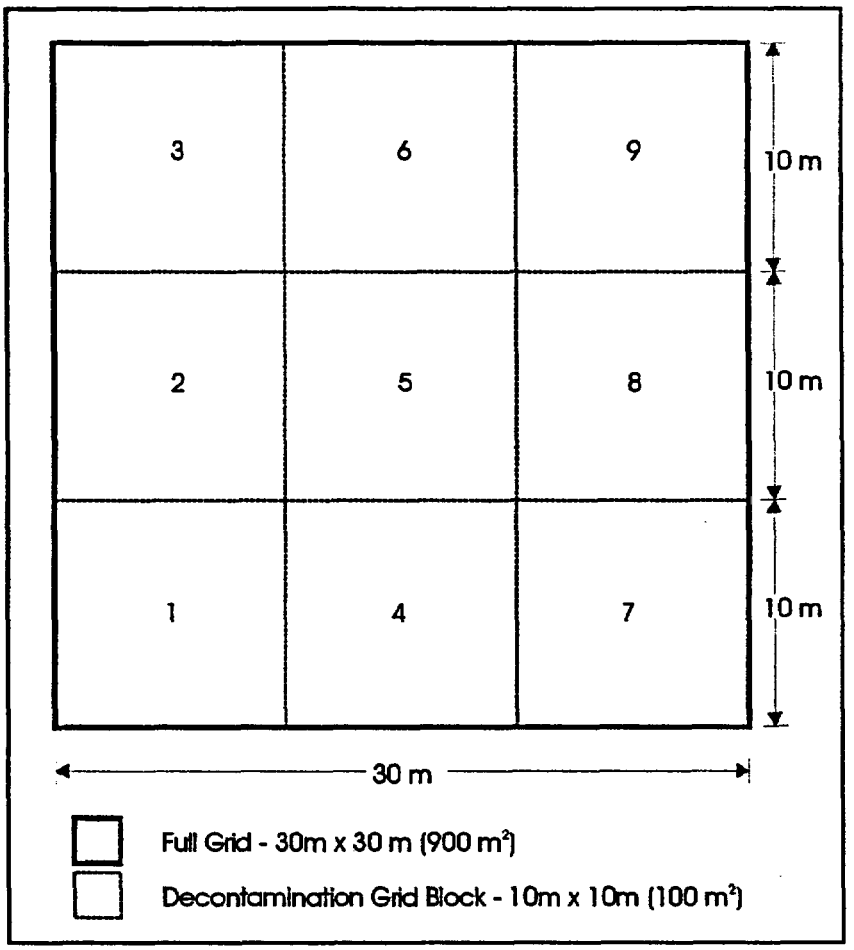
3.4.2 Reference Grid

A grid was established over the affected area upon completion of material excavation for the purpose of referencing locations of samples and measurements (see Figure 3-2). These full grids were 30m x 30m (900 m^2) in size. Each full grid was then divided into nine 10m x 10m sub-grids or "Decontaminated Grid Blocks" (100 m^2 each). Each decontaminated grid block was marked into 2.5m increments to establish the nine individual soil sample locations taken to obtain one composite sample per sub-grid. Figure 3-3 depicts the breakdown of the reference grid system. As previously noted, the entire Section IV (affected area) constituted the survey unit.

C10

Figure 3-3

Reference Grid System



3.4.3 Surface Scans

One hundred percent of the soil surface was initially scanned to identify locations of elevated activity. The gamma scans were conducted in accordance with procedure SOP 1.5, Measurement of Gamma-Ray Fields using a Sodium Iodide (NaI) Detector. As soil was removed, additional gamma scans were conducted to identify remaining locations of contaminated soil. After completion of contaminated soil removal, a final scan was performed of the soil surface prior to obtaining final verification soil samples.

3.4.4 Soil sampling

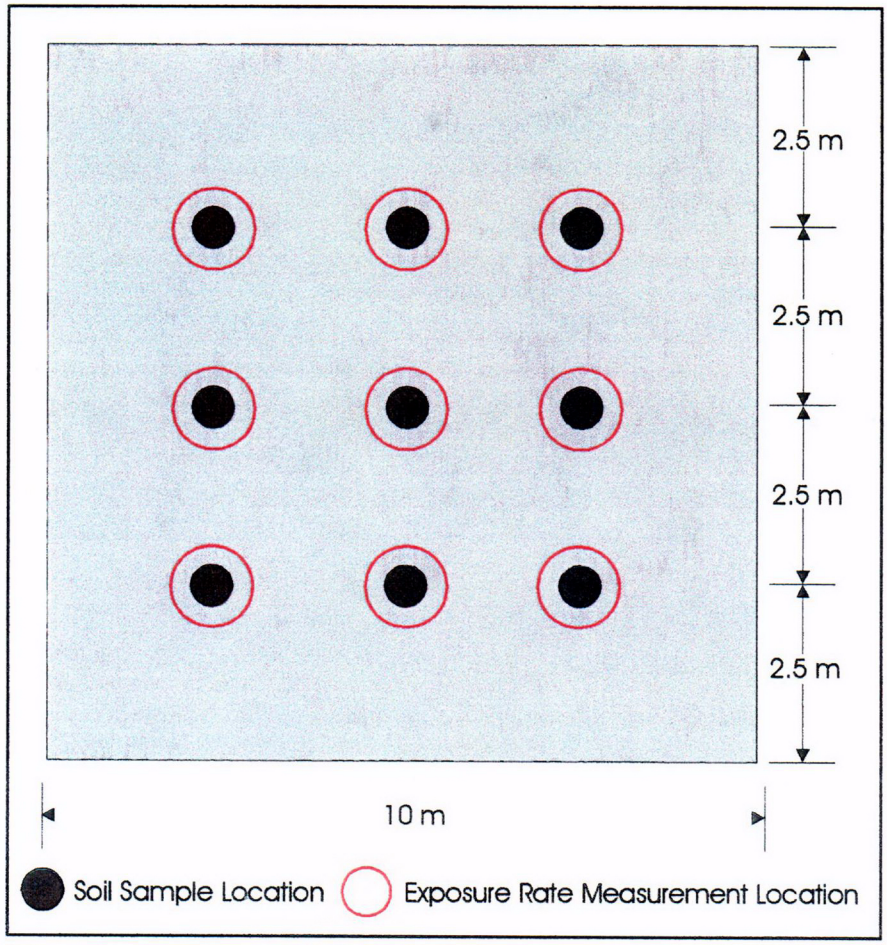
Final survey soil samples consisted of one composite sample obtained from nine individual samples (approximately 1 kg each) from each sub-grid (see Figure 3-4). The samples were collected after gamma levels were measured to preliminarily determine that all contaminated soil had been removed. Each of the nine locations where the individual samples were collected was scanned prior to soil sampling to validate that elevated levels did not exist (>3 times background). These final verification soil samples were analyzed on site through gamma spectroscopy. When the analytical results for Th-232 were less than the guideline value, a conversion factor was applied to the Th-232 concentration to obtain the Th-230 and Th-228 concentrations. After the net total thorium concentration was determined, five percent of all final verification soil samples were sent to Dow Chemical's radioanalytical laboratory in Freeport, Texas for duplicate QA analyses. Soil sample collection was performed in accordance with procedure SOP 1.8, Guide to the Handling, Packaging and Shipping of Samples, and SOP 1.9, Sample Control and Documentation.

3.4.5 Exposure Rate Measurements

Gamma exposure rates were measured in the affected area at 1 meter above the soil surface at nine locations within each sub-grid (see Figure 3-4). This methodology differs from that performed for VAs I – III where a single exposure rate measurement was obtained in the center of the sub-grid. This revised methodology is conservative in that 8 additional measurements are obtained in each sub-grid. Exposure rate measurements were obtained using a Ludlum Model 19 MicroR meter.

Figure 3-4

Sampling Pattern for Composite Preparation Within Decontaminated Grid Block



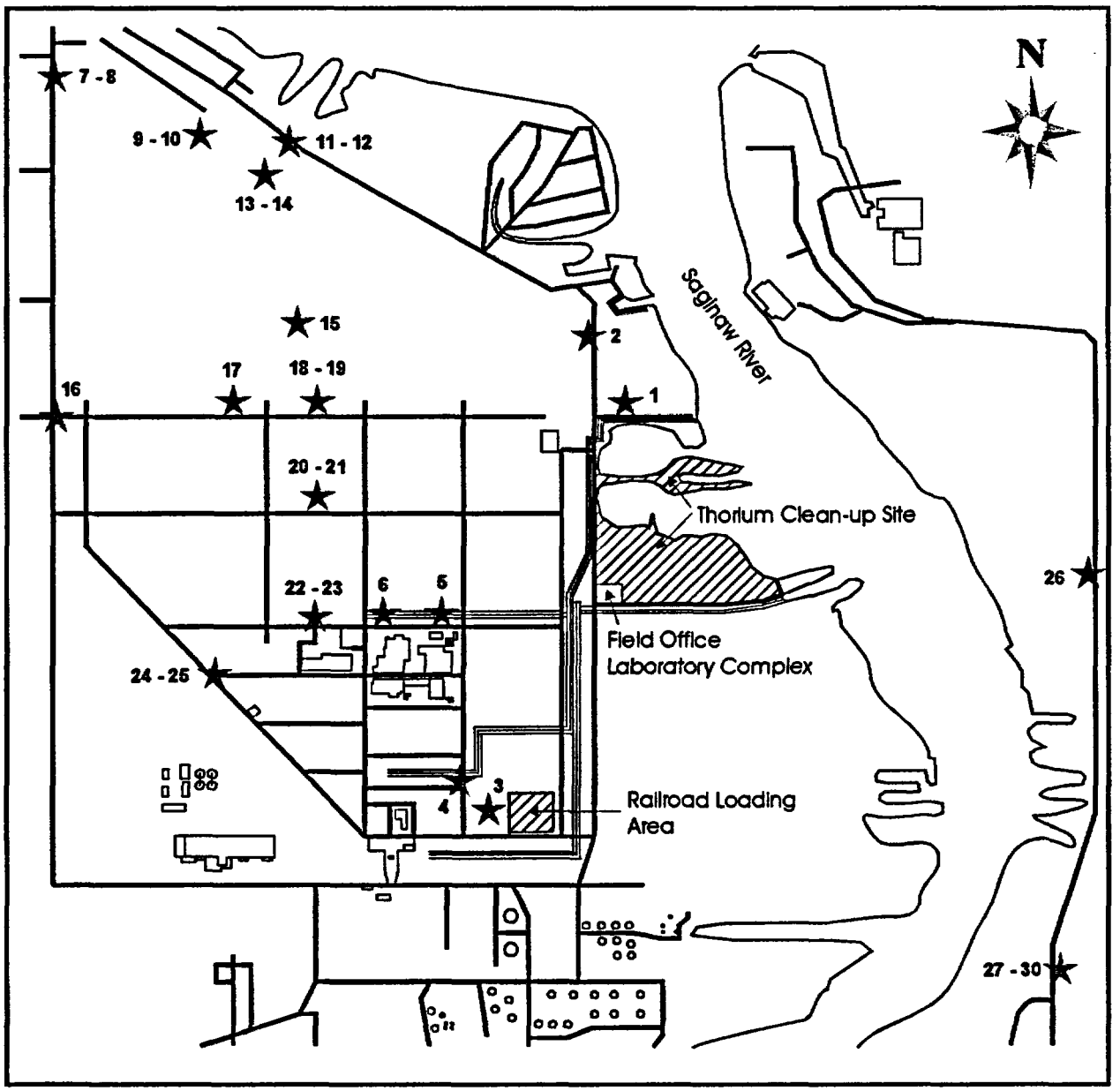
3.5 BACKGROUND LEVEL DETERMINATION

Background soil samples were collected from 30 locations in the unaffected area (Figure 3-5), and 29 samples analyzed for Th-230, Th-232, and Th-228 concentrations in the Freeport Laboratory (sample no. 14 was lost in transit). Sample numbers 1-25 were collected from locations on Dow property that were not impacted by site operations. Sample numbers 26-30 were collected from locations east of the Dow property, across the Saginaw River. Background exposure rates were measured at the same locations as the soil samples. Statistical procedures described in NUREG/CR-5849 (see Table A6) were used to assure that the average thorium concentrations determined were representative of true average background levels.

C11

Figure 3-5

Background Sample Locations



3.6 SAMPLE ANALYSIS

Final survey soil samples were analyzed for Th-232 in the field laboratory using the NaI detector coupled to the MCA. Soil samples were analyzed in accordance with "Procedure for Counting Soil Samples for EOP Characterization". Th-228 and Th-230 concentrations were determined by

multiplying the Th-232 result by 0.94 and 1.63, respectively. Five percent of the FSS samples were analyzed for Th-232, Th-230, and Th-228 using gamma and alpha spectroscopy in the Freeport Laboratory to satisfy QA requirements. The onsite analytical methods were determined to be acceptable by NRC as documented in Inspection Report 040-00017/98001.

3.7 DATA INTERPRETATION

Soil sample locations and survey results for fixed measurements were recorded on data sheets. The data conversion and statistical analysis techniques in NUREG/CR-5849 (Chapter 8.0) were used to convert the reported data into a form that permitted a direct comparison with residual contamination guidelines and thus assess if remediation goals were met. The statistical relationships are shown with the analyzed data in Appendix A (Tables A6, A7). Soil concentrations were converted into units of pCi/g and exposure rates to μR/h. The reported affected area data in Appendix A has been adjusted by subtracting the natural background levels.

Additional soil removal was performed when the remediation control survey measurements showed that residual contamination guidelines were not being met.

3.8 RECORDS

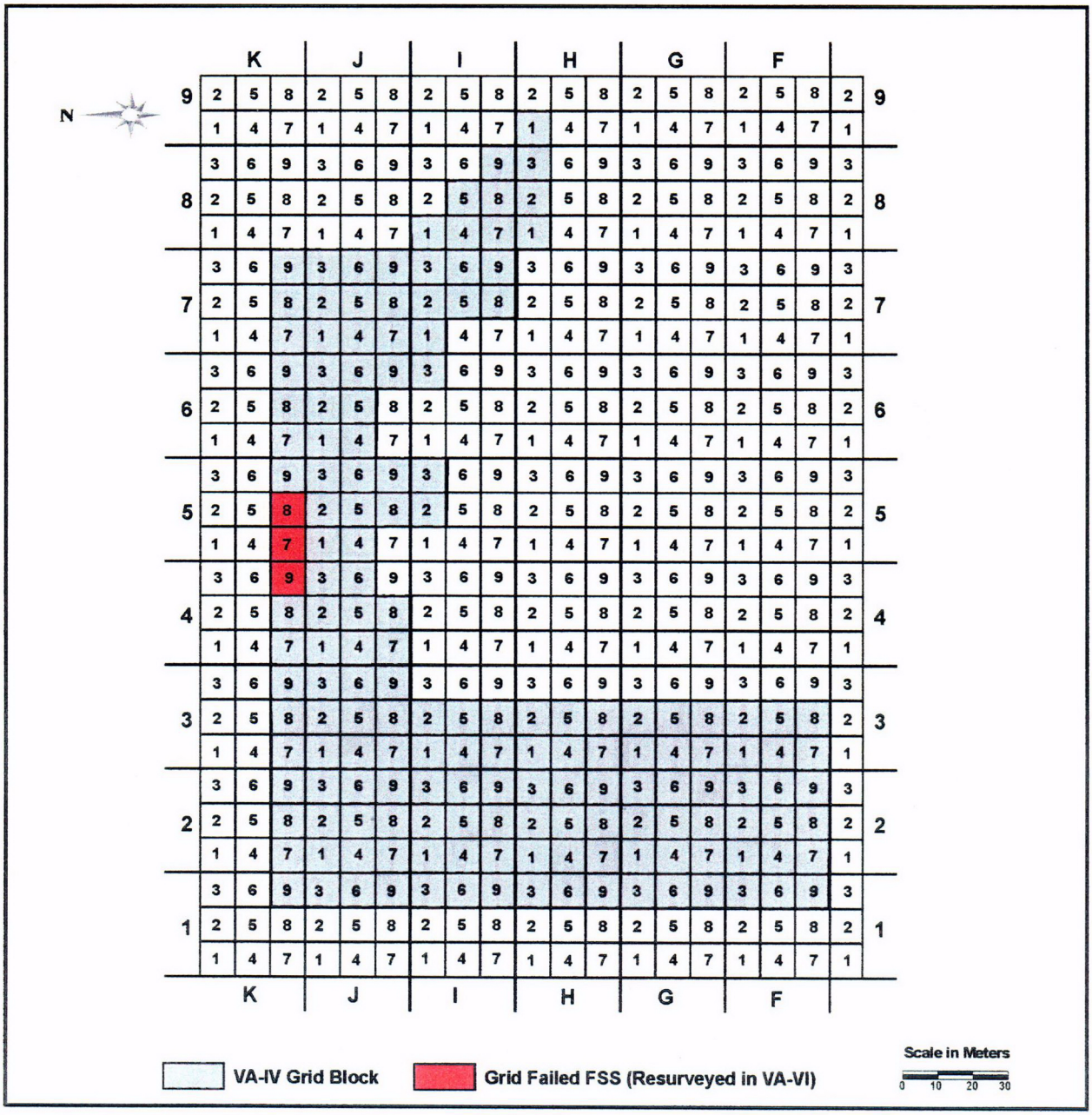
All soil samples, original survey data records, and log-books have been archived at the Dow Bay City facility and will be held until after license termination.

4.0 SURVEY FINDINGS AND RESULTS

Appendix A contains the radiological database collected during the final status survey for VA-IV (as defined in Figure 4-1) that provides the basis for verifying that the residual contamination objectives have been achieved for this area at the Bay City thorium site. Summary Tables, data interpretations and statistical comparisons with residual contamination guidelines in VA-IV are included in Appendix A.

Figure 4-1

Grid Locations for VA-IV



4.1 BACKGROUND LEVELS

Background soil concentrations (Table A1) averaged 0.30 pCi/g for Th-232, 0.49 pCi/g for Th-230, and 0.31 pCi/g for Th-228. Background exterior exposure rates averaged 5 μR/h (Table A2). Both the number of data points collected to obtain the average background soil

C12

concentrations and exposure rates are more than sufficient to meet the test for demonstrating that the measured average background is within ± 20% of the true average at the 95% confidence level.

4.2 GROUND SURVEYS

4.2.1 Scans

Surface scans were used during the remediation control survey to identify locations of elevated gamma radiation to guide the excavation of the material and locate remaining hot spots. There were no discreet areas of elevated activity identified during the verification scan survey. Areas covered by water were not scanned, however, sediment samples were obtained.

4.2.2 Thorium Concentrations in Soil

The results of the analyses of the verification soil samples from VA-IV are provided in Table A3, and related to the grid locations shown in Figure 4-1. QA soil analyses, performed by Dow's Freeport Laboratory on splits of 5 percent of the FSS samples, are also shown in Table A3. Three of the verification samples and two of the QA samples contained total thorium concentrations in excess of the soil residual activity guideline (see Section 2.3). Analysis of the mean concentration of Th-232 shows that the concentration meets the guideline value at the 95% confidence level (Table A6, A7). The number of samples collected (170 in VA-IV) is much greater than the number (<9) statistically required to demonstrate that the concentrations satisfies the guideline value at the 95% confidence level (Table A6, A7).

Table A3 shows the final verification soil concentrations in 3 of the sub-grids exceed the total net thorium guideline value of 14.5 pCi/g (BCS-K4-9v1 was 15.54 pCi/g, BCS-K5-7v1 was 19.15 pCi/g and BCS-K5-8v1 was 15.45 pCi/g). The QA samples with concentrations in excess of the guideline value were split samples taken from BCS-K4-9v1 and BCS-K5-7v1. These sub-grids (K4 and K5) were removed from the VA-IV survey unit to be remediated and re-surveyed at a

later date. These sub-grids were subsequently remediated and re-surveyed as part of the VA-VI survey unit (see Final Status Survey Report for VA-VI, June of 1999).

Discounting the 3 soil samples which exceeded the guideline value and were removed from this survey unit, the maximum total residual thorium concentrations (above background) as measured in sample BCS-J2-3v1 was 6.93 pCi/g which is less than the residual guideline of 14.5 pCi/g.

The 3 sub-grids which exceeded the guideline value had soil concentrations based on composite sampling over a 100 m^2 area and therefore, hot spot averaging techniques could not be applied. Since none of the other verification soil sample concentrations in VA-IV exceeded the guideline value (no hot spots) it was not necessary to apply averaging techniques in any of the grids.

All of the verification soil samples in VA-IV (with the exception of sub-grids K4 and K5) meet the criteria that the sum of the ratios of the concentration of each radionuclide to its respective guideline must not exceed 1 (Appendix A of NUREG/CR-5849).

4.2.3 Exposure Rates

Exposure rate measurements of the remediated VA-IV areas (Figure 4-1) and for each grid block are provided in Table A5. All individual values are within the guideline levels of 5 μR/h above background. Analysis of the statistical mean also shows that the exposure rates in VA-IV meet the guideline at the 95% confidence level (Table A6, A7). The number of measurements (133) is far in excess of the number required (<9) to demonstrate that the exposure rate satisfies the guideline value at the 95% confidence level (Table A6, A7).

4.2.4 NRC Confirmatory Surveys

The NRC performed an inspection of VA-IV on October 1st of 1998. This inspection included the performance of a confirmatory survey. Approximately 80% of VA-IV was scanned using a sodium iodide detector. There were 18 individual locations with activity levels above three time background as identified through NaI scans. These locations were remediated to activity levels

below three times background during the inspection. Dow personnel collected 20 soil samples, per NRC staff direction, at the 18 individual locations after remediation. The soil samples were analyzed for Th-232 at the Bay City field laboratory, under inspector observation, following QA/QC and calibration checks of the counting systems. When analyzed, no activity above release guidelines was found in any of the samples. Exposure rate measurements were also conducted with all readings in the acceptable ranges.

Additionally, scan surveys in grids J5 and J6, which were under water up to 8 feet deep, indicated some activity levels well above three times background. At the time, the licensee proposed to remediate further in grids J5 and J6, and immediately surrounding areas, and resubmit the final survey results. Since the confirmatory survey, grids J5 and J6, as well as grids K4 and K5 mentioned previously, were dewatered and/or remediated, and have all subsequently been re-surveyed as part of VA-VI.

5.0 SUMMARY

Decontamination of the affected area by soil removal at Dow's Bay City facility is an ongoing process. Since the affected area is quite large it is more efficient for Dow to verify that residual contamination criteria have been met in sections, and for the NRC to subsequently validate each section. Thus area VA-IV has been verified and the evaluated database from the final status survey provided in the Appendix. Remediation control surveys were performed to guide the decontamination effort, and a final status survey conducted of VA-IV during September, 1998. Independent QA analysis of soil samples was performed. Results of the final status survey demonstrate that the decontamination program successfully reduced residual activity in VA-IV to within the NRC limits for unrestricted use (with the exception of grids J5, J6, K4 and K5). As each subsequent VA is surveyed, a FSSR will be submitted to NRC.

6.0 REFERENCES

6.1 Dow Decommissioning Work Plan, October 1993

6.2 Supplement to the Decommissioning Work Plan, December 1995

6.3 Letter from Dow to NRC, Response to Comments, March 1996

6.4 NUREG/CR-5849, Manual for Conducting Radiological Surveys in Support of License Termination (Draft for Comment), December 1993

6.5 NRC Inspection Report No. 040-00017/97002 (DNMS), August 14, 1997

6.6 Letter from NRC to Dow, Review of Final Status Survey Reports for the Previously Remediated Areas VA-I through VA-VI, Dow Chemical Company's Bay City, MI, SDMP Site (TAC# L60463), August 16, 2002

6.7 Dow "Background Radiological Survey", October 11-13, 1989

6.8 Dow Bay City Site Procedures

- 6.8.1 SOP 1.1, Access Control Procedures
- 6.8.2 SOP 1.2, Total Alpha Surface Contamination Measurements
- 6.8.3 SOP 1.3, External Dosimetry Procedure
- 6.8.4 SOP 1.4, Beta-Gamma Radiation Measurements using a Geiger-Muller Detector
- 6.8.5 SOP 1.5, Measurement of Gamma-Ray Fields using a Sodium Iodide (NaI) Detector
- 6.8.6 SOP 1.6, Intermediate Volume Air Particulate Sampling
- 6.8.7 SOP 1.7, Sampling for Removable Alpha Contamination
- 6.8.8 SOP 1.8, Guide to the Handling, Packaging and Shipping of Samples
- 6.8.9 SOP 1.9, Sample Control and Documentation
- 6.8.10 SOP 1.10, Radiation Work Permits
- 6.8.11 SOP 1.11, Respiratory Protection Program
- 6.8.12 "Procedure for Counting Soil Samples for EOP Characterization"
- 6.8.13 Dow Central Research Index Report, CRI-TSP-92-076, "Radiological Analysis of Soil Samples from the Madison, Illinois Storage Facility Utilizing a Revised Alpha Spectroscopic Method"

Appendix A

Final Status Survey

Verification Measurements / Analyses

Table A1

BACKGROUND SOIL CONCENTRATIONS							
Bay City							
Sample Name	^{232}Th (pCi/G)	Error (2σ)	MDA (pCi/G)	^{230}Th (pCi/G)	Error (2σ)	^{228}Th (pCi/G)	Error (2σ)
BCBKG01	0.39	0.08	0.13	1.04	0.84	0.48	0.44
BCBKG02	0.36	0.07	0.14	0.46	0.34	0.41	0.31
BCBKG03	0.28	0.08	0.11	0.38	0.31	0.35	0.29
BCBKG04	0.44	0.10	0.13	0.80	0.91	0.62	0.74
BCBKG05	0.43	0.10	0.15	0.70	0.51	0.52	0.40
BCBKG06	0.51	0.18	0.13	0.68	0.47	0.48	0.35
BCBKG07	0.38	0.19	0.13	2.30	3.69	0.77	1.38
BCBKG08	0.16	0.08	0.11	0.37	0.48	0.12	0.20
BCBKG09	0.13	0.07	0.10	0.21	0.25	0.09	0.12
BCBKG10	0.26	0.09	0.13	0.38	0.39	0.23	0.26
BCBKG11	0.19	0.07	0.11	0.04	0.04	0.14	0.10
BCBKG12	0.18	0.08	0.14	0.18	0.14	0.11	0.09
BCBKG13	0.18	0.08	0.14	0.21	0.12	0.19	0.11
BCBKG15	0.23	0.07	0.11	0.12	0.15	0.32	0.31
BCBKG16	0.56	0.12	0.16	0.76	0.51	0.66	0.46
BCBKG17	0.41	0.10	0.16	0.30	0.47	0.30	0.47
BCBKG18	0.10	0.08	0.12	0.18	0.21	0.16	0.19
BCBKG19	0.12	0.06	0.10	0.15	0.14	0.06	0.07
BCBKG20	0.14	0.07	0.11	0.29	0.25	0.09	0.09
BCBKG21	0.19	0.07	0.15	0.23	0.17	0.13	0.11
BCBKG22	0.20	0.07	0.10	0.36	0.39	0.13	0.18
BCBKG23	0.15	0.06	0.11	0.24	0.24	0.30	0.29
BCBKG24	0.12	0.08	0.11	0.13	0.16	0.05	0.08
BCBKG25	0.22	0.07	0.08	0.93	0.89	0.72	0.70
BCBKG26	0.32	0.09	0.13	0.27	0.23	0.16	0.15
BCBKG27	0.56	0.20	0.20	0.93	0.69	0.90	0.67
BCBKG28	0.68	0.24	0.20	0.41	0.45	0.07	0.14
BCBKG29	0.43	0.19	0.21	0.65	1.22	0.43	0.89
BCBKG30	0.34	0.08	0.15	0.44	0.45	0.10	0.16
AVERAGE	0.30			0.49		0.31	
St. Dev.	0.16			0.44		0.24	

Table A2

Background Exposure Rates – Bay City

Sample	Value (μR/hr)
BCBKG1	5
BCBKG2	7
BCBKG3	5
BCBKG4	6
BCBKG5	4
BCBKG6	4
BCBKG7	5
BCBKG8	5
BCBKG9	5
BCBKG10	6
BCBKG11	5
BCBKG12	6
BCBKG13	5
BCBKG14	5
BCBKG15	7
BCBKG16	5
BCBKG17	4
BCBKG18	5
BCBKG19	5
BCBKG20	4
BCBKG21	4
BCBKG22	4
BCBKG23	4
BCBKG24	3
BCBKG25	3
ACROSS THE RIVER	
BCBKG26(1)	3
BCBKG27(2)	5
BCBKG28(3)	5
BCBKG29(4)	4
BCBKG30(5)	5

Number of measurements: 30
Average: 5 μR/hr
Standard Deviation: 1.3 μR/hr (≅ 1.0 μR/hr)

Table A3

Final Verification Soil Concentrations – VA-IV

SAMPLE #	WT. (g)	Gamma Spec. Sys.	Th-232 (pCi/g)	Th-230 (pCi/g)	Th-228 (pCi/g)	Th-232 Net (pCi/g)	Th-230 Net (pCi/g)	Th-228 Net (pCi/g)	Total Net Thorium (pCi/g)
BCS-F1-6-V1	2653.6	3	0.11	0.18	0.10	-0.19	-0.31	-0.20	-0.71
BCS-F1-9-V1	2502.5	3	0.37	0.60	0.35	0.07	0.11	0.05	0.23
BCS-F2-1-V1	2889.3	3	0.28	0.45	0.26	-0.02	-0.04	-0.04	-0.10
BCS-F2-2-V1	2657.3	3	0.29	0.47	0.27	-0.01	-0.02	-0.03	-0.07
BCS-F2-3-V1	2544.7	3	0.23	0.38	0.22	-0.07	-0.11	-0.08	-0.26
BCS-F2-4-V1	2552.9	3	0.72	1.17	0.68	0.42	0.68	0.38	1.47
BCS-F2-4-V1(qc)	2552.9	3	0.91	1.48	0.86	0.61	0.99	0.56	2.16
BCS-F2-5-V1	2948.8	1	0.40	0.66	0.38	0.10	0.17	0.08	0.35
BCS-F2-8-V1	2451.8	2	1.15	1.87	1.08	0.85	1.38	0.78	3.01
BCS-F2-9-V1	2706.3	2	0.59	0.97	0.56	0.29	0.48	0.26	1.03
BCS-F3-1-V1	2731.2	3	0.55	0.89	0.51	0.25	0.40	0.21	0.86
BCS-F3-2-V1	2468.0	3	1.00	1.64	0.94	0.70	1.15	0.64	2.50
BCS-F3-4-V1	2811.8	3	0.36	0.59	0.34	0.06	0.10	0.04	0.20
BCS-F3-5-V1	2628.0	3	0.41	0.67	0.39	0.11	0.18	0.09	0.37
BCS-F3-7-V1	2373.5	3	0.83	1.35	0.78	0.53	0.86	0.48	1.87
BCS-F3-7-V1(qc)	2373.5	3	0.70	1.14	0.66	0.40	0.65	0.36	1.40
BCS-F3-8-V1	2585.2	3	0.32	0.52	0.30	0.02	0.03	0.00	0.06
BCS-G1-3-V1	2982.3	1	0.51	0.84	0.48	0.21	0.35	0.18	0.75
BCS-G1-6-V1	2586.7	1	0.35	0.57	0.33	0.05	0.08	0.03	0.15
BCS-G1-9-V1	3084.9	2	0.15	0.25	0.14	-0.15	-0.24	-0.16	-0.54
BCS-G2-1-V1	2753.0	2	0.37	0.61	0.35	0.07	0.12	0.05	0.24
BCS-G2-1-V1(qc)	2753.0	2	0.21	0.34	0.19	-0.09	-0.15	-0.11	-0.35
BCS-G2-2-V1	2662.5	1	0.66	1.07	0.62	0.36	0.58	0.32	1.25
BCS-G2-2-V1(qc)	2662.5	1	0.54	0.88	0.50	0.24	0.39	0.20	0.83
BCS-G2-3-V1	2632.9	3	0.31	0.51	0.29	0.01	0.02	-0.01	0.02
BCS-G2-4-V1	3013.0	1	0.25	0.41	0.24	-0.05	-0.08	-0.06	-0.19
BCS-G2-5-V1	2753.2	1	0.21	0.34	0.20	-0.09	-0.15	-0.10	-0.35
BCS-G2-6-V1	2885.0	1	0.28	0.45	0.26	-0.02	-0.04	-0.04	-0.10
BCS-G2-7-V1	2957.4	1	0.24	0.39	0.22	-0.06	-0.10	-0.08	-0.24
BCS-G2-8-V1	2789.0	1	0.34	0.56	0.32	0.04	0.07	0.02	0.13
BCS-G2-9-V1	2835.9	1	0.27	0.44	0.25	-0.03	-0.05	-0.05	-0.13
BCS-G3-1-V1	2800.6	1	0.29	0.47	0.27	-0.01	-0.02	-0.03	-0.07
BCS-G3-2-V1	2660.9	3	0.51	0.84	0.48	0.21	0.35	0.18	0.75
BCS-G3-4-V1	3050.4	1	0.11	0.18	0.10	-0.19	-0.31	-0.20	-0.70
BCS-G3-5-V1	2713.4	1	0.46	0.75	0.43	0.16	0.26	0.13	0.55
BCS-G3-7-V1	3034.3	3	1.19	1.94	1.12	0.89	1.45	0.82	3.16
BCS-G3-8-V1	2959.8	1	0.33	0.53	0.31	0.03	0.04	0.01	0.08
BCS-H2-1-V1	2392.8	2	1.98	3.23	1.86	1.68	2.74	1.56	5.99
BCS-H2-2-V2	1999.3	2	1.15	1.87	1.08	0.85	1.38	0.78	3.01
BCS-H2-3-V2	2166.5	2	0.46	0.75	0.43	0.16	0.26	0.13	0.55
BCS-H2-4-V2	2296.9	2	0.94	1.54	0.89	0.64	1.05	0.59	2.28
BCS-H2-5-V2	2434.1	2	2.10	3.43	1.98	1.80	2.94	1.68	6.42
BCS-H2-6-V1	2622.5	2	0.23	0.38	0.22	-0.07	-0.11	-0.08	-0.27
BCS-H2-7-V2	2412.0	2	0.53	0.87	0.50	0.23	0.38	0.20	0.82
BCS-H2-8-V1	2711.9	2	0.62	1.01	0.58	0.32	0.52	0.28	1.12
BCS-H2-9-v1	2921.2	1	0.51	0.83	0.48	0.21	0.34	0.18	0.72
BCS-H2-9-v1(qc)	2921.2	1	0.54	0.88	0.51	0.24	0.39	0.21	0.83
BCS-H3-1-V1	2395.4	1	0.44	0.71	0.41	0.14	0.22	0.11	0.46
BCS-H3-2-V1	2457.4	1	0.68	1.10	0.64	0.38	0.61	0.34	1.33
BCS-H3-4-V1	2524.8	1	0.47	0.77	0.44	0.17	0.28	0.14	0.59
BCS-H3-4-V1(qc)	2524.8	1	0.45	0.73	0.42	0.15	0.24	0.12	0.51
BCS-H3-5-V1	2493.9	2	0.34	0.56	0.32	0.04	0.07	0.02	0.13
BCS-H3-7-V1	2308.9	2	0.40	0.65	0.37	0.10	0.16	0.07	0.33
BCS-H3-7-V1(qc)	2308.9	2	0.52	0.86	0.49	0.22	0.37	0.19	0.78
BCS-H3-8-V1	2557.0	2	0.35	0.56	0.33	0.05	0.07	0.03	0.14
BCS-H8-1-V1	2388.0	2	1.10	1.79	1.03	0.80	1.30	0.73	2.84
BCS-H8-2-V1	3195.3	1	0.65	1.07	0.61	0.35	0.58	0.31	1.24

Table A3

SAMPLE #	WT. (g)	Gamma Spec. Sys.	Th-232 (pCi/g)	Th-230 (pCi/g)	Th-228 (pCi/g)	Th-232 Net (pCi/g)	Th-230 Net (pCi/g)	Th-228 Net (pCi/g)	Total Net Thorium (pCi/g)
BCS-H8-3-V1	2779.1	2	0.54	0.87	0.50	0.24	0.38	0.20	0.82
BCS-H9-1-V1	2463.9	2	0.63	1.03	0.59	0.33	0.54	0.29	1.17
BCS-I2-1-V1	2863.2	2	0.51	0.84	0.48	0.21	0.35	0.18	0.75
BCS-I2-2-V1	2619.0	2	0.60	0.97	0.56	0.30	0.48	0.26	1.04
BCS-I2-3-V1	2543.9	2	0.39	0.64	0.37	0.09	0.15	0.07	0.32
BCS-I2-4-V1	2663.7	3	0.85	1.39	0.80	0.55	0.90	0.50	1.96
BCS-I2-4-V1 Dup	2945.8	3	0.80	1.30	0.75	0.50	0.81	0.45	1.75
BCS-I2-5-V1	2324.1	1	0.81	1.31	0.76	0.51	0.82	0.46	1.79
BCS-I2-6-V1	2342.0	1	0.74	1.21	0.70	0.44	0.72	0.40	1.55
BCS-I2-7-V1	2435.9	1	0.57	0.93	0.54	0.27	0.44	0.24	0.96
BCS-I2-8-V1	2024.7	1	1.52	2.47	1.43	1.22	1.98	1.13	4.33
BCS-I2-9-V1	1619.9	3	0.43	0.70	0.40	0.13	0.21	0.10	0.44
BCS-I3-1-V2	2490.0	3	0.98	1.60	0.92	0.68	1.11	0.62	2.41
BCS-I3-2-V1	2589.3	3	1.12	1.82	1.05	0.82	1.33	0.75	2.90
BCS-I3-4-V1	2217.3	3	0.83	1.35	0.78	0.53	0.86	0.48	1.87
BCS-I3-5-V1	2742.0	3	0.89	1.45	0.84	0.59	0.96	0.54	2.08
BCS-I3-7-V1	2513.4	3	0.93	1.52	0.87	0.63	1.03	0.57	2.23
BCS-I3-8-V1	2631.2	3	0.71	1.15	0.66	0.41	0.66	0.36	1.43
BCS-I5-2-V1	2797.9	2	0.48	0.79	0.46	0.18	0.30	0.16	0.64
BCS-I5-3-V1	2602.2	2	0.53	0.86	0.50	0.23	0.37	0.20	0.80
BCS-I6-3-V1	2582.4	2	1.03	1.68	0.97	0.73	1.19	0.67	2.58
BCS-I6-3-V1 Dup	2582.4	2	1.11	1.87	1.08	0.85	1.38	0.78	3.01
BCS-I7-1-V1	2764.1	1	1.01	1.64	0.95	0.71	1.15	0.65	2.51
BCS-I7-2-V1	2841.3	1	0.76	1.23	0.71	0.46	0.74	0.41	1.61
BCS-I7-3-V1	2730.7	3	0.77	1.25	0.72	0.47	0.76	0.42	1.66
BCS-I7-5-V1	2484.9	1	0.76	1.23	0.71	0.46	0.74	0.41	1.61
BCS-I7-6-V1	3045.0	2	0.51	0.83	0.48	0.21	0.34	0.18	0.72
BCS-I7-8-V1	3215.8	1	1.97	3.21	1.85	1.67	2.72	1.55	5.95
BCS-I7-9-V1	2498.2	2	0.87	1.42	0.82	0.57	0.93	0.52	2.03
BCS-I7-9-V1 Dup	2498.2	2	1.12	1.83	1.06	0.82	1.34	0.76	2.93
BCS-I8-1-V1	2172.7	3	1.23	2.00	1.15	0.93	1.51	0.85	3.30
BCS-I8-4-V1	2615.8	2	0.84	1.38	0.79	0.54	0.89	0.49	1.92
BCS-I8-5-V1	2038.9	2	0.89	1.46	0.84	0.59	0.97	0.54	2.10
BCS-I8-5-V1 Dup	2038.9	2	0.78	1.27	0.73	0.48	0.78	0.43	1.69
BCS-I8-7-V1	2963.2	1	1.39	2.27	1.31	1.09	1.78	1.01	3.89
BCS-I8-8-V1	2889.6	1	0.41	0.66	0.38	0.11	0.17	0.08	0.36
BCS-I8-8-V1 Dup	2889.6	1	0.43	0.70	0.40	0.13	0.21	0.10	0.44
BCS-I8-9-V1	2682.7	2	0.69	1.12	0.65	0.39	0.63	0.35	1.37
BCS-J2-1-V1	2513.6	3	1.72	2.80	1.61	1.42	2.31	1.31	5.04
BCS-J2-2-V1	2577.5	3	1.29	2.10	1.21	0.99	1.61	0.91	3.51
BCS-J2-3-V1	3072.8	3	2.25	3.66	2.11	1.95	3.17	1.81	6.93
BCS-J2-3-V1 Dup	3072.8	3	2.48	4.05	2.33	2.18	3.56	2.03	7.77
BCS-J2-4-V1	2686.9	2	1.25	2.03	1.17	0.95	1.54	0.87	3.36
BCS-J2-5-V1	3171.7	3	0.69	1.13	0.65	0.39	0.64	0.35	1.38
BCS-J2-6-V1	2466.4	3	1.70	2.76	1.59	1.40	2.27	1.29	4.96
BCS-J2-7-V1	2474.6	2	0.58	0.94	0.54	0.28	0.45	0.24	0.97
BCS-J2-8-V1	2929.8	3	0.61	0.99	0.57	0.31	0.50	0.27	1.09
BCS-J2-9-V1	2736.1	2	0.50	0.81	0.47	0.20	0.32	0.17	0.68
BCS-J3-1-V1	2737.7	3	0.80	1.30	0.75	0.50	0.81	0.45	1.76
BCS-J3-2-V1	2805.9	3	0.93	1.51	0.87	0.63	1.02	0.57	2.22
BCS-J3-3-V1	2830.5	3	1.00	1.63	0.94	0.70	1.14	0.64	2.48
BCS-J3-4-V1	2595.6	1	0.74	1.21	0.70	0.44	0.72	0.40	1.57
BCS-J3-5-V1	2899.4	2	1.16	1.90	1.09	0.86	1.41	0.79	3.06
BCS-J3-6-V1	2402.4	1	0.31	0.51	0.29	0.01	0.02	-0.01	0.03
BCS-J3-7-V1	2639.8	2	0.77	1.26	0.72	0.47	0.77	0.42	1.66
BCS-J3-8-V1	2673.8	3	1.08	1.76	1.01	0.78	1.27	0.71	2.75
BCS-J3-9-V1	2919.4	1	0.42	0.68	0.39	0.12	0.19	0.09	0.39

Table A3

SAMPLE #	WT. (g)	Gamma Spec. Sys.	Th-232 (pCi/g)	Th-230 (pCi/g)	Th-228 (pCi/g)	Th-232 Net (pCi/g)	Th-230 Net (pCi/g)	Th-228 Net (pCi/g)	Total Net Thorium (pCi/g)
BCS-J4-1-V1	2612.5	1	0.84	1.37	0.79	0.54	0.88	0.49	1.91
BCS-J4-2-V1	2166.7	2	1.95	3.18	1.83	1.65	2.69	1.53	5.87
BCS-J4-3-V1	2732.6	3	1.11	1.81	1.04	0.81	1.32	0.74	2.88
BCS-J4-4-V1	2583.7	1	0.54	0.87	0.50	0.24	0.38	0.20	0.82
BCS-J4-5-V1	2930.6	3	0.72	1.17	0.67	0.42	0.68	0.37	1.47
BCS-J4-6-V1	2473.3	1	0.30	0.48	0.28	0.00	-0.01	-0.02	-0.03
BCS-J4-7-V1	3153.6	1	0.49	0.81	0.47	0.19	0.32	0.17	0.68
BCS-J4-8-V1	2725.1	1	0.87	1.41	0.82	0.57	0.92	0.52	2.01
BCS-J5-1-V2	2508.7	1	1.18	1.92	1.11	0.88	1.43	0.81	3.11
BCS-J5-2-V1	2420.1	3	2.05	3.34	1.93	1.75	2.85	1.63	6.23
BCS-J5-2-V1(QC)	2420.1	[redacted]	[redacted]	3.15	1.82	1.63	2.66	1.52	5.81
BCS-J5-3-V1	2336.1	3	1.97	3.21	1.85	1.67	2.72	1.55	5.94
BCS-J5-4-V1	2514.0	1	0.70	1.14	0.66	0.40	0.65	0.36	1.41
BCS-J5-5-V1	2383.7	3	1.01	1.64	0.95	0.71	1.15	0.65	2.50
BCS-J5-6-V1	2971.1	2	1.19	1.95	1.12	0.89	1.46	0.82	3.17
BCS-J5-8-V1	2354.3	1	0.86	1.40	0.81	0.56	0.91	0.51	1.97
BCS-J5-9-V1	2737.4	2	0.73	1.19	0.68	0.43	0.70	0.38	1.51
BCS-J5-9-V1(QC)	2737.4	[redacted]	[redacted]	1.18	0.68	0.43	0.69	0.38	1.50
BCS-J6-1-V1	2194.7	3	1.59	2.59	1.49	1.29	2.10	1.19	4.59
BCS-J6-2-V1	2354.2	2	0.79	1.28	0.74	0.49	0.79	0.44	1.72
BCS-J6-3-V1	2833.9	2	1.04	1.70	0.98	0.74	1.21	0.68	2.63
BCS-J6-4-V1	2499.7	2	0.93	1.52	0.88	0.63	1.03	0.58	2.24
BCS-J6-5-V1	2096.0	2	1.48	2.41	1.39	1.18	1.92	1.09	4.18
BCS-J6-6-V1	2601.4	2	0.63	1.03	0.59	0.33	0.54	0.29	1.17
BCS-J6-9-V1	2423.2	2	0.78	1.28	0.74	0.48	0.79	0.44	1.71
BCS-J7-1-V1	2893.1	3	1.28	2.09	1.21	0.98	1.60	0.91	3.49
BCS-J7-2-V1	2827.1	1	1.68	2.74	1.58	1.38	2.25	1.28	4.92
BCS-J7-3-V1	1114.4	2	1.06	1.73	1.00	0.76	1.24	0.70	2.70
BCS-J7-4-V1	2314.8	3	1.00	1.62	0.94	0.70	1.13	0.64	2.47
BCS-J7-5-V1	3146.9	3	0.76	1.24	0.71	0.46	0.75	0.41	1.62
BCS-J7-6-V1	1532.9	2	0.83	1.35	0.78	0.53	0.86	0.48	1.87
BCS-J7-7-V1	2616.8	2	1.24	2.02	1.17	0.94	1.53	0.87	3.34
BCS-J7-8-V1	2846.7	2	1.04	1.70	0.98	0.74	1.21	0.68	2.64
BCS-J7-9-V2	1873.3	3	0.86	1.41	0.81	0.56	0.92	0.51	2.00
BCS-J7-9-V2(QC)	1873.3	[redacted]	[redacted]	1.67	0.96	0.73	1.18	0.66	2.57
BCS-K2-7-V1	2752.0	2	0.91	1.49	0.86	0.61	1.00	0.56	2.16
BCS-K2-8-V1	2886.2	2	0.86	1.41	0.81	0.56	0.92	0.51	1.99
BCS-K2-9-V1	2856.9	2	0.69	1.13	0.65	0.39	0.64	0.35	1.38
BCS-K3-7-V1	2972.1	2	0.60	0.98	0.57	0.30	0.49	0.27	1.06
BCS-K3-8-V1	2642.3	2	0.57	0.94	0.54	0.27	0.45	0.24	0.96
BCS-K3-8-V1(QC)	2642.3	[redacted]	[redacted]	1.23	0.71	0.45	0.74	0.41	1.59
BCS-K3-9-V1	2653.5	2	0.65	1.07	0.62	0.35	0.58	0.32	1.25
BCS-K4-7-V1	2533.3	3	0.92	1.49	0.86	0.62	1.00	0.56	2.18
BCS-K4-8-V1	2399.5	1	0.70	1.14	0.66	0.40	0.65	0.36	1.41
BCS-K4-9-V1	2227.6	2	4.66	7.59	4.38	4.36	7.10	4.08	15.54
BCS-K4-9-V1(QC)	2227.6	[redacted]	[redacted]	8.53	4.92	4.93	8.04	4.62	17.59
BCS-K5-7-V1	1851.5	1	5.67	9.24	5.33	5.37	8.75	5.03	19.15
BCS-K5-7-V1(QC)	1851.5	[redacted]	[redacted]	8.65	4.99	5.01	8.16	4.69	17.86
BCS-K5-8-V1	1846.9	3	4.63	7.55	4.36	4.33	7.06	4.06	15.45
BCS-K5-9-V1	2817.7	3	1.85	3.02	1.74	1.55	2.53	1.44	5.52
BCS-K6-7-V1	2625.8	3	1.56	2.55	1.47	1.26	2.06	1.17	4.49
BCS-K6-8-V1	2354.9	2	0.88	1.44	0.83	0.58	0.95	0.53	2.06
BCS-K6-9-V1	2945.3	3	1.45	2.37	1.37	1.15	1.88	1.07	4.10
BCS-K7-7-V1	2815.2	2	0.68	1.10	0.63	0.38	0.61	0.33	1.32
BCS-K7-8-V1	2923.2	3	0.98	1.60	0.92	0.68	1.11	0.62	2.41
BCS-K7-9-V1	1406.7	3	1.82	2.97	1.71	1.52	2.48	1.41	5.41

Table A3

Final Verification Soil Concentrations – VA-IV

Equations
Th-230 (pCi/g) = 1.63 * Th-232 (pCi/g)
Th-228 (pCi/g) = 0.94 * Th-232 (pCi/g)
Th-232 Net (pCi/g) = Th-232 (pCi/g) - 0.3
Th-230 Net (pCi/g) = Th-230 (pCi/g) - 0.49
Th-228 Net (pCi/g) = Th-228 (pCi/g) - 0.3
Total Net Thorium = Th-232 Net + Th-230 Net + Th-228 Net

Table A5

Final Gamma Exposure Rates – VA-IV

Grid Number	Gross Exposure (μR/hr)	Net Exposure (μR/hr)	Grid Number	Gross Exposure (μR/hr)	Net Exposure (μR/hr)
BCS-F1-6-V1	7	2	BCS-H2-6-V1	6	1
BCS-F1-9-V1	7	2	BCS-H2-7-V2	6	1
BCS-F2-1-V1	6	1	BCS-H2-8-V1	7	2
BCS-F2-2-V1	6	1	BCS-H2-9-v1	8	3
BCS-F2-3-V1	7	2	BCS-H3-1-V1	8	3
BCS-F2-4-V1	7	2	BCS-H3-2-V1	7	2
BCS-F2-5-V1	6	1	BCS-H3-4-V1	7	2
BCS-F2-8-V1	8	3	BCS-H3-5-V1	7	2
BCS-F2-9-V1	9	4	BCS-H3-7-V1	7	2
BCS-F3-1-V1	6	1	BCS-H3-8-V1	6	1
BCS-F3-2-V1	7	2	BCS-H8-1-V1	8	3
BCS-F3-4-V1	7	2	BCS-H8-2-V1	7	2
BCS-F3-5-V1	8	3	BCS-H8-3-V1	7	2
BCS-F3-7-V1	8	3	BCS-H9-1-V1	7	2
BCS-F3-8-V1	8	3	BCS-I2-1-V1	8	3
BCS-G1-3-V1	7	2	BCS-I2-2-V1	7	2
BCS-G1-6-V1	7	2	BCS-I2-3-V1	8	3
BCS-G1-9-V1	6	1	BCS-I2-4-V1	8	3
BCS-G2-1-V1	6	1	BCS-I2-5-V1	7	2
BCS-G2-2-V1	6	1	BCS-I2-6-V1	8	3
BCS-G2-3-V1	6	1	BCS-I2-7-V1	8	3
BCS-G2-4-V1	7	2	BCS-I2-8-V1	7	2
BCS-G2-5-V1	6	1	BCS-I2-9-V1	6	1
BCS-G2-6-V1	6	1	BCS-I3-1-V2	7	2
BCS-G2-7-V1	6	1	BCS-I3-2-V1	7	2
BCS-G2-8-V1	6	1	BCS-I3-4-V1	7	2
BCS-G2-9-V1	7	2	BCS-I3-5-V1	7	2
BCS-G3-1-V1	6	1	BCS-I3-7-V1	7	2
BCS-G3-2-V1	7	2	BCS-I3-8-V1	7	2
BCS-G3-4-V1	6	1	BCS-I5-2-V1	7	2
BCS-G3-5-V1	7	2	BCS-I5-3-V1	7	2
BCS-G3-7-V1	6	1	BCS-I6-3-V1	10	5
BCS-G3-8-V1	7	2	BCS-I7-1-V1	11	6
BCS-H2-1-V1	7	2	BCS-I7-2-V1	8	3
BCS-H2-2-V2	8	3	BCS-I7-3-V1	7	2
BCS-H2-3-V2	6	1	BCS-I7-5-V1	8	3
BCS-H2-4-V2	7	2	BCS-I7-6-V1	7	2
BCS-H2-5-V2	9	4	BCS-I7-8-V1	8	3

Table A5

Final Gamma Exposure Rates – VA-IV

Grid Number	Gross Exposure (μR/hr)	Net Exposure (μR/hr)	Grid Number	Gross Exposure (μR/hr)	Net Exposure (μR/hr)
BCS-I7-9-V1	8	3	BCS-J4-6-V1	8	3
BCS-I8-1-V1	7	2	BCS-J4-7-V1	9	4
BCS-I8-4-V1	7	2	BCS-J4-8-V1	10	5
BCS-I8-5-V1	8	3	BCS-J5-1-V2	6	1
BCS-I8-8-V1	8	3	BCS-J5-5-V1	7	2
BCS-I8-9-V1	7	2	BCS-J5-8-V1	9	4
BCS-J2-1-V1	8	3	BCS-J5-9-V1	7	2
BCS-J2-2-V1	7	2	BCS-J6-9-V1	9	4
BCS-J2-3-V1	7	2	BCS-J7-1-V1	9	4
BCS-J2-4-V1	8	3	BCS-J7-2-V1	9	4
BCS-J2-5-V1	8	3	BCS-J7-3-V1	6	1
BCS-J2-6-V1	8	3	BCS-J7-4-V1	7	2
BCS-J2-7-V1	8	3	BCS-J7-5-V1	7	2
BCS-J2-8-V1	6	1	BCS-J7-6-V1	7	2
BCS-J2-9-V1	6	1	BCS-J7-7-V1	10	5
BCS-J3-1-V1	7	2	BCS-J7-8-V1	8	3
BCS-J3-2-V1	7	2	BCS-J7-9-V1	7	2
BCS-J3-3-V1	7	2	BCS-K2-7-V1	8	3
BCS-J3-4-V1	8	3	BCS-K2-8-V1	8	3
BCS-J3-5-V1	7	2	BCS-K2-9-V1	7	2
BCS-J3-6-V1	9	4	BCS-K3-7-V1	7	2
BCS-J3-7-V1	7	2	BCS-K3-8-V1	7	2
BCS-J3-8-V1	8	3	BCS-K3-9-V1	7	2
BCS-J3-9-V1	9	4	BCS-K4-7-V1	7	2
BCS-J4-1-V1	8	3	BCS-K4-8-V1	7	2
BCS-J4-2-V1	8	3	BCS-K7-7-V1	8	3
BCS-J4-3-V1	9	4	BCS-K7-8-V1	8	3
BCS-J4-4-V1	9	4	BCS-K7-9-V1	6	1
BCS-J4-5-V1	10	5			

Total Number of Sub-grids	133	
Average Gross Exposure	7	μR/hr
Average Net Exposure	2	μR/hr

Table A6

Final Status Survey: Statistical Analysis

The following statistical relations were used to assess the database for the Bay City survey unit:

Survey Data Average ($\bar{x}$):

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

Standard Deviation (S_x):

$$S_x = \sqrt{\frac{\sum_{i=1}^{n}(\bar{x} - x_i)^2}{n-1}}$$

Determination of Number of Background data points (n_B):

$$n_B = \left[\frac{t_{95.5\%,df} S_x}{0.2 \bullet \bar{x}_B}\right]^2$$

Comparison of statistical mean ($\mu\alpha$) with guideline values:

$$\mu_\alpha = \bar{x} + t_{1-\alpha,df}\frac{S_x}{\sqrt{n}}$$

Identifying additional measurement/sampling needs:

$$\text{Estimating Factor} = \frac{C_G - \bar{x}}{S_x}$$

(Tables B-2 in NUREG/CR-5849)

Note: See chapter 8.0 of NUREG/CR-5849 for detailed discussion of above-listed statistical analyses.

Where:

X_i = measurement (analysis) at point i
n = number of measurements (analyses)
t_i - α, df = 95% confidence level from Table B-1 of Appendix B of NUREG/CR-5849
C_G = Guideline Value

Table A7

Final Status Survey: Summary Statistics

Exposure Rates							
Section	n	X (μR/h)	Sx (μR/h)	μα (μR/h)	C_G (μR/h)	Estimating Factor	No. Verification Samples Needed
VA-IV	133	2.4	1.0	2.5	5.0	2.6	<9
Th-232 Soil Concentrations							
Section	n	X (pCi/g)	Sx (pCi/g)	μα (pCi/g)	C_G (pCi/g)	Estimating Factor	No. Verification Samples Needed
VA-IV	170	0.6	0.7	0.7	3.2	3.7	<9

Final Status Survey Report for VA-V
Magnesium-Thorium Slag Storage Area
The Dow Chemical Company's
Bay City, Michigan Facility

DOW U.S.A.

The Dow Chemical Company
Midland, Michigan 48674

Revision 1
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TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

1.0 BACKGROUND INFORMATION

The radioactive material at the Dow Chemical Company's Bay City site consisted primarily of foundry slag containing Thorium. This material, and similar material originally stored at Dow's Midland site, was produced in the period from 1940 to 1970 as the residual from the production of a magnesium-thorium alloy. This lightweight alloy was used for defense purposes, including aircraft engines and aeronautical structural components.

A single license (STB-527) was originally granted by the NRC in 1973 for the Bay City and Midland sites to store up to 200,000 pounds of thorium slag. The license expired in 1978, but has remained in effect under timely renewal.

The Midland site was decontaminated with the material removed and transported to Bay City for consolidation with the Bay City material and subsequent transport to the Envirocare facility in Clive, Utah. A final survey was conducted at the Midland site by Dow with the results documented in a Final Status Survey Report of March, 1997, showing that the residual contamination criteria had been met. The NRC subsequently conducted an independent survey of the Midland site and verified that the residual contamination criteria had been met.

The material transported from the Midland site to the Bay City site originally consisted of magnesium with up to two percent thorium. Portions of this process slag were mixed with soil or limited amounts of construction debris. As a result of this mixing, the thorium concentrations, as determined by Dow characterization soil sampling, varied from 2-7000 pCi/g at the Bay City Site (with an average concentration of 188 pCi/g) . A total activity of 9.7 Ci of Th-232 was originally distributed throughout approximately 52,000 cubic yards of soil, slag, and construction debris.

Initial remedial action support surveys, performed in 1996, identified wide spread areas of elevated contamination. The gamma scan surveys were conducted using a sodium iodide detector. Readings were generally higher the closer the proximity to the original thorium pile but several hot spots in the 300,000 to 600,000 cpm range were identified. Construction debris, such as drums, were removed from these areas along with the contaminated soil.

Decontamination of the Bay City site is ongoing. In accordance with NRC and Dow discussions, as confirmed in Dow's letter of June 12, 1997, verification that residual contamination criteria have been achieved on this large site is being performed in sections. This Final Status Survey Report (FSR) provides the descriptive text on the site and the parameters of the survey program and includes the analyzed verification data for Verification Area (VA) V. As the database is acquired for subsequent VAs addendums to the Final Survey Report will be submitted to the NRC containing the analyzed database.

Supporting information on the Bay City site and decommissioning project is presented in the October, 1993 Decommissioning Work Plan, the December, 1995 Supplement to the Decommissioning Work Plan, and the March, 1996 Response to Comments.

This document is a revision to the original Final Status Survey Report for VA-V dated December 1, 1998.

On December 8th through December 9th of 1998, after the original report submittal, the NRC Region III conducted an inspection of the VA-V portion of the Dow Bay City facility. The primary purpose of the inspection was to conduct an independent confirmatory survey of VA-V. This revision to the original report is provided to include the findings of the NRC confirmatory surveys documented in NRC Report No. 040-00017/98002 (DNMS) dated December 17, 1998.

Additionally, this revision to the original report is provided to address deficiencies identified by NRC staff in a letter to Dow dated August 16, 2002 (Review of Final Status Survey Reports for the Previously Remediated Areas VA-I through VA-VI, Dow Chemical Company's Bay City, MI, SDMP Site (TAC# L60463)).

2.0 SITE INFORMATION

2.1 SITE DESCRIPTION

The Bay City thoriated material storage site is on a Dow facility near the Town of Bay City, Michigan about one-mile south of Saginaw Bay. The Bay City site (pile) is shown on Figure 2-1 in relation to adjacent land features and other facilities.

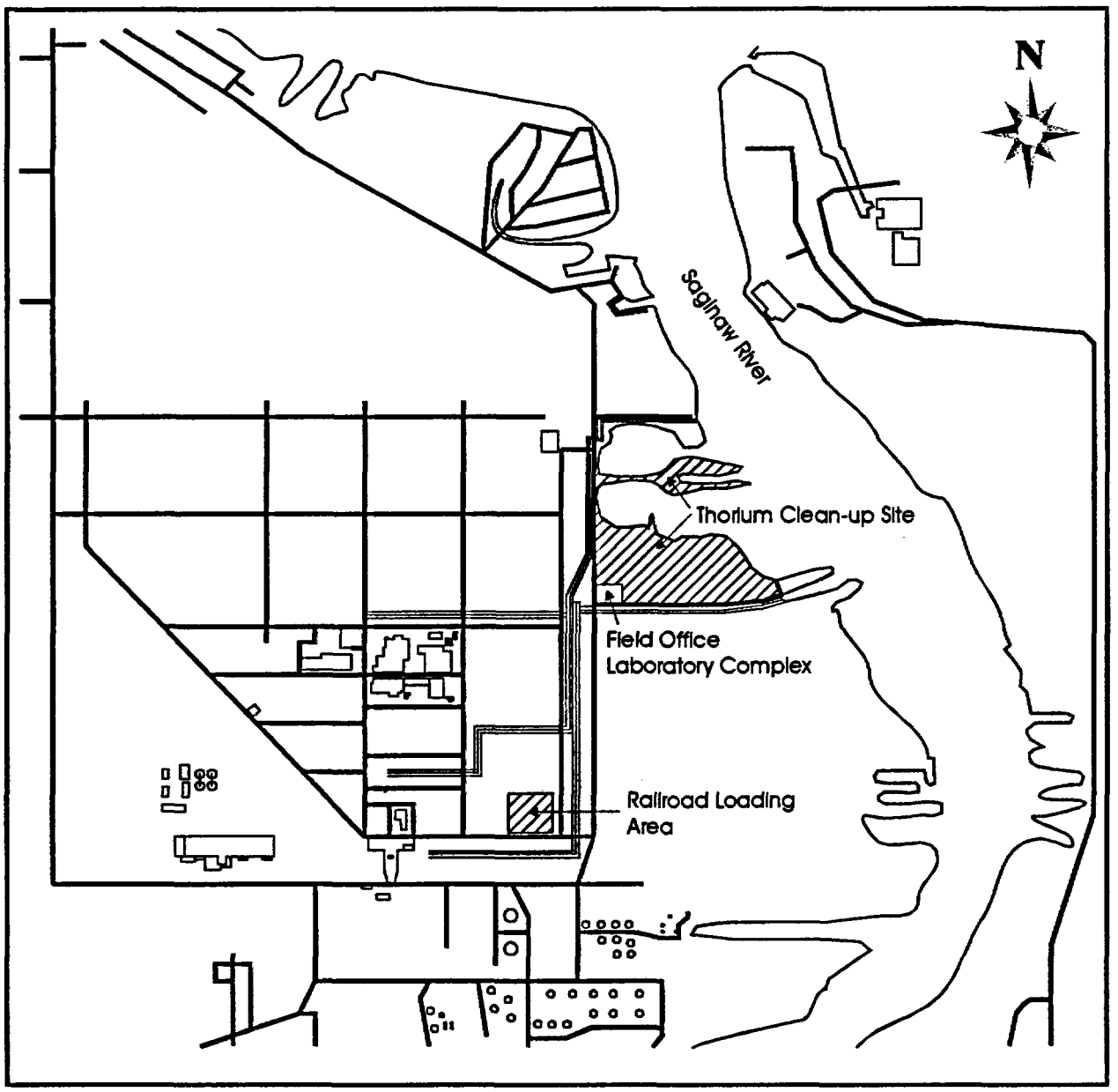
The thoriated material site is located adjacent to and north of an inlet canal, which enters the Saginaw River to the east. The Saginaw River is located to the north and east of the material. Access to the Dow manufacturing facility is restricted to authorized personnel. The storage site within the facility is posted as a radiation control area and delineated with a fence.

The area surrounding the material is relatively level, with some marshy areas and ponds. Any sediments containing elevated levels of thorium are being excavated as part of the decontamination program.

The affected area of the Bay City storage site was initially based on knowledge of the operating history, and subsequently on radiological characterization surveys. While areas immediately surrounding the Bay City storage area were included in the affected area, some further outward adjustment of the affected area boundary was required during site remediation to encompass surface and subsurface contamination uncovered during remedial operations.

Figure 2-1

Bay City Thorium Disposal Site



2.2 SITE CONDITIONS AT TIME OF FINAL SURVEY

The decommissioning activities at the Bay City site involve excavation of the contaminated soil, loading on to trucks, onsite transportation of the material to the stockpile at the railhead, loading on to the rail cars, and transport of the material to the Envirocare burial site in Clive, Utah. Soil removal is to varying depths continuing until sample analysis showed residual concentrations to be within NRC defined limits. Final verification samples were taken in the VA and analyzed on site through gamma spectroscopy. When the gamma spectral analysis results showed the Th-232 levels to be less than the guideline value, a conversion factor was applied to the Th-232 concentration to obtain the Th-230 and Th-228 concentrations. After the net total thorium concentration was determined, five percent of all final verification soil samples were sent to Dow Chemical's radioanalytical laboratory, Freeport, Texas, where the samples were monitored by the Dow Quality Assurance coordinator.

2.3 IDENTITY OF POTENTIAL CONTAMINANTS AND RELEASE GUIDELINES

Based on the knowledge of the process that generated the slag material, and the results of the characterization survey, the significant radiological contaminants were determined to be Th-232, Th-230, and Th-228. The above background residual soil concentration measurements used as a basis for the final verification for all the verification samples analyzed to date at Bay City provided the average soil activity ratios at Bay City of approximately:

Th-232	-	22%
Th-230	-	60%
Th-228	-	18%

Using the approach described in Section 3.1 ("Release Criteria") of the December, 1995 Supplement to the Decommissioning Work Plan and response No. 8 of the Response to Comments (on the Work Plan) of March, 1996, in conjunction with the methodology in Appendix A of NUREG/CR 5849 gives a residual soil gross activity guideline of 14.5 pCi/g total

thorium. The site-specific guideline levels for each of the contributory radionuclides is thus 3.2 pCi/g for Th-232, 2.6 pCi/g for Th-228, and 8.7 pCi/g for Th-230.

The gross activity guideline is determined as follows:

$$\textit{Gross Activity Guideline} = \frac{1}{\frac{0.22}{10} + \frac{0.18}{10} + \frac{0.60}{21}} = 14.5\ pCi/g$$

where Th-232, Th-230, and Th-228 are present in net activity ratios of 0.22, 0.60, and 0.18 respectively in the residual soil. The guideline concentrations for Th-232 plus Th-228 are 10 pCi/g and 21 pCi/g for Th-230 (see March, 1996 Response to Comments).

3.0 FINAL STATUS SURVEY OVERVIEW

3.1 SURVEY OBJECTIVES

The purpose of the final status survey was to demonstrate that the residual radiological concentrations in the soil at the Bay City thorium storage site satisfy the NRC guidelines (see 2.3 above) and that the storage site can, therefore, be released for future use without radiological controls. Specifically, the final status survey soil database should show that:

- Average residual radionuclide concentrations are at or below the soil guideline values defined in Section 2.3. Averaging is based on a 100 m^2 (10m x 10m) grid area. Note an actual grid size of 33.3 ft. x 33.3 ft. was used for convenience in measuring rather than 10m x 10m (32.8 ft. x 32.8 ft.).

- Reasonable efforts have been made to identify, evaluate, and remove, if necessary, areas of residual activity exceeding the guideline values. Areas of residual activity exceeding the guideline value (elevated areas) may be acceptable provided they do not exceed the guideline value by greater than a factor of $(100/A)^{1/2}$, where A is the area of residual

activity in m^2, and provided the activity level at any location does not exceed three times the guideline values.

In addition, exposure rates should not exceed 5 μR/h above background at 1 m above the soil surface. Exposure rates may be averaged over a 100 m^2 grid area. Maximum exposure rates over any discrete area may not exceed 10 μR/h above background.

A 95% minimum level of confidence that the above conditions have been met was to be demonstrated. The entire Section V of the Bay City storage area (affected area) is treated as a single survey unit, and the 95% level of confidence was applied to the entire survey unit.

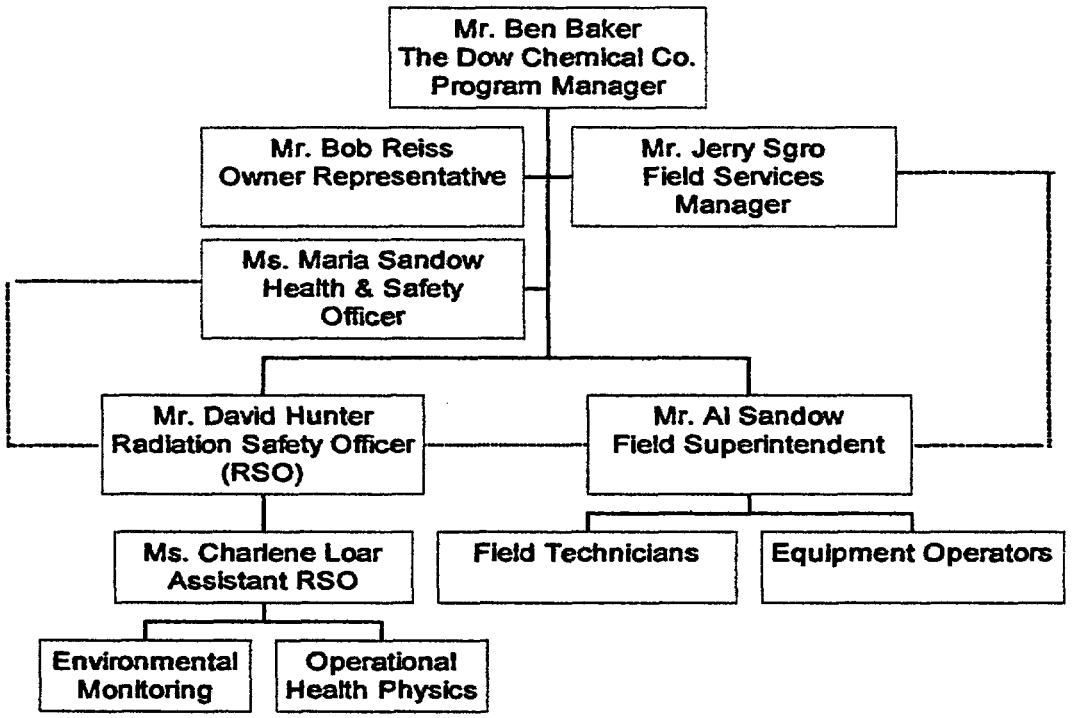
3.2 ORGANIZATION AND RESPONSIBILITIES

The final status survey was conducted by the same qualified Dow and subcontractor personnel who had conducted the characterization survey, and remediation control survey. The Project Organization is shown in Figure 3-1.

The sampling and analysis methods to be used during the remediation control survey was designed to achieve the sampling sensitivity and elevated activity guidelines defined in NUREG/CR-5849 relative to the site specific residual contamination criteria. The approach consisted of first performing a gamma scan survey of the remediated area to determine if any localized areas of elevated activity remained. Elevated areas of activity identified by the scan survey were remediated. If no areas of elevated activity were identified, composite soil samples were then collected and analyzed in the field laboratory using a NaI crystal coupled to the MCA to provide rapid turnaround on the Th-232 levels. If the Th-232 level exceeded the guideline value, further remediation was performed. The soil sample results of the analysis of the final samples collected, that demonstrated that the administrative cleanup level had been achieved, were then used as input into the final status survey.

Figure 3-1

Project Organization for Remediation of the Midland and Bay City Storage Sites



3.3 INSTRUMENTATION

Table 3-1 lists the field radiological monitoring instrumentation used on the project inclusive of the specific use of each instrumentation and detection sensitivities. Each instrument was initially calibrated to NIST-traceable standards prior to use on the project, and then checked for radiation response and efficiency prior to daily use.

Table 3-1

Field Radiological Monitoring Instrumentation

Instrument	Measures	Detector Efficiency*	LLD/MDA
Ludlum Model 43-5 w/ Ludlum Model 12	Alpha Surface	15%	22 dpm
Ludlum Model 43-90 w/ Ludlum Model 2221	Alpha Surface	22%	12 dpm
Ludlum Model 44-9 w/ Ludlum Model 12	Alpha, Beta, Gamma	12% alpha 15% beta 1% gamma	
Ludlum Model 43-10 w/ Ludlum 1000	Alpha (air filters, smears)	43%	0.04 dpm
Ludlum Model 19	Exposure Rate		1 microR/h
Air Particulate			
Eberline RAS-1 Air Pump	Flow Rate = 40-100 lpm		
MSA Escort Lapel Sampler	Flow Rate = 2-3 lpm		
General Metal Works–2000 High Vol Sampler	Flow Rate = 30-60 cfm		
Test/Calibration Equipment			
Ludlum Model 500 Pulser	NIST Traceable		
AFC-85L Air Flow Calibrator	NIST Traceable		
GMW-Calibrator Orifice for High Vol Sampler	NIST Traceable		
MSA Optiflow 660 Air Flow Calibrator	NIST Traceable		
Field Laboratory Equipment			
Canberra Gamma Spectrometer	Soil Th-232 Concentration		0.8 pCi/g

* Detector efficiencies are approximate and appropriate for Th-230, Tc-99, and Co-60

3.4 SURVEY PROCEDURES

Survey planning and procedures are consistent with the methods described in the Decommissioning Plan. The soil survey procedures are summarized in this section and can be found in greater detail in Appendices D-2 and D-3 of the March, 1996 Response to Comments.

3.4.1 Area Classification

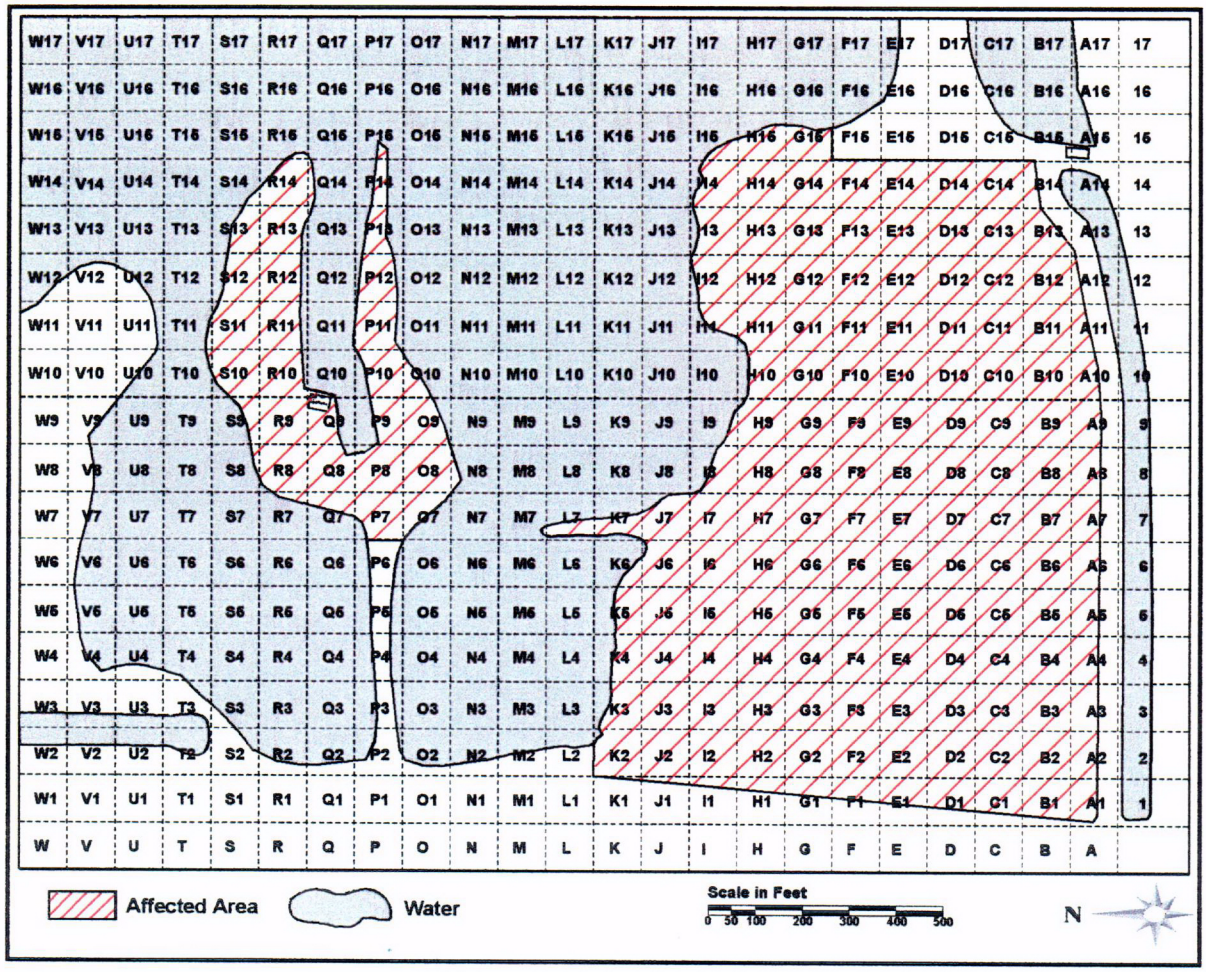
The Bay City storage site was divided into affected and unaffected areas to establish the sampling pattern and frequency. The basis for the affected and unaffected classification, as applied to the Bay City site are:

- **Affected Area** – As shown in Figure 3-2, the thorium material storage area and region immediately surrounding the storage area was defined as the affected area based on both historical records and prior characterization surveys. This location had known thorium contamination in the soil that had been placed there via backfill operations and storage.

- **Unaffected Area** – The region surrounding the affected area (see Figure 3-2) was treated as unaffected since it did not contain residual radioactivity.

Figure 3-2

Bay City Site Affected Areas



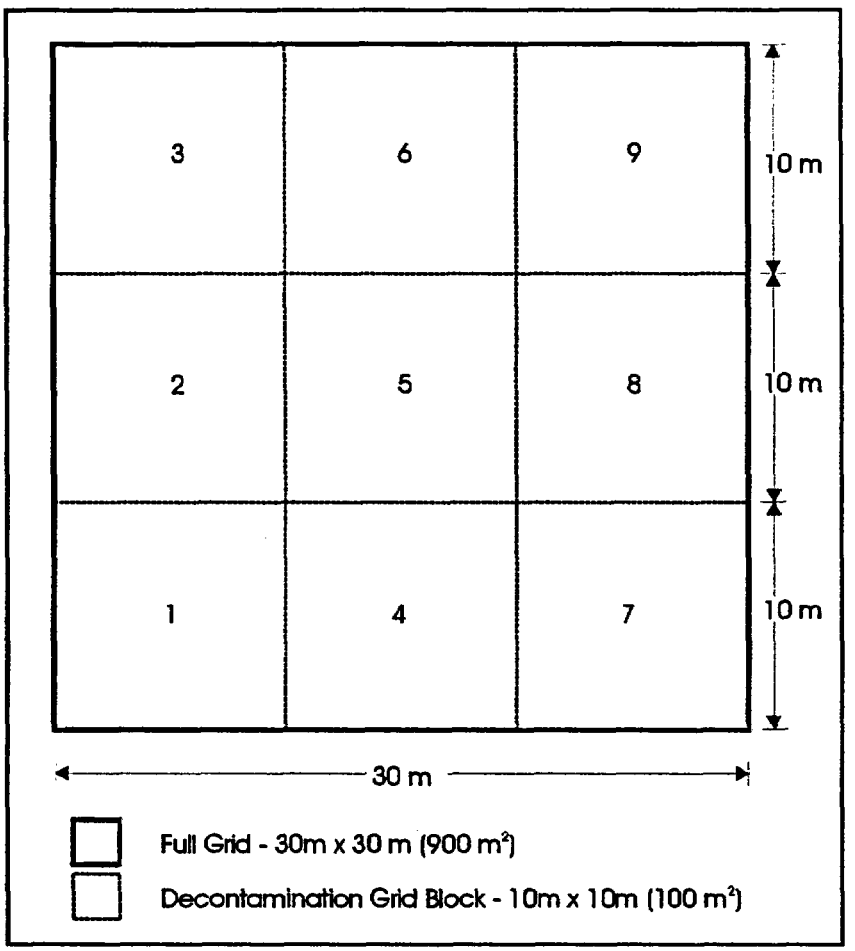
3.4.2 Reference Grid

A grid was established over the affected area upon completion of material excavation for the purpose of referencing locations of samples and measurements (see Figure 3-2). These full grids were 30m x 30m (900 m^2) in size. Each full grid was then divided into nine 10m x 10m sub-grids (100 m^2 each). Each sub-grid was marked into 5-meter increments to establish the four quadrants (A-D) where soil samples were taken to obtain four composite samples per sub-grid. Figure 3-3 depicts the breakdown of the reference grid system. As previously noted, the entire Section V (affected area) constituted the survey unit.

C13

Figure 3-3

Reference Grid System



3.4.3 Surface Scans

One hundred percent of the soil surface was initially scanned to identify locations of elevated activity. The gamma scans were conducted in accordance with procedure SOP 1.5, Measurement of Gamma-Ray Fields using a Sodium Iodide (NaI) Detector. As soil was removed, additional gamma scans were conducted to identify remaining locations of contaminated soil. After completion of contaminated soil removal, a final scan was performed of the soil surface prior to obtaining final verification soil samples.

3.4.4 Soil sampling

Final survey soil samples consisted of 4 composite samples (approximately 2 kg each) from each sub-grid (see Figure 3-4). This sampling method differs from the method used in VA-I through VA-IV where nine individual samples were combined into one composite sample for each sub-grid. The modification to the sampling procedure was made by the RSO to be more consistent with NUREG/CR-5849. The sampling method used in VA-V and VA-VI is conservative relative to that used in VA-I – VA-IV in that a minimum of 3 soil samples from each 25 m^2 quadrant were composited, providing a total of 12 individual samples from each 100 m^2 sub-grid. This exceeds the decommissioning plan requirement of 9 soil samples (composited into 1) in each 100 m^2 sub-grid. One of the three individual samples from each quadrant was collected at the location with the highest scan reading. The remaining two sample locations were randomly selected.

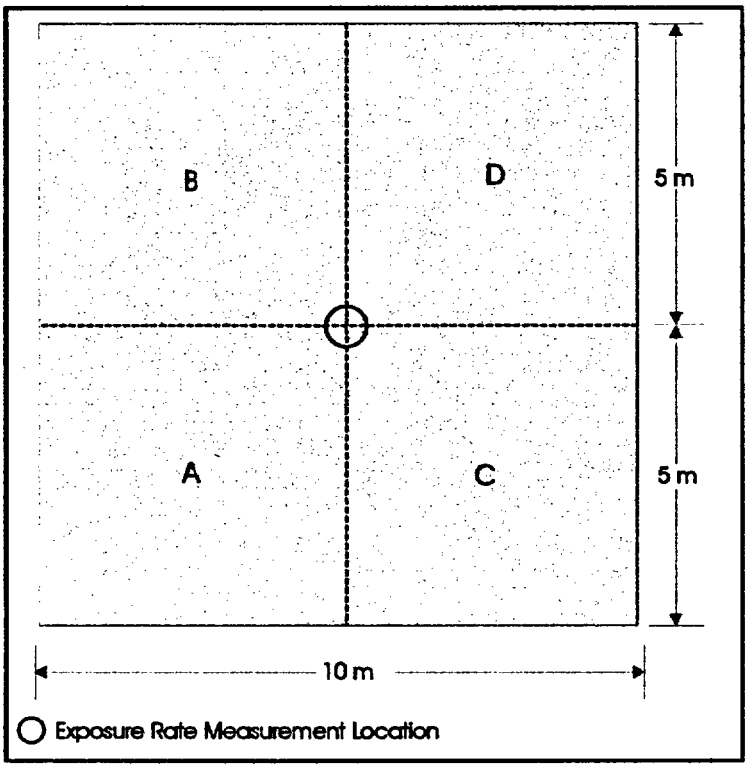
The samples were collected after gamma levels were measured to preliminarily determine that all contaminated soil had been removed. Each of the twelve locations where the individual samples were collected was scanned prior to soil sampling to validate that elevated levels did not exist (>3 times background). These final verification soil samples were analyzed on site through gamma spectroscopy. When the analytical results for Th-232 were less than the guideline value, a conversion factor was applied to the Th-232 concentration to obtain the Th-230 and Th-228 concentrations. After the net total thorium concentration was determined, five percent of all final verification soil samples were sent to Dow Chemical's radioanalytical laboratory in Freeport, Texas for duplicate QA analyses. Soil sample collection was performed in accordance with procedure SOP 1.8, Guide to the Handling, Packaging and Shipping of Samples, and SOP 1.9, Sample Control and Documentation.

3.4.5 Exposure Rate Measurements

Gamma exposure rates were measured in the affected area at 1 meter above the soil surface at the center of each sub-grid (see Figure 3-4). Exposure rate measurements were obtained using a Ludlum Model 19 MicroR meter.

Figure 3-4

Sub-grid Quadrant Designation

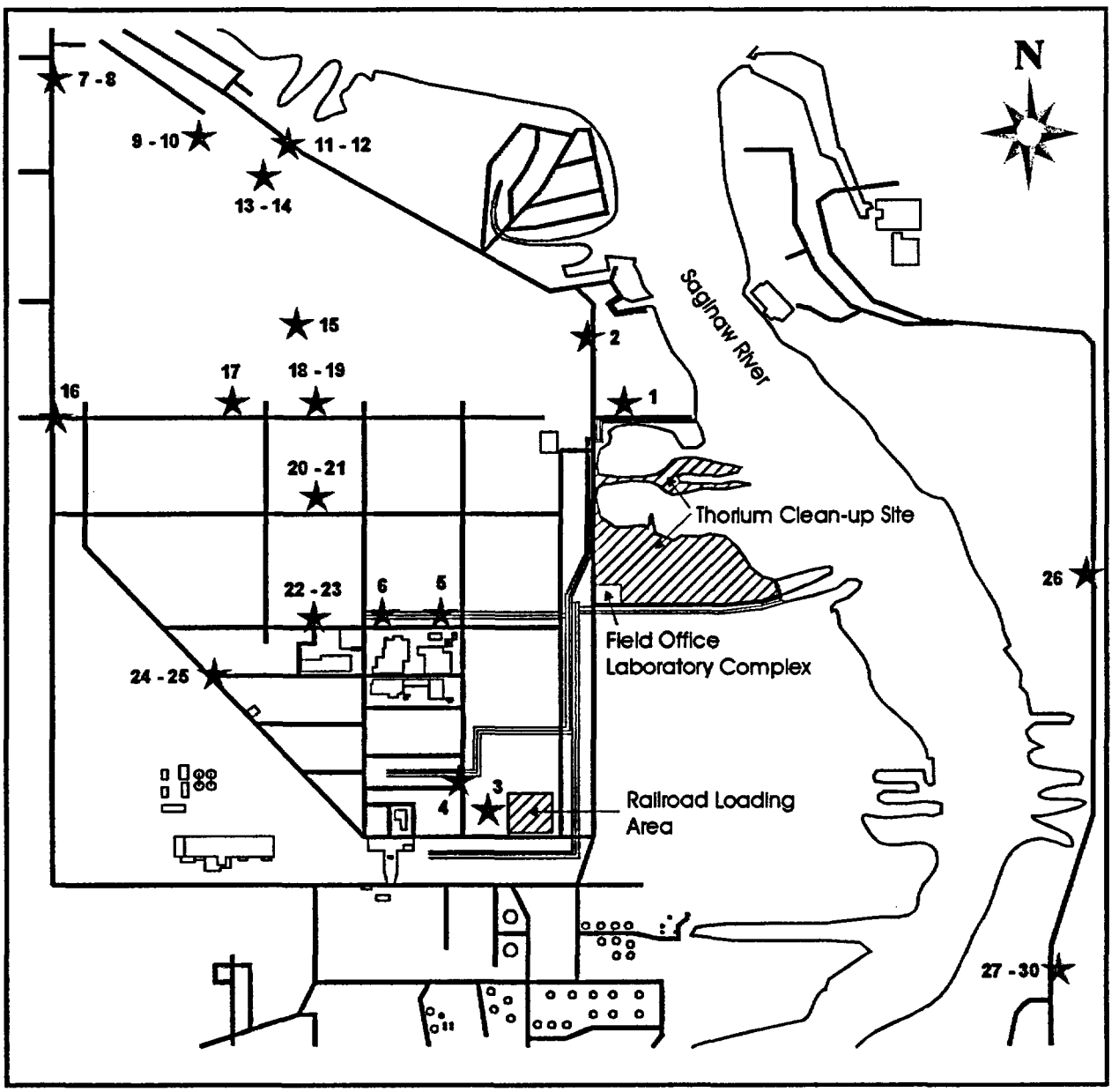


3.5 BACKGROUND LEVEL DETERMINATION

Background soil samples were collected from 30 locations in the unaffected area (Figure 3-5), and 29 samples analyzed for Th-230, Th-232, and Th-228 concentrations in the Freeport Laboratory (sample no. 14 was lost in transit). Sample numbers 1-25 were collected from locations on Dow property that were not impacted by site operations. Sample numbers 26-30 were collected from locations east of the Dow property, across the Saginaw River. Background exposure rates were measured at the same locations as the soil samples. Statistical procedures described in NUREG/CR-5849 (see Table A6) were used to assure that the average thorium concentrations determined were representative of true average background levels.

Figure 3-5

Background Sample Locations



3.6 SAMPLE ANALYSIS

Final survey soil samples were analyzed for Th-232 in the field laboratory using the NaI detector coupled to the MCA. Soil samples were analyzed in accordance with "Procedure for Counting Soil Samples for EOP Characterization". Th-228 and Th-230 concentrations were determined by

multiplying the Th-232 result by 0.94 and 1.63, respectively. Five percent of the FSS samples were analyzed for Th-232, Th-230, and Th-228 using gamma and alpha spectroscopy in the Freeport Laboratory to satisfy QA requirements. The onsite analytical methods were determined to be acceptable by NRC as documented in Inspection Report 040-00017/98002.

3.7 DATA INTERPRETATION

Soil sample locations and survey results for fixed measurements were recorded on data sheets. The data conversion and statistical analysis techniques in NUREG/CR-5849 (Chapter 8.0) were used to convert the reported data into a form that permitted a direct comparison with residual contamination guidelines and thus assess if remediation goals were met. The statistical relationships are shown with the analyzed data in Appendix A (Tables A6, A7). Soil concentrations were converted into units of pCi/g and exposure rates to μR/h. The reported affected area data in Appendix A has been adjusted by subtracting the natural background levels.

Additional soil removal was performed when the remediation control survey measurements showed that residual contamination guidelines were not being met. As a result, there were no remaining "hot spots" and Hot spot averaging criteria were not applied.

3.8 RECORDS

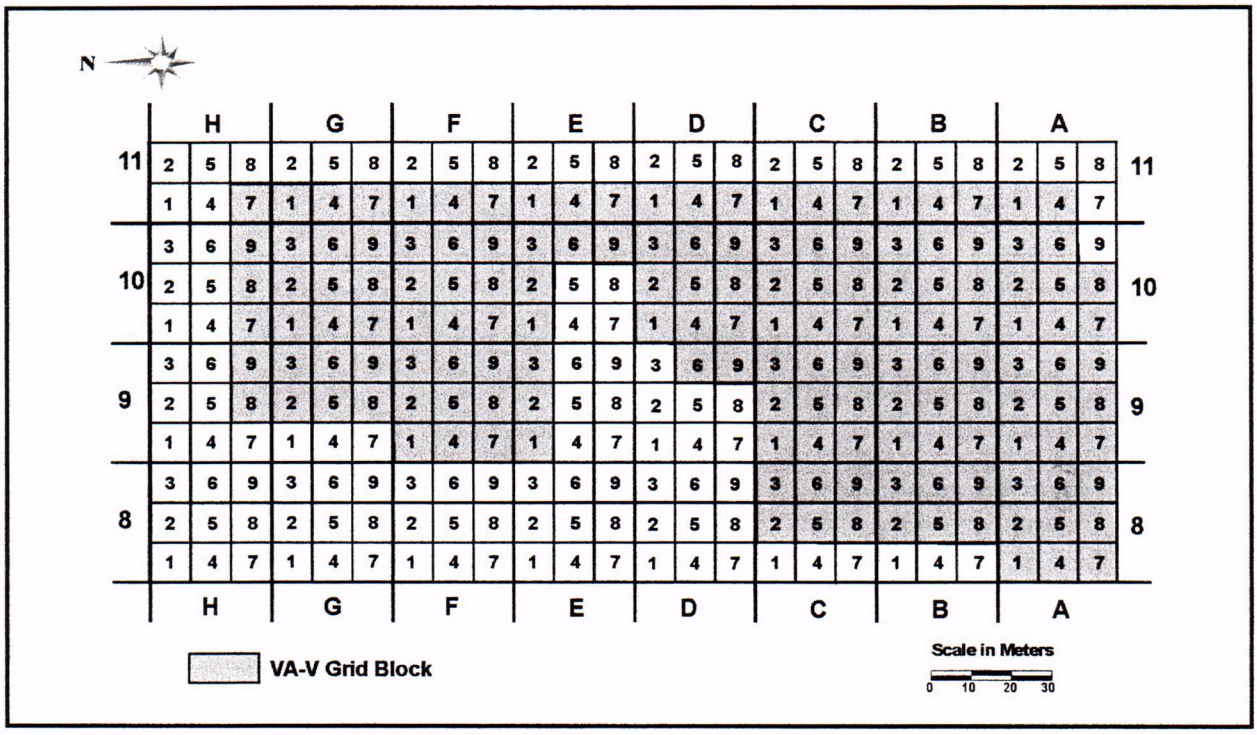
All soil samples, original survey data records, and log books have been archived at the Dow Bay City facility and will be held until after license termination.

4.0 SURVEY FINDINGS AND RESULTS

Appendix A contains the radiological database collected during the final status survey for VA-V (as defined in Figure 4-1) that provides the basis for verifying that the residual contamination objectives have been achieved for this area at the Bay City thorium site. Summary Tables, data interpretations and statistical comparisons with residual contamination guidelines in VA-V are included in Appendix A.

Figure 4-1

Grid Locations for VA-V



4.1 BACKGROUND LEVELS

Background soil concentrations (Table A1) averaged 0.30 pCi/g for Th-232, 0.49 pCi/g for Th-230, and 0.31 pCi/g for Th-228. Background exterior exposure rates averaged 5 μR/h (Table A2). Both the number of data points collected to obtain the average background soil concentrations and exposure rates are more than sufficient to meet the test for demonstrating that the measured average background is within ± 20% of the true average at the 95% confidence level.

4.2 GROUND SURVEYS

4.2.1 Scans

Surface scans were used during the remediation control survey to identify locations of elevated gamma radiation to guide the excavation of the material and locate remaining hot spots. There

C14

were 31 sub-grids with discreet areas of elevated activity identified during the verification scan survey. These areas were remediated and re-scanned with satisfactory results.

4.2.2 Thorium Concentrations in Soil

The results of the analyses of the verification soil samples from VA-V are provided in Table A3, and related to the grid locations shown in Figure 4-1. QA soil analyses, performed by Dow's Freeport Laboratory on duplicate analysis of 5 percent of the FSS samples, are also shown in Table A3. None of the FSS or QA samples contained total thorium concentrations in excess of the soil residual activity guideline (see Section 2.3). Analysis of the mean concentration of Th-232 shows that the concentration meets the guideline value at the 95% confidence level (Table A6, A7). The number of samples collected (594 in VA-V) is much greater than the number (<9) statistically required to demonstrate that the concentrations satisfies the guideline value at the 95% confidence level (Table A6, A7).

The maximum total residual thorium concentrations (above background) as measured in sample BCS-A8-8v1 was 12.59 pCi/g which is less than the residual guideline of 14.5 pCi/g.

Since none of the verification soil sample concentrations in VA-V exceeded the guideline value (no hot spots) it was not necessary to apply averaging techniques in any of the grids.

All of the verification soil samples in VA-V (Table A3) meet the criteria that the sum of the ratios of the concentration of each radionuclide to its respective guideline must not exceed 1 (Appendix A of NUREG/CR-5849).

4.2.3 Exposure Rates

Exposure rate measurements of the remediated VA-V areas (Figure 4-1) and for each grid block are provided in Table A5. Exposure rates ranged from 0 to 8 μR/h above background. All individual values are within the guideline levels of 5 μR/h above background with the exception of 23 sub-grids. The average exposure rate over 100 m^2 for each of the sub-grids is less than 5

μR/h and no individual exposure rate exceeded 10 μR/h, thus meeting the release criteria. Analysis of the statistical mean also shows that the exposure rates in VA-V meet the guideline at the 95% confidence level (Table A6, A7). The number of measurements (153) is in excess of the number required (17) to demonstrate that the exposure rate satisfies the guideline value at the 95% confidence level (Table A6, A7).

4.2.4 NRC Confirmatory Surveys

The NRC performed an inspection of VA-V on December 8th and 9th of 1998. This inspection included the performance of a confirmatory survey. Approximately 80% of VA-V was scanned using a sodium iodide detector. There were 10 individual locations with activity levels above three time background as identified through NaI scans. These locations were remediated to activity levels below three times background during the inspection. Dow personnel collected 10 soil samples, per NRC staff direction, at the 10 individual locations after remediation. The soil samples were analyzed for Th-232 at the Bay City field laboratory, under inspector observation, following QA/QC and calibration checks of the counting systems. When analyzed, no activity above release guidelines was found in any of the samples. Exposure rate measurements were also conducted with all readings in the acceptable ranges.

5.0 SUMMARY

Decontamination of the affected area by soil removal at Dow's Bay City facility is an ongoing process. Since the affected area is quite large it is more efficient for Dow to verify that residual contamination criteria have been met in sections, and for the NRC to subsequently validate each section. Thus area VA-V has been verified and the evaluated database from the final status survey provided in the Appendix. Remediation control surveys were performed to guide the decontamination effort, and a final status survey conducted of VA-V during November, 1998. Independent QA analysis of soil samples was performed. Results of the final status survey demonstrate that the decontamination program successfully reduced residual activity in VA-V to within the NRC limits for unrestricted use. As each subsequent VA is surveyed, a FSSR will be submitted to NRC.

6.0 REFERENCES

6.1 Dow Decommissioning Work Plan, October 1993

6.2 Supplement to the Decommissioning Work Plan, December 1995

6.3 Letter from Dow to NRC, Response to Comments, March 1996

6.4 NUREG/CR-5849, Manual for Conducting Radiological Surveys in Support of License Termination (Draft for Comment), December 1993

6.5 NRC Inspection Report No. 040-00017/97002 (DNMS), August 14, 1997

6.6 Letter from NRC to Dow, Review of Final Status Survey Reports for the Previously Remediated Areas VA-I through VA-VI, Dow Chemical Company's Bay City, MI, SDMP Site (TAC# L60463), August 16, 2002

6.7 Dow "Background Radiological Survey", October 11-13, 1989

6.8 Dow Bay City Site Procedures

6.8.1 SOP 1.1, Access Control Procedures

6.8.2 SOP 1.2, Total Alpha Surface Contamination Measurements

6.8.3 SOP 1.3, External Dosimetry Procedure

6.8.4 SOP 1.4, Beta-Gamma Radiation Measurements using a Geiger-Muller Detector

6.8.5 SOP 1.5, Measurement of Gamma-Ray Fields using a Sodium Iodide (NaI) Detector

6.8.6 SOP 1.6, Intermediate Volume Air Particulate Sampling

6.8.7 SOP 1.7, Sampling for Removable Alpha Contamination

6.8.8 SOP 1.8, Guide to the Handling, Packaging and Shipping of Samples

6.8.9 SOP 1.9, Sample Control and Documentation

6.8.10 SOP 1.10, Radiation Work Permits

6.8.11 SOP 1.11, Respiratory Protection Program

6.8.12 "Procedure for Counting Soil Samples for EOP Characterization"

6.8.13 Dow Central Research Index Report, CRI-TSP-92-076, "Radiological Analysis of Soil Samples from the Madison, Illinois Storage Facility Utilizing a Revised Alpha Spectroscopic Method"

Appendix A
Final Status Survey
Verification Measurements / Analyses

Table A1

BACKGROUND SOIL CONCENTRATIONS							
Bay City							
Sample Name	^{232}Th (pCi/G)	Error (2σ)	MDA (pCi/G)	^{230}Th (pCi/G)	Error (2σ)	^{228}Th (pCi/G)	Error (2σ)
BCBKG01	0.39	0.08	0.13	1.04	0.84	0.48	0.44
BCBKG02	0.36	0.07	0.14	0.46	0.34	0.41	0.31
BCBKG03	0.28	0.08	0.11	0.38	0.31	0.35	0.29
BCBKG04	0.44	0.10	0.13	0.80	0.91	0.62	0.74
BCBKG05	0.43	0.10	0.15	0.70	0.51	0.52	0.40
BCBKG06	0.51	0.18	0.13	0.68	0.47	0.48	0.35
BCBKG07	0.38	0.19	0.13	2.30	3.69	0.77	1.38
BCBKG08	0.16	0.08	0.11	0.37	0.48	0.12	0.20
BCBKG09	0.13	0.07	0.10	0.21	0.25	0.09	0.12
BCBKG10	0.26	0.09	0.13	0.38	0.39	0.23	0.26
BCBKG11	0.19	0.07	0.11	0.04	0.04	0.14	0.10
BCBKG12	0.18	0.08	0.14	0.18	0.14	0.11	0.09
BCBKG13	0.18	0.08	0.14	0.21	0.12	0.19	0.11
BCBKG15	0.23	0.07	0.11	0.12	0.15	0.32	0.31
BCBKG16	0.56	0.12	0.16	0.76	0.51	0.66	0.46
BCBKG17	0.41	0.10	0.16	0.30	0.47	0.30	0.47
BCBKG18	0.10	0.08	0.12	0.18	0.21	0.16	0.19
BCBKG19	0.12	0.06	0.10	0.15	0.14	0.06	0.07
BCBKG20	0.14	0.07	0.11	0.29	0.25	0.09	0.09
BCBKG21	0.19	0.07	0.15	0.23	0.17	0.13	0.11
BCBKG22	0.20	0.07	0.10	0.36	0.39	0.13	0.18
BCBKG23	0.15	0.06	0.11	0.24	0.24	0.30	0.29
BCBKG24	0.12	0.08	0.11	0.13	0.16	0.05	0.08
BCBKG25	0.22	0.07	0.08	0.93	0.89	0.72	0.70
BCBKG26	0.32	0.09	0.13	0.27	0.23	0.16	0.15
BCBKG27	0.56	0.20	0.20	0.93	0.69	0.90	0.67
BCBKG28	0.68	0.24	0.20	0.41	0.45	0.07	0.14
BCBKG29	0.43	0.19	0.21	0.65	1.22	0.43	0.89
BCBKG30	0.34	0.08	0.15	0.44	0.45	0.10	0.16
AVERAGE	0.30			0.49		0.31	
St. Dev.	0.16			0.44		0.24	

Table A2

Background Exposure Rates – Bay City

Sample	Value (μR/hr)
BCBKG1	5
BCBKG2	7
BCBKG3	5
BCBKG4	6
BCBKG5	4
BCBKG6	4
BCBKG7	5
BCBKG8	5
BCBKG9	5
BCBKG10	6
BCBKG11	5
BCBKG12	6
BCBKG13	5
BCBKG14	5
BCBKG15	7
BCBKG16	5
BCBKG17	4
BCBKG18	5
BCBKG19	5
BCBKG20	4
BCBKG21	4
BCBKG22	4
BCBKG23	4
BCBKG24	3
BCBKG25	3
ACROSS THE RIVER	
BCBKG26(1)	3
BCBKG27(2)	5
BCBKG28(3)	5
BCBKG29(4)	4
BCBKG30(5)	5

Number of measurements: 30
Average: 5 μR/hr
Standard Deviation: 1.3 μR/hr (≅ 1.0 μR/hr)

Table A3

Final Verification Soil Concentrations – VA-V

SAMPLE #	WT. (g)	Gamma Spec Sys.	Th-232 (pCi/g)	Th-230 (pCi/g)	Th-228 (pCi/g)	Th-232 Net (pCi/g)	Th-230 Net (pCi/g)	Th-228 Net (pCi/g)	Total Net Thorium (pCi/g)
BCS-A10-1-V1-A	2209.5	2	0.30	0.49	0.28	0.00	0.00	-0.02	-0.03
BCS-A10-1-V1-B	2122.6	2	0.10	0.16	0.09	-0.20	-0.33	-0.21	-0.73
BCS-A10-1-V1-C	2229.0	2	0.51	0.83	0.48	0.21	0.34	0.18	0.73
BCS-A10-1-V1-D	2328.8	2	0.18	0.29	0.17	-0.12	-0.20	-0.13	-0.44
BCS-A10-2-V1-A	1953.3	2	0.19	0.31	0.18	-0.11	-0.18	-0.12	-0.41
BCS-A10-2-V1-B	1862.4	2	0.34	0.55	0.32	0.04	0.06	0.02	0.12
BCS-A10-2-V1-C	1645.7	2	0.10	0.16	0.09	-0.20	-0.33	-0.21	-0.75
BCS-A10-2-V1-D	2118.5	2	0.30	0.49	0.28	0.00	0.00	-0.02	-0.02
BCS-A10-3-V1-A	2384.4	2	0.18	0.30	0.17	-0.12	-0.19	-0.13	-0.44
BCS-A10-3-V1-B	2387.2	2	0.29	0.47	0.27	-0.01	-0.02	-0.03	-0.07
BCS-A10-3-V1-C	2213.8	2	0.36	0.59	0.34	0.06	0.10	0.04	0.20
BCS-A10-3-V1-D	1809.5	2	0.30	0.48	0.28	0.00	-0.01	-0.02	-0.03
BCS-A10-3-V1-D(qc)	1809.5	2	0.32	0.52	0.30	0.02	0.03	0.00	0.04
BCS-A10-4-V1-A	2089.6	2	0.69	1.12	0.65	0.39	0.63	0.35	1.36
BCS-A10-4-V1-B	2475.6	2	0.36	0.59	0.34	0.06	0.10	0.04	0.20
BCS-A10-4-V1-C	2144.6	2	0.47	0.76	0.44	0.17	0.27	0.14	0.57
BCS-A10-4-V1-D	2267.8	2	0.28	0.46	0.27	-0.02	-0.03	-0.03	-0.08
BCS-A10-4-V1-D(qc)	2267.8	2	0.41	0.67	0.39	0.11	0.18	0.09	0.37
BCS-A10-5-V1-A	1798.2	2	0.19	0.31	0.18	-0.11	-0.18	-0.12	-0.40
BCS-A10-5-V1-B	2177.8	2	0.29	0.47	0.27	-0.01	-0.02	-0.03	-0.05
BCS-A10-5-V1-C	2199.3	2	0.17	0.28	0.16	-0.13	-0.21	-0.14	-0.47
BCS-A10-5-V1-D	2223.6	2	0.60	0.98	0.57	0.30	0.49	0.27	1.06
BCS-A10-6-V1-A	2626.0	2	0.29	0.47	0.27	-0.01	-0.02	-0.03	-0.05
BCS-A10-6-V1-B	2071.8	2	0.33	0.54	0.31	0.03	0.05	0.01	0.10
BCS-A10-6-V1-C	2188.7	2	0.54	0.88	0.51	0.24	0.39	0.21	0.84
BCS-A10-6-V1-D	2418.4	2	0.19	0.31	0.18	-0.11	-0.18	-0.12	-0.42
BCS-A10-7-V1-A	2560.0	3	0.39	0.63	0.36	0.09	0.14	0.06	0.29
BCS-A10-7-V1-B	2572.2	3	0.51	0.83	0.48	0.21	0.34	0.18	0.72
BCS-A10-8-V1-A	2493.6	2	0.32	0.52	0.30	0.02	0.03	0.00	0.05
BCS-A11-1-V1-A	1890.1	2	0.26	0.42	0.24	-0.04	-0.07	-0.06	-0.17
BCS-A11-1-V1-B	2001.0	2	0.34	0.55	0.32	0.04	0.06	0.02	0.12
BCS-A11-1-V1-C	2202.3	2	0.35	0.56	0.33	0.05	0.07	0.03	0.15
BCS-A11-1-V1-D	2551.5	2	0.21	0.34	0.20	-0.09	-0.15	-0.10	-0.34
BCS-A11-4-V1-A	2156.4	2	0.32	0.53	0.30	0.02	0.04	0.00	0.06
BCS-A11-4-V1-B	2265.7	2	0.13	0.21	0.12	-0.17	-0.28	-0.18	-0.62
BCS-A11-4-V1-C	2063.3	2	0.17	0.28	0.16	-0.13	-0.21	-0.14	-0.47
BCS-A11-4-V1-D	2190.4	2	0.49	0.80	0.46	0.19	0.31	0.16	0.67
BCS-A8-1-V1-A	2710.7	3	0.56	0.92	0.53	0.26	0.43	0.23	0.92
BCS-A8-1-V1-B	2441.1	3	0.43	0.70	0.40	0.13	0.21	0.10	0.45
BCS-A8-1-V1-C	2606.0	3	0.22	0.37	0.21	-0.08	-0.12	-0.09	-0.29

SAMPLE #	WT. (g)	Gamma Spec Sys.	Th-232 (pCi/g)	Th-230 (pCi/g)	Th-228 (pCi/g)	Th-232 Net (pCi/g)	Th-230 Net (pCi/g)	Th-228 Net (pCi/g)	Total Net Thorium (pCi/g)
BCS-A8-1-V1-D	2601.5	3	0.34	0.55	0.32	0.04	0.06	0.02	0.12
BCS-A8-2-V1-A	1678.7	2	0.53	0.87	0.50	0.23	0.38	0.20	0.81
BCS-A8-2-V1-B	2038.2	2	1.02	1.66	0.95	0.72	1.17	0.65	2.54
BCS-A8-2-V1-C	2682.2	2	0.13	0.21	0.12	-0.17	-0.28	-0.18	-0.64
BCS-A8-2-V1-D	2302.2	2	0.43	0.70	0.40	0.13	0.21	0.10	0.44
BCS-A8-3-V1-A	2214.3	3	1.30	2.12	1.22	1.00	1.63	0.92	3.56
BCS-A8-3-V1-B	1594.2	3	1.43	2.33	1.34	1.13	1.84	1.04	4.01
BCS-A8-3-V1-C	2479.7	3	0.73	1.19	0.69	0.43	0.70	0.39	1.53
BCS-A8-3-V1-D	1513.5	3	1.28	2.08	1.20	0.98	1.59	0.90	3.47
BCS-A8-4-V1-A	2823.6	3	0.41	0.66	0.38	0.11	0.17	0.08	0.37
BCS-A8-4-V1-B	2635.0	3	0.37	0.61	0.35	0.07	0.12	0.05	0.24
BCS-A8-4-V1-C	2594.0	3	0.53	0.87	0.50	0.23	0.38	0.20	0.82
BCS-A8-4-V1-D	2555.3	3	0.96	1.56	0.90	0.66	1.07	0.60	2.33
BCS-A8-5-V1-A	2425.8	2	0.50	0.82	0.47	0.20	0.33	0.17	0.71
BCS-A8-5-V1-B	2162.5	2	0.30	0.49	0.29	0.00	0.00	-0.01	-0.01
BCS-A8-5-V1-C	2551.4	2	0.47	0.77	0.45	0.17	0.28	0.15	0.60
BCS-A8-5-V1-D	2693.7	2	0.33	0.54	0.31	0.03	0.05	0.01	0.10
BCS-A8-6-V1-A	1618.4	2	0.83	1.35	0.78	0.53	0.86	0.48	1.87
BCS-A8-6-V1-B	1917.0	2	0.54	0.89	0.51	0.24	0.40	0.21	0.85
BCS-A8-6-V1-C	2284.2	2	0.78	1.27	0.73	0.48	0.78	0.43	1.70
BCS-A8-6-V1-D	2144.5	2	0.60	0.98	0.57	0.30	0.49	0.27	1.06
BCS-A8-7-V1-A	2407.4	3	1.50	2.45	1.41	1.20	1.96	1.11	4.27
BCS-A8-7-V1-B	2687.6	3	1.18	1.92	1.11	0.88	1.43	0.81	3.12
BCS-A8-8-V1-A	2294.8	2	3.04	4.95	2.86	2.74	4.46	2.56	9.76
BCS-A8-8-V1-B	2241.9	2	3.83	6.24	3.60	3.53	5.75	3.30	12.59
BCS-A8-9-V1-A	2615.0	2	0.41	0.67	0.39	0.11	0.18	0.09	0.38
BCS-A8-9-V1-B	3203.2	2	0.37	0.61	0.35	0.07	0.12	0.05	0.24
BCS-A8-9-V1-B(qc)	3203.2	2	0.32	0.52	0.30	0.02	0.03	0.00	0.06
BCS-A9-1-V1-A	1821.8	3	1.19	1.94	1.12	0.89	1.45	0.82	3.17
BCS-A9-1-V1-B	2000.0	3	1.53	2.50	1.44	1.23	2.01	1.14	4.39
BCS-A9-1-V1-C	1854.1	3	1.24	2.02	1.16	0.94	1.53	0.86	3.33
BCS-A9-1-V1-D	1805.0	3	1.29	2.10	1.21	0.99	1.61	0.91	3.51
BCS-A9-2-V1-A	1940.4	3	1.40	2.28	1.32	1.10	1.79	1.02	3.91
BCS-A9-2-V1-B	1724.5	3	1.39	2.27	1.31	1.09	1.78	1.01	3.89
BCS-A9-2-V1-C	1981.4	3	0.79	1.29	0.74	0.49	0.80	0.44	1.73
BCS-A9-2-V1-D	2017.1	3	1.07	1.75	1.01	0.77	1.26	0.71	2.74
BCS-A9-2-V1-D(qc)	2017.1	3	0.80	1.30	0.75	0.50	0.81	0.45	1.76
BCS-A9-3-V1-A	2388.6	3	0.80	1.30	0.75	0.50	0.81	0.45	1.76
BCS-A9-3-V1-B	2106.1	3	0.53	0.86	0.50	0.23	0.37	0.20	0.79
BCS-A9-3-V1-C	1450.5	3	1.06	1.73	1.00	0.76	1.24	0.70	2.69
BCS-A9-3-V1-D	2065.1	3	1.12	1.82	1.05	0.82	1.33	0.75	2.89
BCS-A9-4-V1-A	2230.4	3	1.01	1.64	0.95	0.71	1.15	0.65	2.50
BCS-A9-4-V1-B	1985.2	3	1.04	1.70	0.98	0.74	1.21	0.68	2.64
BCS-A9-4-V1-C	2980.9	3	0.42	0.69	0.40	0.12	0.20	0.10	0.42
BCS-A9-4-V1-D	2772.0	3	0.71	1.15	0.67	0.41	0.66	0.37	1.44

SAMPLE #	WT. (g)	Gamma Spec Sys.	Th-232 (pCi/g)	Th-230 (pCi/g)	Th-228 (pCi/g)	Th-232 Net (pCi/g)	Th-230 Net (pCi/g)	Th-228 Net (pCi/g)	Total Net Thorium (pCi/g)
BCS-A9-5-V1-A	1807.9	2	1.10	1.79	1.03	0.80	1.30	0.73	2.84
BCS-A9-5-V1-B	1981.4	2	0.76	1.24	0.71	0.46	0.75	0.41	1.62
BCS-A9-5-V1-C	2392.6	2	0.62	1.02	0.59	0.32	0.53	0.29	1.14
BCS-A9-5-V1-D	2116.1	2	0.71	1.16	0.67	0.41	0.67	0.37	1.45
BCS-A9-5-V1-D(qc)	2116.1	2	0.52	0.85	0.49	0.22	0.36	0.19	0.77
BCS-A9-6-V1-A	1907.5	2	0.61	0.99	0.57	0.31	0.50	0.27	1.08
BCS-A9-6-V1-B	1848.6	2	0.69	1.13	0.65	0.39	0.64	0.35	1.38
BCS-A9-6-V1-C	2533.5	2	0.30	0.48	0.28	0.00	-0.01	-0.02	-0.03
BCS-A9-6-V1-D	2396.6	2	0.44	0.72	0.42	0.14	0.23	0.12	0.50
BCS-A9-7-V1-A	2897.5	2	0.51	0.82	0.48	0.21	0.33	0.18	0.72
BCS-A9-7-V1-B	3041.1	2	0.46	0.75	0.43	0.16	0.26	0.13	0.54
BCS-A9-8-V1-A	2606.3	3	0.69	1.13	0.65	0.39	0.64	0.35	1.38
BCS-A9-8-V1-B	2483.3	3	0.65	1.06	0.61	0.35	0.57	0.31	1.23
BCS-A9-9-V1-A	2374.2	2	0.41	0.67	0.39	0.11	0.18	0.09	0.37
BCS-A9-9-V1-B	2545.4	2	0.38	0.62	0.36	0.08	0.13	0.06	0.27
BCS-B10-1-V1-A	1701.4	3	0.73	1.18	0.68	0.43	0.69	0.38	1.51
BCS-B10-1-V1-B	1912.4	3	0.77	1.25	0.72	0.47	0.76	0.42	1.64
BCS-B10-1-V1-C	1910.1	3	0.75	1.23	0.71	0.45	0.74	0.41	1.60
BCS-B10-1-V1-D	2074.5	3	0.43	0.71	0.41	0.13	0.22	0.11	0.46
BCS-B10-1-V1-D(qc)	2074.5	3	0.62	1.01	0.58	0.32	0.52	0.28	1.12
BCS-B10-2-V1-A	1628.5	3	0.95	1.54	0.89	0.65	1.05	0.59	2.29
BCS-B10-2-V1-B	1752.4	3	1.01	1.65	0.95	0.71	1.16	0.65	2.53
BCS-B10-2-V1-C	1735.6	3	0.93	1.52	0.88	0.63	1.03	0.58	2.24
BCS-B10-2-V1-D	1575.2	3	0.90	1.47	0.85	0.60	0.98	0.55	2.13
BCS-B10-2-V1-D(qc)	1575.2	3	0.84	1.36	0.79	0.54	0.87	0.49	1.90
BCS-B10-3-V1-A	1456.5	3	0.84	1.38	0.79	0.54	0.89	0.49	1.92
BCS-B10-3-V1-B	1502.0	3	0.87	1.42	0.82	0.57	0.93	0.52	2.03
BCS-B10-3-V1-C	1519.4	3	1.15	1.87	1.08	0.85	1.38	0.78	3.00
BCS-B10-3-V1-D	1636.2	3	1.14	1.85	1.07	0.84	1.36	0.77	2.96
BCS-B10-4-V1-A	1659.7	3	0.71	1.16	0.67	0.41	0.67	0.37	1.45
BCS-B10-4-V1-B	1628.9	3	0.73	1.19	0.69	0.43	0.70	0.39	1.52
BCS-B10-4-V1-C	1871.3	3	0.75	1.22	0.70	0.45	0.73	0.40	1.58
BCS-B10-4-V1-D	1966.1	3	0.68	1.10	0.64	0.38	0.61	0.34	1.33
BCS-B10-5-V1-A	1547.2	3	0.61	0.99	0.57	0.31	0.50	0.27	1.09
BCS-B10-5-V1-B	1580.9	3	0.72	1.18	0.68	0.42	0.69	0.38	1.49
BCS-B10-5-V1-C	1643.7	3	0.60	0.97	0.56	0.30	0.48	0.26	1.04
BCS-B10-5-V1-D	1737.4	3	1.23	2.01	1.16	0.93	1.52	0.86	3.31
BCS-B10-6-V1-A	1549.4	3	0.92	1.50	0.86	0.62	1.01	0.56	2.20
BCS-B10-6-V1-B	1611.5	3	0.91	1.49	0.86	0.61	1.00	0.56	2.17
BCS-B10-6-V1-C	1885.4	3	0.44	0.72	0.42	0.14	0.23	0.12	0.50
BCS-B10-6-V1-D	2551.5	3	0.49	0.80	0.46	0.19	0.31	0.16	0.66
BCS-B10-7-V1-A	2053.7	3	0.64	1.05	0.60	0.34	0.56	0.30	1.20
BCS-B10-7-V1-B	2061.9	3	0.78	1.28	0.74	0.48	0.79	0.44	1.71
BCS-B10-7-V1-C	1968.1	3	0.63	1.02	0.59	0.33	0.53	0.29	1.15
BCS-B10-7-V1-D	2221.6	3	0.21	0.34	0.19	-0.09	-0.15	-0.11	-0.36

SAMPLE #	WT. (g)	Gamma Spec Sys.	Th-232 (pCi/g)	Th-230 (pCi/g)	Th-228 (pCi/g)	Th-232 Net (pCi/g)	Th-230 Net (pCi/g)	Th-228 Net (pCi/g)	Total Net Thorium (pCi/g)
BCS-B10-8-V1-A	2222.7	3	0.49	0.79	0.46	0.19	0.30	0.16	0.65
BCS-B10-8-V1-B	2308.9	3	0.46	0.75	0.43	0.16	0.26	0.13	0.56
BCS-B10-8-V1-C	2575.5	3	0.32	0.52	0.30	0.02	0.03	0.00	0.06
BCS-B10-8-V1-D	2044.5	3	0.57	0.93	0.54	0.27	0.44	0.24	0.95
BCS-B10-9-V1-A	2368.0	3	0.36	0.59	0.34	0.06	0.10	0.04	0.21
BCS-B10-9-V1-B	2469.5	3	0.36	0.58	0.33	0.06	0.09	0.03	0.18
BCS-B10-9-V1-C	2434.6	3	0.33	0.53	0.31	0.03	0.04	0.01	0.07
BCS-B10-9-V1-D	2282.4	3	0.45	0.74	0.43	0.15	0.25	0.13	0.53
BCS-B11-1-V1-A	1668.4	3	0.83	1.35	0.78	0.53	0.86	0.48	1.86
BCS-B11-1-V1-B	1561.8	3	0.93	1.51	0.87	0.63	1.02	0.57	2.22
BCS-B11-1-V1-C	1653.5	3	0.97	1.57	0.91	0.67	1.08	0.61	2.36
BCS-B11-1-V1-D	1452.3	3	0.96	1.56	0.90	0.66	1.07	0.60	2.33
BCS-B11-1-V1-D(qc)	1452.3	3	1.00	1.63	0.94	0.70	1.14	0.64	2.48
BCS-B11-4-V1-A	1635.0	3	1.06	1.72	0.99	0.76	1.23	0.69	2.69
BCS-B11-4-V1-B	1578.7	3	1.04	1.69	0.98	0.74	1.20	0.68	2.62
BCS-B11-4-V1-C	2686.6	3	0.37	0.60	0.35	0.07	0.11	0.05	0.23
BCS-B11-4-V1-D	2815.6	3	0.26	0.42	0.24	-0.04	-0.07	-0.06	-0.16
BCS-B11-7-V1-A	2093.8	3	0.41	0.67	0.39	0.11	0.18	0.09	0.39
BCS-B11-7-V1-B	2456.7	3	0.38	0.62	0.36	0.08	0.13	0.06	0.26
BCS-B11-7-V1-C	2637.5	3	0.28	0.45	0.26	-0.02	-0.04	-0.04	-0.09
BCS-B11-7-V1-D	2527.2	3	0.35	0.56	0.32	0.05	0.07	0.02	0.14
BCS-B8-2-V1-A	2608.0	2	0.86	1.41	0.81	0.56	0.92	0.51	1.99
BCS-B8-2-V1-B	2249.9	2	0.82	1.33	0.77	0.52	0.84	0.47	1.83
BCS-B8-2-V1-C	2473.1	2	1.39	2.26	1.30	1.09	1.77	1.00	3.86
BCS-B8-2-V1-D	2575.8	2	0.60	0.98	0.56	0.30	0.49	0.26	1.05
BCS-B8-3-V1-A	2793.4	2	2.46	4.01	2.31	2.16	3.52	2.01	7.69
BCS-B8-3-V1-B	2525.3	2	0.58	0.94	0.54	0.28	0.45	0.24	0.97
BCS-B8-3-V1-C	2410.7	2	0.92	1.49	0.86	0.62	1.00	0.56	2.18
BCS-B8-3-V1-D	2752.6	2	0.62	1.02	0.59	0.32	0.53	0.29	1.14
BCS-B8-3-V1-D (qc)	2752.6	2	0.67	1.09	0.63	0.37	0.60	0.33	1.30
BCS-B8-5-V1-A	2197.6	2	1.17	1.90	1.10	0.87	1.41	0.80	3.08
BCS-B8-5-V1-B	2424.5	2	0.70	1.14	0.66	0.40	0.65	0.36	1.42
BCS-B8-5-V1-C	1270.5	2	1.50	2.44	1.41	1.20	1.95	1.11	4.26
BCS-B8-5-V1-D	1809.9	2	1.72	2.80	1.61	1.42	2.31	1.31	5.04
BCS-B8-6-V1-A	2143.6	3	1.38	2.24	1.29	1.08	1.75	0.99	3.82
BCS-B8-6-V1-B	1898.9	3	1.65	2.68	1.55	1.35	2.19	1.25	4.79
BCS-B8-6-V1-C	1843.9	3	1.05	1.72	0.99	0.75	1.23	0.69	2.67
BCS-B8-6-V1-D	2012.2	3	0.64	1.04	0.60	0.34	0.55	0.30	1.20
BCS-B8-8-V1-A	1715.7	2	1.06	1.73	1.00	0.76	1.24	0.70	2.70
BCS-B8-8-V1-B	2011.8	2	1.76	2.87	1.66	1.46	2.38	1.36	5.21
BCS-B8-8-V1-C	1599.9	2	1.34	2.18	1.26	1.04	1.69	0.96	3.69
BCS-B8-8-V1-D	1982.2	2	0.99	1.61	0.93	0.69	1.12	0.63	2.44
BCS-B8-9-V1-A	1392.8	2	1.67	2.73	1.57	1.37	2.24	1.27	4.88
BCS-B8-9-V1-B	1934.1	2	1.45	2.36	1.36	1.15	1.87	1.06	4.07
BCS-B8-9-V1-C	2359.0	2	1.25	2.03	1.17	0.95	1.54	0.87	3.36

SAMPLE #	WT. (g)	Gamma Spec Sys.	Th-232 (pCi/g)	Th-230 (pCi/g)	Th-228 (pCi/g)	Th-232 Net (pCi/g)	Th-230 Net (pCi/g)	Th-228 Net (pCi/g)	Total Net Thorium (pCi/g)
BCS-B8-9-V1-D	1836.1	2	1.26	2.05	1.18	0.96	1.56	0.88	3.41
BCS-B9-1-V1-A	2643.7	3	1.03	1.68	0.97	0.73	1.19	0.67	2.58
BCS-B9-1-V1-B	2298.6	3	0.90	1.47	0.85	0.60	0.98	0.55	2.13
BCS-B9-1-V1-C	2641.3	3	0.70	1.13	0.65	0.40	0.64	0.35	1.39
BCS-B9-1-V1-D	2178.5	3	0.98	1.60	0.92	0.68	1.11	0.62	2.41
BCS-B9-2-V1-A	2848.5	2	0.22	0.37	0.21	-0.08	-0.12	-0.09	-0.29
BCS-B9-2-V1-B	2862.3	2	0.35	0.57	0.33	0.05	0.08	0.03	0.16
BCS-B9-2-V1-C	2492.2	2	0.21	0.34	0.20	-0.09	-0.15	-0.10	-0.34
BCS-B9-2-V1-D	2769.9	2	0.27	0.43	0.25	-0.03	-0.06	-0.05	-0.14
BCS-B9-3-V1-A	1944.7	3	0.91	1.49	0.86	0.61	1.00	0.56	2.17
BCS-B9-3-V1-B	2171.4	3	0.60	0.97	0.56	0.30	0.48	0.26	1.04
BCS-B9-3-V1-C	2019.7	3	0.48	0.78	0.45	0.18	0.29	0.15	0.62
BCS-B9-3-V1-D	2021.5	3	0.57	0.93	0.53	0.27	0.44	0.23	0.94
BCS-B9-4-V1-A	2302.1	3	0.74	1.21	0.70	0.44	0.72	0.40	1.56
BCS-B9-4-V1-B	2300.2	3	0.85	1.39	0.80	0.55	0.90	0.50	1.96
BCS-B9-4-V1-C	2358.5	3	0.82	1.33	0.77	0.52	0.84	0.47	1.83
BCS-B9-4-V1-D	2643.3	3	1.08	1.76	1.01	0.78	1.27	0.71	2.76
BCS-B9-4-V1-D(qc)	2643.3	3	1.12	1.82	1.05	0.82	1.33	0.75	2.91
BCS-B9-5-V1-A	2117.4	2	0.54	0.88	0.51	0.24	0.39	0.21	0.84
BCS-B9-5-V1-B	2464.2	2	0.32	0.52	0.30	0.02	0.03	0.00	0.05
BCS-B9-5-V1-C	2321.4	2	0.71	1.16	0.67	0.41	0.67	0.37	1.44
BCS-B9-5-V1-D	1977.2	2	0.82	1.33	0.77	0.52	0.84	0.47	1.83
BCS-B9-6-V1-A	2514.8	3	0.58	0.95	0.55	0.28	0.46	0.25	0.99
BCS-B9-6-V1-B	2181.2	3	0.75	1.22	0.71	0.45	0.73	0.41	1.59
BCS-B9-6-V1-C	2053.6	3	0.94	1.53	0.88	0.64	1.04	0.58	2.26
BCS-B9-6-V1-D	2331.7	3	0.59	0.96	0.55	0.29	0.47	0.25	1.01
BCS-B9-7-V1-A	1932.5	2	1.79	2.91	1.68	1.49	2.42	1.38	5.29
BCS-B9-7-V1-B	1941.4	2	0.92	1.49	0.86	0.62	1.00	0.56	2.18
BCS-B9-7-V1-C	1939.6	2	1.37	2.23	1.29	1.07	1.74	0.99	3.79
BCS-B9-7-V1-D	1732.3	2	1.36	2.22	1.28	1.06	1.73	0.98	3.78
BCS-B9-8-V1-A	1921.0	2	1.42	2.31	1.33	1.12	1.82	1.03	3.98
BCS-B9-8-V1-B	1617.5	2	0.74	1.21	0.70	0.44	0.72	0.40	1.55
BCS-B9-8-V1-C	1452.0	2	1.46	2.38	1.37	1.16	1.89	1.07	4.13
BCS-B9-8-V1-D	1778.2	2	1.56	2.54	1.47	1.26	2.05	1.17	4.48
BCS-B9-8-V1-D(qc)	1778.2	2	1.69	2.75	1.59	1.39	2.26	1.29	4.93
BCS-B9-9-V1-A	1931.1	3	0.93	1.51	0.87	0.63	1.02	0.57	2.22
BCS-B9-9-V1-B	2063.9	3	0.50	0.81	0.47	0.20	0.32	0.17	0.69
BCS-B9-9-V1-C	2018.4	3	0.89	1.46	0.84	0.59	0.97	0.54	2.10
BCS-B9-9-V1-D	2101.2	3	0.49	0.80	0.46	0.19	0.31	0.16	0.66
BCS-C10-1-V1-A	2079.8	2	0.43	0.70	0.40	0.13	0.21	0.10	0.44
BCS-C10-1-V1-B	3188.5	2	0.28	0.45	0.26	-0.02	-0.04	-0.04	-0.10
BCS-C10-1-V1-C	2376.2	2	0.62	1.01	0.58	0.32	0.52	0.28	1.13
BCS-C10-1-V1-D	2522.1	2	0.74	1.21	0.70	0.44	0.72	0.40	1.56
BCS-C10-1-V1-D(qc)	2522.1	2	0.58	0.95	0.55	0.28	0.46	0.25	0.99
BCS-C10-2-V1-A	2094.4	3	0.78	1.27	0.73	0.48	0.78	0.43	1.68

SAMPLE #	WT. (g)	Gamma Spec Sys.	Th-232 (pCi/g)	Th-230 (pCi/g)	Th-228 (pCi/g)	Th-232 Net (pCi/g)	Th-230 Net (pCi/g)	Th-228 Net (pCi/g)	Total Net Thorium (pCi/g)
BCS-C10-2-V1-B	1958.5	3	0.65	1.06	0.61	0.35	0.57	0.31	1.24
BCS-C10-2-V1-C	2294.8	3	0.51	0.83	0.48	0.21	0.34	0.18	0.73
BCS-C10-2-V1-D	2287.1	3	0.59	0.96	0.56	0.29	0.47	0.26	1.02
BCS-C10-2-V1-D(qc)	2287.1	3	0.62	1.01	0.59	0.32	0.52	0.29	1.13
BCS-C10-3-V1-A	1994.4	2	0.37	0.60	0.35	0.07	0.11	0.05	0.23
BCS-C10-3-V1-B	1765.0	2	0.60	0.97	0.56	0.30	0.48	0.26	1.04
BCS-C10-3-V1-C	1736.4	2	0.57	0.92	0.53	0.27	0.43	0.23	0.93
BCS-C10-3-V1-D	1885.8	2	0.96	1.56	0.90	0.66	1.07	0.60	2.33
BCS-C10-4-V1-A	2428.9	2	0.40	0.65	0.37	0.10	0.16	0.07	0.33
BCS-C10-4-V1-B	1535.0	2	0.66	1.07	0.62	0.36	0.58	0.32	1.26
BCS-C10-4-V1-C	1918.7	2	0.74	1.20	0.69	0.44	0.71	0.39	1.55
BCS-C10-4-V1-D	2375.8	2	0.47	0.77	0.45	0.17	0.28	0.15	0.60
BCS-C10-5-V1-A	2130.7	2	0.59	0.95	0.55	0.29	0.46	0.25	1.00
BCS-C10-5-V1-B	1770.3	2	0.62	1.01	0.59	0.32	0.52	0.29	1.13
BCS-C10-5-V1-C	1911.3	2	0.44	0.72	0.42	0.14	0.23	0.12	0.49
BCS-C10-5-V1-D	1710.0	2	0.73	1.19	0.69	0.43	0.70	0.39	1.52
BCS-C10-5-V1-D(qc)	1710.0	2	0.72	1.17	0.68	0.42	0.68	0.38	1.48
BCS-C10-6-V1-A	1818.1	2	0.79	1.29	0.74	0.49	0.80	0.44	1.74
BCS-C10-6-V1-B	1717.6	2	0.48	0.78	0.45	0.18	0.29	0.15	0.62
BCS-C10-6-V1-C	1770.1	2	1.05	1.71	0.99	0.75	1.22	0.69	2.65
BCS-C10-6-V1-D	2089.7	2	0.34	0.56	0.32	0.04	0.07	0.02	0.14
BCS-C10-7-V1-A	1647.9	2	0.61	0.99	0.57	0.31	0.50	0.27	1.08
BCS-C10-7-V1-B	1931.2	2	0.49	0.81	0.46	0.19	0.32	0.16	0.67
BCS-C10-7-V1-C	1568.3	2	0.87	1.42	0.82	0.57	0.93	0.52	2.01
BCS-C10-7-V1-D	1452.1	2	0.83	1.36	0.78	0.53	0.87	0.48	1.88
BCS-C10-8-V1-A	2291.9	2	0.31	0.51	0.29	0.01	0.02	-0.01	0.02
BCS-C10-8-V1-B	1713.0	2	0.89	1.45	0.84	0.59	0.96	0.54	2.09
BCS-C10-8-V1-C	1499.1	2	0.80	1.30	0.75	0.50	0.81	0.45	1.76
BCS-C10-8-V1-D	1624.4	2	1.01	1.65	0.95	0.71	1.16	0.65	2.53
BCS-C10-8-V1-D(qc)	1624.4	2	0.98	1.59	0.92	0.68	1.10	0.62	2.39
BCS-C10-9-V1-A	1689.7	2	0.69	1.13	0.65	0.39	0.64	0.35	1.39
BCS-C10-9-V1-B	2086.4	2	0.54	0.88	0.50	0.24	0.39	0.20	0.83
BCS-C10-9-V1-C	1747.5	2	0.58	0.94	0.54	0.28	0.45	0.24	0.98
BCS-C10-9-V1-D	1772.4	2	0.87	1.42	0.82	0.57	0.93	0.52	2.01
BCS-C10-9-V1-D(qc)	1772.4	2	1.07	1.74	1.00	0.77	1.25	0.70	2.72
BCS-C11-1-V1-A	1773.6	2	0.99	1.62	0.93	0.69	1.13	0.63	2.46
BCS-C11-1-V1-B	1854.4	2	0.95	1.55	0.89	0.65	1.06	0.59	2.31
BCS-C11-1-V1-C	1791.9	2	0.43	0.70	0.41	0.13	0.21	0.11	0.45
BCS-C11-1-V1-D	1806.5	2	0.84	1.37	0.79	0.54	0.88	0.49	1.90
BCS-C11-4-V1-A	1846.1	2	1.01	1.64	0.95	0.71	1.15	0.65	2.50
BCS-C11-4-V1-B	1826.8	2	1.14	1.86	1.07	0.84	1.37	0.77	2.99
BCS-C11-4-V1-C	1971.8	2	0.85	1.39	0.80	0.55	0.90	0.50	1.95
BCS-C11-4-V1-D	1875.1	2	0.95	1.54	0.89	0.65	1.05	0.59	2.29
BCS-C11-7-V1-A	1693.0	2	1.21	1.97	1.14	0.91	1.48	0.84	3.23
BCS-C11-7-V1-B	1733.8	2	0.57	0.93	0.54	0.27	0.44	0.24	0.94

SAMPLE #	WT. (g)	Gamma Spec Sys.	Th-232 (pCi/g)	Th-230 (pCi/g)	Th-228 (pCi/g)	Th-232 Net (pCi/g)	Th-230 Net (pCi/g)	Th-228 Net (pCi/g)	Total Net Thorium (pCi/g)
BCS-C11-7-V1-C	1763.9	2	0.59	0.96	0.55	0.29	0.47	0.25	1.01
BCS-C11-7-V1-D	1741.9	2	0.96	1.56	0.90	0.66	1.07	0.60	2.32
BCS-C8-2-V1-A	2693.3	2	0.13	0.21	0.12	-0.17	-0.28	-0.18	-0.63
BCS-C8-2-V1-B	3201.5	2	0.21	0.34	0.19	-0.09	-0.15	-0.11	-0.35
BCS-C8-2-V1-C	2874.0	2	0.18	0.29	0.16	-0.12	-0.20	-0.14	-0.46
BCS-C8-2-V1-D	2754.4	2	0.58	0.95	0.55	0.28	0.46	0.25	0.99
BCS-C8-3-V1-A	2907.2	2	0.31	0.51	0.29	0.01	0.02	-0.01	0.03
BCS-C8-3-V1-B	2596.6	2	0.12	0.20	0.11	-0.18	-0.29	-0.19	-0.66
BCS-C8-3-V1-C	3119.8	2	0.42	0.69	0.40	0.12	0.20	0.10	0.42
BCS-C8-3-V1-D	1758.1	2	1.71	2.79	1.61	1.41	2.30	1.31	5.03
BCS-C8-5-V1-A	2971.1	3	0.28	0.45	0.26	-0.02	-0.04	-0.04	-0.10
BCS-C8-5-V1-B	2645.2	3	0.51	0.83	0.48	0.21	0.34	0.18	0.74
BCS-C8-5-V1-C	2540.3	3	0.52	0.85	0.49	0.22	0.36	0.19	0.78
BCS-C8-5-V1-D	2341.4	3	1.09	1.77	1.02	0.79	1.28	0.72	2.79
BCS-C8-6-V1-A	2293.7	3	0.80	1.30	0.75	0.50	0.81	0.45	1.76
BCS-C8-6-V1-B	3676.1	3	0.53	0.86	0.50	0.23	0.37	0.20	0.80
BCS-C8-6-V1-C	2126.3	3	1.76	2.87	1.65	1.46	2.38	1.35	5.19
BCS-C8-6-V1-D	3124.7	3	0.51	0.83	0.48	0.21	0.34	0.18	0.72
BCS-C8-8-V1-A	2506.2	3	0.58	0.95	0.55	0.28	0.46	0.25	0.99
BCS-C8-8-V1-B	1768.3	3	0.26	0.43	0.25	-0.04	-0.06	-0.05	-0.15
BCS-C8-8-V1-C	2407.3	3	1.30	2.11	1.22	1.00	1.62	0.92	3.54
BCS-C8-8-V1-D	2421.7	3	0.58	0.94	0.54	0.28	0.45	0.24	0.97
BCS-C8-9-V1-A	2034.9	3	0.47	0.77	0.44	0.17	0.28	0.14	0.59
BCS-C8-9-V1-B	2677.0	3	0.85	1.39	0.80	0.55	0.90	0.50	1.95
BCS-C8-9-V1-C	2436.0	3	0.87	1.42	0.82	0.57	0.93	0.52	2.02
BCS-C8-9-V1-D	2468.5	3	0.72	1.17	0.67	0.42	0.68	0.37	1.47
BCS-C9-1-V1-A	2616.3	3	0.40	0.66	0.38	0.10	0.17	0.08	0.34
BCS-C9-1-V1-B	3237.2	3	1.20	1.96	1.13	0.90	1.47	0.83	3.20
BCS-C9-1-V1-C	2570.4	3	0.76	1.24	0.71	0.46	0.75	0.41	1.62
BCS-C9-1-V1-D	2563.3	3	0.94	1.53	0.88	0.64	1.04	0.58	2.27
BCS-C9-1-V1-D(qc)	2563.3	3	1.02	1.66	0.96	0.72	1.17	0.66	2.54
BCS-C9-2-V1-A	2400.5	2	0.92	1.51	0.87	0.62	1.02	0.57	2.21
BCS-C9-2-V1-B	2668.1	2	1.04	1.70	0.98	0.74	1.21	0.68	2.62
BCS-C9-2-V1-C	2562.8	2	1.15	1.87	1.08	0.85	1.38	0.78	3.01
BCS-C9-2-V1-D	2123.2	2	0.77	1.25	0.72	0.47	0.76	0.42	1.65
BCS-C9-2-V1-D(qc)	2123.2	2	0.89	1.45	0.84	0.59	0.96	0.54	2.08
BCS-C9-3-V1-A	2117.6	3	1.25	2.03	1.17	0.95	1.54	0.87	3.36
BCS-C9-3-V1-B	2298.1	3	0.92	1.50	0.87	0.62	1.01	0.57	2.20
BCS-C9-3-V1-B (qc)	2298.1	3	0.90	1.47	0.85	0.60	0.98	0.55	2.12
BCS-C9-3-V1-C	2426.9	3	0.82	1.33	0.77	0.52	0.84	0.47	1.83
BCS-C9-3-V1-D	2515.5	3	0.86	1.41	0.81	0.56	0.92	0.51	2.00
BCS-C9-4-V1-A	2880.9	2	0.44	0.71	0.41	0.14	0.22	0.11	0.47
BCS-C9-4-V1-B	2270.3	2	0.47	0.77	0.45	0.17	0.28	0.15	0.60
BCS-C9-4-V1-C	2688.1	2	0.40	0.66	0.38	0.10	0.17	0.08	0.35
BCS-C9-4-V1-D	2015.1	2	0.70	1.14	0.66	0.40	0.65	0.36	1.41

SAMPLE #	WT. (g)	Gamma Spec Sys.	Th-232 (pCi/g)	Th-230 (pCi/g)	Th-228 (pCi/g)	Th-232 Net (pCi/g)	Th-230 Net (pCi/g)	Th-228 Net (pCi/g)	Total Net Thorium (pCi/g)
BCS-C9-5-V1-A	2882.9	3	1.31	2.13	1.23	1.01	1.64	0.93	3.58
BCS-C9-5-V1-B	2491.3	3	1.23	2.00	1.15	0.93	1.51	0.85	3.29
BCS-C9-5-V1-C	2328.5	3	0.91	1.49	0.86	0.61	1.00	0.56	2.17
BCS-C9-5-V1-D	2379.9	3	0.58	0.95	0.55	0.28	0.46	0.25	0.98
BCS-C9-6-V1-A	2344.1	3	1.30	2.12	1.22	1.00	1.63	0.92	3.54
BCS-C9-6-V1-B	2582.9	3	0.71	1.15	0.66	0.41	0.66	0.36	1.43
BCS-C9-6-V1-C	2464.9	3	0.70	1.14	0.66	0.40	0.65	0.36	1.42
BCS-C9-6-V1-D	2430.7	3	0.53	0.86	0.50	0.23	0.37	0.20	0.80
BCS-C9-6-V1-D (qc)	2430.7	3	0.60	0.99	0.57	0.30	0.50	0.27	1.07
BCS-C9-7-V1-A	2356.1	3	0.89	1.44	0.83	0.59	0.95	0.53	2.07
BCS-C9-7-V1-B	2227.2	3	1.70	2.77	1.60	1.40	2.28	1.30	4.98
BCS-C9-7-V1-C	2173.7	3	1.35	2.21	1.27	1.05	1.72	0.97	3.74
BCS-C9-7-V1-D	2602.4	3	0.54	0.88	0.51	0.24	0.39	0.21	0.83
BCS-C9-8-V1-A	2262.5	2	1.19	1.93	1.12	0.89	1.44	0.82	3.15
BCS-C9-8-V1-B	2408.7	2	0.40	0.66	0.38	0.10	0.17	0.08	0.35
BCS-C9-8-V1-C	2272.1	2	0.38	0.61	0.35	0.08	0.12	0.05	0.25
BCS-C9-8-V1-D	2270.0	2	0.26	0.43	0.25	-0.04	-0.06	-0.05	-0.15
BCS-C9-9-V1-A	2220.9	2	0.47	0.76	0.44	0.17	0.27	0.14	0.58
BCS-C9-9-V1-B	2116.4	2	0.74	1.21	0.70	0.44	0.72	0.40	1.56
BCS-C9-9-V1-C	2009.3	2	0.56	0.91	0.53	0.26	0.42	0.23	0.90
BCS-C9-9-V1-D	2018.1	2	0.72	1.18	0.68	0.42	0.69	0.38	1.49
BCS-D10-1-V1-A	3026.8	2	0.00	-0.01	0.00	-0.30	-0.50	-0.30	-1.11
BCS-D10-1-V1-B	3043.0	2	0.53	0.87	0.50	0.23	0.38	0.20	0.81
BCS-D10-1-V1-C	2814.0	2	0.46	0.75	0.43	0.16	0.26	0.13	0.56
BCS-D10-1-V1-D	2918.0	2	0.42	0.69	0.40	0.12	0.20	0.10	0.42
BCS-D10-2-V1-A	3300.2	2	0.12	0.19	0.11	-0.18	-0.30	-0.19	-0.66
BCS-D10-2-V1-B	3097.3	2	0.34	0.55	0.32	0.04	0.06	0.02	0.11
BCS-D10-2-V1-C	3501.9	2	0.18	0.29	0.17	-0.12	-0.20	-0.13	-0.45
BCS-D10-2-V1-D	2953.2	2	1.00	1.63	0.94	0.70	1.14	0.64	2.48
BCS-D10-2-V1-D (qc)	2953.2	2	0.67	1.09	0.63	0.37	0.60	0.33	1.31
BCS-D10-3-V1-A	2900.0	2	1.56	2.55	1.47	1.26	2.06	1.17	4.49
BCS-D10-3-V1-B	2675.4	2	1.14	1.86	1.08	0.84	1.37	0.78	2.99
BCS-D10-3-V1-C	2616.4	2	0.82	1.34	0.77	0.52	0.85	0.47	1.84
BCS-D10-3-V1-D	2711.4	2	0.49	0.81	0.46	0.19	0.32	0.16	0.68
BCS-D10-3-V1-D(qc)	2711.4	2	0.44	0.72	0.41	0.14	0.23	0.11	0.49
BCS-D10-4-V1-A	3045.9	3	0.53	0.87	0.50	0.23	0.38	0.20	0.82
BCS-D10-4-V1-B	3130.0	3	0.32	0.52	0.30	0.02	0.03	0.00	0.05
BCS-D10-4-V1-C	2846.3	3	0.68	1.11	0.64	0.38	0.62	0.34	1.34
BCS-D10-4-V1-D	2431.3	3	0.66	1.07	0.62	0.36	0.58	0.32	1.26
BCS-D10-4-V1-D(qc)	2431.3	3	0.52	0.85	0.49	0.22	0.36	0.19	0.77
BCS-D10-5-V1-A	3693.9	2	0.72	1.18	0.68	0.42	0.69	0.38	1.50
BCS-D10-5-V1-B	3056.5	2	0.68	1.12	0.64	0.38	0.63	0.34	1.36
BCS-D10-5-V1-C	3556.1	2	0.43	0.70	0.41	0.13	0.21	0.11	0.45
BCS-D10-5-V1-D	2816.4	2	0.52	0.85	0.49	0.22	0.36	0.19	0.78
BCS-D10-6-V1-A	2939.4	3	1.06	1.74	1.00	0.76	1.25	0.70	2.71

SAMPLE #	WT. (g)	Gamma Spec Sys.	Th-232 (pCi/g)	Th-230 (pCi/g)	Th-228 (pCi/g)	Th-232 Net (pCi/g)	Th-230 Net (pCi/g)	Th-228 Net (pCi/g)	Total Net Thorium (pCi/g)
BCS-D10-6-V1-B	2173.2	3	0.98	1.59	0.92	0.68	1.10	0.62	2.40
BCS-D10-6-V1-C	2191.2	3	1.00	1.63	0.94	0.70	1.14	0.64	2.49
BCS-D10-6-V1-D	2123.1	3	0.70	1.14	0.66	0.40	0.65	0.36	1.41
BCS-D10-7-V1-A	2595.7	2	0.47	0.77	0.45	0.17	0.28	0.15	0.60
BCS-D10-7-V1-B	2574.6	2	0.33	0.54	0.31	0.03	0.05	0.01	0.10
BCS-D10-7-V1-C	2945.5	2	0.43	0.70	0.40	0.13	0.21	0.10	0.45
BCS-D10-7-V1-D	2814.2	2	0.24	0.39	0.23	-0.06	-0.10	-0.07	-0.23
BCS-D10-7-V1-D(qc)	2814.2	2	0.30	0.49	0.28	0.00	0.00	-0.02	-0.01
BCS-D10-8-V1-A	2507.6	2	0.31	0.50	0.29	0.01	0.01	-0.01	0.01
BCS-D10-8-V1-B	2264.8	2	0.69	1.13	0.65	0.39	0.64	0.35	1.38
BCS-D10-8-V1-C	2468.9	2	0.80	1.30	0.75	0.50	0.81	0.45	1.75
BCS-D10-8-V1-D	2187.4	2	0.79	1.29	0.74	0.49	0.80	0.44	1.73
BCS-D10-9-V1-A	2249.5	3	0.64	1.04	0.60	0.34	0.55	0.30	1.19
BCS-D10-9-V1-B	1618.0	3	0.77	1.25	0.72	0.47	0.76	0.42	1.64
BCS-D10-9-V1-C	1961.0	3	0.72	1.18	0.68	0.42	0.69	0.38	1.48
BCS-D10-9-V1-D	1636.6	3	0.92	1.50	0.86	0.62	1.01	0.56	2.18
BCS-D10-9-V1-D(qc)	1636.6	3	0.85	1.39	0.80	0.55	0.90	0.50	1.96
BCS-D11-1-V1-A	2323.4	3	0.32	0.51	0.30	0.02	0.02	0.00	0.04
BCS-D11-1-V1-B	1742.9	3	1.30	2.12	1.22	1.00	1.63	0.92	3.55
BCS-D11-1-V1-C	2082.7	3	0.94	1.53	0.88	0.64	1.04	0.58	2.26
BCS-D11-1-V1-D	1939.7	3	0.77	1.25	0.72	0.47	0.76	0.42	1.65
BCS-D11-4-V1-A	1649.6	3	0.79	1.29	0.74	0.49	0.80	0.44	1.73
BCS-D11-4-V1-B	1647.2	3	0.65	1.06	0.61	0.35	0.57	0.31	1.24
BCS-D11-4-V1-C	1725.1	3	0.58	0.95	0.55	0.28	0.46	0.25	0.98
BCS-D11-4-V1-D	1851.6	3	1.02	1.66	0.96	0.72	1.17	0.66	2.56
BCS-D11-7-V1-A	1731.1	3	0.71	1.16	0.67	0.41	0.67	0.37	1.45
BCS-D11-7-V1-B	1706.8	3	0.98	1.59	0.92	0.68	1.10	0.62	2.40
BCS-D11-7-V1-C	1864.4	3	0.84	1.37	0.79	0.54	0.88	0.49	1.91
BCS-D11-7-V1-D	1779.0	3	0.99	1.61	0.93	0.69	1.12	0.63	2.45
BCS-D9-6-V1-A	3237.8	3	0.57	0.93	0.54	0.27	0.44	0.24	0.94
BCS-D9-6-V1-B	3356.5	3	0.27	0.44	0.26	-0.03	-0.05	-0.04	-0.12
BCS-D9-6-V1-C	3203.1	3	0.71	1.16	0.67	0.41	0.67	0.37	1.46
BCS-D9-6-V1-D	2920.7	3	0.85	1.38	0.80	0.55	0.89	0.50	1.94
BCS-D9-9-V1-A	2513.4	3	0.98	1.59	0.92	0.68	1.10	0.62	2.40
BCS-D9-9-V1-B	2964.7	3	0.64	1.05	0.61	0.34	0.56	0.31	1.21
BCS-D9-9-V1-C	3026.1	3	0.75	1.22	0.70	0.45	0.73	0.40	1.58
BCS-D9-9-V1-D	2763.3	3	0.68	1.11	0.64	0.38	0.62	0.34	1.34
BCS-E10-1-V1-A	2731.4	3	1.25	2.03	1.17	0.95	1.54	0.87	3.36
BCS-E10-1-V1-B	2611.3	3	0.75	1.21	0.70	0.45	0.72	0.40	1.57
BCS-E10-1-V1-C	3094.3	3	0.54	0.89	0.51	0.24	0.40	0.21	0.85
BCS-E10-1-V1-D	2444.3	3	0.73	1.19	0.69	0.43	0.70	0.39	1.52
BCS-E10-1-V1-D(qc)	2444.3	3	0.63	1.02	0.59	0.33	0.53	0.29	1.15
BCS-E10-2-V1-A	2849.7	3	0.46	0.76	0.44	0.16	0.27	0.14	0.56
BCS-E10-2-V1-B	2981.6	3	0.69	1.12	0.65	0.39	0.63	0.35	1.37
BCS-E10-2-V1-C	2289.4	3	0.63	1.03	0.59	0.33	0.54	0.29	1.17

SAMPLE #	WT. (g)	Gamma Spec Sys.	Th-232 (pCi/g)	Th-230 (pCi/g)	Th-228 (pCi/g)	Th-232 Net (pCi/g)	Th-230 Net (pCi/g)	Th-228 Net (pCi/g)	Total Net Thorium (pCi/g)
BCS-E10-2-V1-D	2941.6	3	0.92	1.49	0.86	0.62	1.00	0.56	2.18
BCS-E10-3-V1-A	2430.3	3	0.81	1.31	0.76	0.51	0.82	0.46	1.79
BCS-E10-3-V1-B	3407.1	3	0.28	0.46	0.26	-0.02	-0.03	-0.04	-0.08
BCS-E10-3-V1-C	2721.9	3	0.90	1.46	0.84	0.60	0.97	0.54	2.12
BCS-E10-3-V1-D	2908.2	3	0.93	1.51	0.87	0.63	1.02	0.57	2.23
BCS-E10-6-V1-A	2871.0	3	0.86	1.40	0.81	0.56	0.91	0.51	1.97
BCS-E10-6-V1-B	3069.2	3	0.92	1.50	0.86	0.62	1.01	0.56	2.19
BCS-E10-6-V1-C	3095.9	3	0.72	1.17	0.67	0.42	0.68	0.37	1.47
BCS-E10-6-V1-D	2948.6	3	0.81	1.32	0.76	0.51	0.83	0.46	1.80
BCS-E10-9-V1-A	2964.1	2	1.19	1.95	1.12	0.89	1.46	0.82	3.17
BCS-E10-9-V1-B	2802.7	2	0.80	1.30	0.75	0.50	0.81	0.45	1.76
BCS-E10-9-V1-B(qc)	2802.7	2	1.04	1.69	0.98	0.74	1.20	0.68	2.62
BCS-E10-9-V1-C	3003.2	2	0.56	0.91	0.52	0.26	0.42	0.22	0.90
BCS-E10-9-V1-D	2990.5	2	0.71	1.15	0.66	0.41	0.66	0.36	1.43
BCS-E11-1-V1-A	1505.9	2	0.58	0.94	0.54	0.28	0.45	0.24	0.97
BCS-E11-1-V1-B	2543.5	2	0.38	0.61	0.35	0.08	0.12	0.05	0.25
BCS-E11-1-V1-C	2886.3	2	0.42	0.69	0.40	0.12	0.20	0.10	0.42
BCS-E11-1-V1-D	3243.6	2	0.45	0.73	0.42	0.15	0.24	0.12	0.51
BCS-E11-4-V1-A	3243.3	2	0.34	0.56	0.32	0.04	0.07	0.02	0.13
BCS-E11-4-V1-B	3198.2	2	0.57	0.94	0.54	0.27	0.45	0.24	0.96
BCS-E11-4-V1-C	2935.9	2	0.62	1.01	0.58	0.32	0.52	0.28	1.13
BCS-E11-4-V1-D	2514.9	2	0.38	0.62	0.36	0.08	0.13	0.06	0.27
BCS-E11-7-V1-A	2816.4	3	1.07	1.74	1.01	0.77	1.25	0.71	2.73
BCS-E11-7-V1-B	2687.2	3	0.25	0.40	0.23	-0.05	-0.09	-0.07	-0.21
BCS-E11-7-V1-C	2827.3	3	0.50	0.81	0.47	0.20	0.32	0.17	0.68
BCS-E11-7-V1-D	1906.7	3	1.03	1.67	0.97	0.73	1.18	0.67	2.58
BCS-E9-1-V1-A	2899.1	2	0.59	0.97	0.56	0.29	0.48	0.26	1.03
BCS-E9-1-V1-B	2799.9	2	0.93	1.52	0.88	0.63	1.03	0.58	2.25
BCS-E9-1-V1-C	3366.5	2	0.32	0.53	0.30	0.02	0.04	0.00	0.06
BCS-E9-1-V1-D	2341.5	2	0.83	1.36	0.78	0.53	0.87	0.48	1.89
BCS-E9-2-V1-A	3157.3	2	0.76	1.23	0.71	0.46	0.74	0.41	1.61
BCS-E9-2-V1-B	2592.1	2	0.61	1.00	0.58	0.31	0.51	0.28	1.09
BCS-E9-2-V1-C	2743.8	2	0.55	0.90	0.52	0.25	0.41	0.22	0.88
BCS-E9-2-V1-D	3150.6	2	0.61	1.00	0.58	0.31	0.51	0.28	1.09
BCS-E9-2-V1-D(qc)	3150.6	2	0.67	1.08	0.63	0.37	0.59	0.33	1.29
BCS-E9-3-V1-A	2796.8	2	0.37	0.61	0.35	0.07	0.12	0.05	0.25
BCS-E9-3-V1-B	2710.8	2	0.65	1.05	0.61	0.35	0.56	0.31	1.22
BCS-E9-3-V1-C	3281.7	2	0.77	1.26	0.73	0.47	0.77	0.43	1.68
BCS-E9-3-V1-D	2778.3	2	0.08	0.12	0.07	-0.22	-0.37	-0.23	-0.82
BCS-F10-1-V1-A	2765.1	3	0.52	0.84	0.49	0.22	0.35	0.19	0.76
BCS-F10-1-V1-B	3075.7	3	0.57	0.93	0.53	0.27	0.44	0.23	0.94
BCS-F10-1-V1-C	3180.0	3	0.30	0.49	0.28	0.00	0.00	-0.02	-0.01
BCS-F10-1-V1-D	2423.6	3	0.65	1.06	0.61	0.35	0.57	0.31	1.23
BCS-F10-2-V1-A	2620.1	2	0.48	0.78	0.45	0.18	0.29	0.15	0.62
BCS-F10-2-V1-B	3318.5	2	0.48	0.79	0.45	0.18	0.30	0.15	0.63

SAMPLE #	WT. (g)	Gamma Spec Sys.	Th-232 (pCi/g)	Th-230 (pCi/g)	Th-228 (pCi/g)	Th-232 Net (pCi/g)	Th-230 Net (pCi/g)	Th-228 Net (pCi/g)	Total Net Thorium (pCi/g)
BCS-F10-2-V1-C	2690.8	2	0.56	0.91	0.52	0.26	0.42	0.22	0.89
BCS-F10-2-V1-D	2938.6	2	0.42	0.69	0.40	0.12	0.20	0.10	0.42
BCS-F10-3-V1-A	2411.5	3	0.56	0.92	0.53	0.26	0.43	0.23	0.92
BCS-F10-3-V1-B	2800.2	3	0.78	1.27	0.73	0.48	0.78	0.43	1.68
BCS-F10-3-V1-C	2370.3	3	0.72	1.18	0.68	0.42	0.69	0.38	1.49
BCS-F10-3-V1-D	2810.0	3	0.58	0.95	0.55	0.28	0.46	0.25	0.99
BCS-F10-4-V1-A	3017.5	2	0.54	0.88	0.51	0.24	0.39	0.21	0.84
BCS-F10-4-V1-B	2606.4	2	0.52	0.85	0.49	0.22	0.36	0.19	0.77
BCS-F10-4-V1-C	2893.0	2	0.49	0.80	0.46	0.19	0.31	0.16	0.66
BCS-F10-4-V1-D	2985.2	2	0.63	1.03	0.59	0.33	0.54	0.29	1.17
BCS-F10-5-V1-A	2425.0	3	0.40	0.65	0.38	0.10	0.16	0.08	0.34
BCS-F10-5-V1-B	3105.9	3	0.47	0.76	0.44	0.17	0.27	0.14	0.58
BCS-F10-5-V1-C	3489.1	3	0.96	1.56	0.90	0.66	1.07	0.60	2.32
BCS-F10-5-V1-D	3317.7	3	0.17	0.28	0.16	-0.13	-0.21	-0.14	-0.48
BCS-F10-6-V1-A	2895.4	3	0.69	1.13	0.65	0.39	0.64	0.35	1.39
BCS-F10-6-V1-B	3224.4	3	0.43	0.70	0.40	0.13	0.21	0.10	0.44
BCS-F10-6-V1-C	3084.4	3	0.37	0.60	0.35	0.07	0.11	0.05	0.22
BCS-F10-6-V1-D	2744.8	3	0.28	0.46	0.26	-0.02	-0.03	-0.04	-0.09
BCS-F10-7-V1-A	3174.9	2	0.37	0.60	0.35	0.07	0.11	0.05	0.22
BCS-F10-7-V1-B	2819.7	2	0.72	1.17	0.67	0.42	0.68	0.37	1.47
BCS-F10-7-V1-C	3636.1	2	0.28	0.46	0.27	-0.02	-0.03	-0.03	-0.08
BCS-F10-7-V1-D	2769.8	2	0.53	0.86	0.49	0.23	0.37	0.19	0.79
BCS-F10-8-V1-A	3318.3	3	0.31	0.50	0.29	0.01	0.01	-0.01	0.01
BCS-F10-8-V1-B	3050.5	3	0.98	1.60	0.93	0.68	1.11	0.63	2.42
BCS-F10-8-V1-C	2886.1	3	0.72	1.17	0.68	0.42	0.68	0.38	1.48
BCS-F10-8-V1-D	2744.1	3	0.24	0.39	0.22	-0.06	-0.10	-0.08	-0.24
BCS-F10-9-V1-A	2971.4	3	0.43	0.71	0.41	0.13	0.22	0.11	0.46
BCS-F10-9-V1-B	3129.4	3	0.29	0.48	0.27	-0.01	-0.01	-0.03	-0.05
BCS-F10-9-V1-C	3249.7	3	0.52	0.85	0.49	0.22	0.36	0.19	0.77
BCS-F10-9-V1-D	3263.4	3	0.28	0.46	0.27	-0.02	-0.03	-0.03	-0.08
BCS-F11-1-V1-A	2870.7	3	0.31	0.51	0.30	0.01	0.02	0.00	0.03
BCS-F11-1-V1-B	3121.5	3	0.66	1.07	0.62	0.36	0.58	0.32	1.25
BCS-F11-1-V1-C	3271.1	3	0.35	0.57	0.33	0.05	0.08	0.03	0.15
BCS-F11-1-V1-D	3282.5	3	0.53	0.87	0.50	0.23	0.38	0.20	0.82
BCS-F11-1-V1-D(qc)	3282.5	3	0.50	0.81	0.47	0.20	0.32	0.17	0.69
BCS-F11-4-V1-A	2953.6	2	0.33	0.53	0.31	0.03	0.04	0.01	0.08
BCS-F11-4-V1-B	3379.2	2	0.20	0.33	0.19	-0.10	-0.16	-0.11	-0.37
BCS-F11-4-V1-C	3422.0	2	0.21	0.34	0.20	-0.09	-0.15	-0.10	-0.35
BCS-F11-4-V1-D	3059.0	2	0.40	0.65	0.38	0.10	0.16	0.08	0.34
BCS-F11-7-V1-A	3064.4	2	0.21	0.35	0.20	-0.09	-0.14	-0.10	-0.33
BCS-F11-7-V1-B	3002.7	2	0.53	0.86	0.50	0.23	0.37	0.20	0.80
BCS-F11-7-V1-C	2835.0	2	0.13	0.21	0.12	-0.17	-0.28	-0.18	-0.63
BCS-F11-7-V1-D	2844.4	2	0.46	0.75	0.43	0.16	0.26	0.13	0.56
BCS-F9-1-V1-A	3337.8	3	0.75	1.22	0.71	0.45	0.73	0.41	1.59
BCS-F9-1-V1-B	3067.7	3	0.45	0.74	0.42	0.15	0.25	0.12	0.52

SAMPLE #	WT. (g)	Gamma Spec Sys.	Th-232 (pCi/g)	Th-230 (pCi/g)	Th-228 (pCi/g)	Th-232 Net (pCi/g)	Th-230 Net (pCi/g)	Th-228 Net (pCi/g)	Total Net Thorium (pCi/g)
BCS-F9-1-V1-C	2847.7	3	0.53	0.86	0.50	0.23	0.37	0.20	0.80
BCS-F9-1-V1-D	3053.0	3	0.34	0.56	0.32	0.04	0.07	0.02	0.13
BCS-F9-2-V1-A	2558.3	3	0.70	1.15	0.66	0.40	0.66	0.36	1.42
BCS-F9-2-V1-B	2315.9	3	1.14	1.86	1.07	0.84	1.37	0.77	2.98
BCS-F9-2-V1-C	2539.5	3	0.52	0.84	0.48	0.22	0.35	0.18	0.75
BCS-F9-2-V1-D	2393.5	3	0.49	0.80	0.46	0.19	0.31	0.16	0.66
BCS-F9-3-V1-A	2956.2	2	0.29	0.48	0.28	-0.01	-0.01	-0.02	-0.04
BCS-F9-3-V1-B	3185.6	2	0.16	0.25	0.15	-0.14	-0.24	-0.15	-0.54
BCS-F9-3-V1-C	3006.0	2	0.33	0.53	0.31	0.03	0.04	0.01	0.08
BCS-F9-3-V1-D	3184.1	2	0.38	0.62	0.36	0.08	0.13	0.06	0.26
BCS-F9-4-V1-A	2559.7	3	0.49	0.80	0.46	0.19	0.31	0.16	0.66
BCS-F9-4-V1-B	3463.7	3	0.43	0.69	0.40	0.13	0.20	0.10	0.43
BCS-F9-4-V1-C	3393.8	3	0.72	1.17	0.67	0.42	0.68	0.37	1.47
BCS-F9-4-V1-D	2937.1	3	0.53	0.87	0.50	0.23	0.38	0.20	0.81
BCS-F9-5-V1-A	2842.0	2	0.46	0.75	0.44	0.16	0.26	0.14	0.56
BCS-F9-5-V1-B	3386.2	2	0.24	0.39	0.22	-0.06	-0.10	-0.08	-0.24
BCS-F9-5-V1-C	2922.7	2	0.59	0.96	0.55	0.29	0.47	0.25	1.00
BCS-F9-5-V1-D	3646.5	2	0.71	1.16	0.67	0.41	0.67	0.37	1.45
BCS-F9-6-V1-A	3338.5	2	0.36	0.59	0.34	0.06	0.10	0.04	0.20
BCS-F9-6-V1-B	3380.3	2	0.44	0.71	0.41	0.14	0.22	0.11	0.47
BCS-F9-6-V1-C	2956.5	2	0.36	0.59	0.34	0.06	0.10	0.04	0.21
BCS-F9-6-V1-D	3192.1	2	0.16	0.26	0.15	-0.14	-0.23	-0.15	-0.53
BCS-F9-7-V1-A	3043.2	3	0.76	1.24	0.72	0.46	0.75	0.42	1.64
BCS-F9-7-V1-B	3855.8	3	0.60	0.97	0.56	0.30	0.48	0.26	1.04
BCS-F9-7-V1-C	2916.4	3	0.56	0.91	0.52	0.26	0.42	0.22	0.90
BCS-F9-7-V1-D	2929.6	3	0.53	0.86	0.50	0.23	0.37	0.20	0.80
BCS-F9-7-V1-D(qc)	2929.6	3	0.49	0.80	0.46	0.19	0.31	0.16	0.65
BCS-F9-8-V1-A	3015.2	2	0.59	0.96	0.55	0.29	0.47	0.25	1.01
BCS-F9-8-V1-B	3234.8	2	0.48	0.78	0.45	0.18	0.29	0.15	0.63
BCS-F9-8-V1-C	2456.0	2	0.38	0.62	0.36	0.08	0.13	0.06	0.26
BCS-F9-8-V1-D	2496.1	2	0.61	0.99	0.57	0.31	0.50	0.27	1.09
BCS-F9-9-V1-A	2877.0	2	0.64	1.05	0.60	0.34	0.56	0.30	1.21
BCS-F9-9-V1-B	2838.8	2	0.44	0.72	0.42	0.14	0.23	0.12	0.49
BCS-F9-9-V1-C	3397.6	2	0.55	0.89	0.51	0.25	0.40	0.21	0.86
BCS-F9-9-V1-D	3321.8	2	0.26	0.43	0.25	-0.04	-0.06	-0.05	-0.15
BCS-F9-9-V1-D(qc)	3321.8	2	0.28	0.46	0.26	-0.02	-0.03	-0.04	-0.09
BCS-G10-1-V1-A	2975.4	3	0.69	1.13	0.65	0.39	0.64	0.35	1.37
BCS-G10-1-V1-B	2990.5	3	0.27	0.44	0.26	-0.03	-0.05	-0.04	-0.12
BCS-G10-1-V1-C	2959.7	3	0.67	1.09	0.63	0.37	0.60	0.33	1.30
BCS-G10-1-V1-D	3130.8	3	0.66	1.07	0.62	0.36	0.58	0.32	1.26
BCS-G10-2-V1-A	3132.5	2	0.77	1.25	0.72	0.47	0.76	0.42	1.65
BCS-G10-2-V1-B	3206.3	2	0.94	1.53	0.88	0.64	1.04	0.58	2.26
BCS-G10-2-V1-C	2724.5	2	0.31	0.51	0.29	0.01	0.02	-0.01	0.02
BCS-G10-2-V1-D	3193.3	2	0.64	1.04	0.60	0.34	0.55	0.30	1.19
BCS-G10-2-V1-D(qc)	3193.3	2	0.70	1.14	0.66	0.40	0.65	0.36	1.42

SAMPLE #	WT. (g)	Gamma Spec Sys.	Th-232 (pCi/g)	Th-230 (pCi/g)	Th-228 (pCi/g)	Th-232 Net (pCi/g)	Th-230 Net (pCi/g)	Th-228 Net (pCi/g)	Total Net Thorium (pCi/g)
BCS-G10-3-V1-A	2836.0	2	0.83	1.35	0.78	0.53	0.86	0.48	1.86
BCS-G10-3-V1-B	3690.4	2	0.35	0.57	0.33	0.05	0.08	0.03	0.16
BCS-G10-3-V1-C	3284.8	2	0.41	0.67	0.39	0.11	0.18	0.09	0.38
BCS-G10-3-V1-D	3855.6	2	0.32	0.53	0.30	0.02	0.04	0.00	0.07
BCS-G10-4-V1-A	2809.9	3	0.47	0.77	0.44	0.17	0.28	0.14	0.60
BCS-G10-4-V1-B	2951.6	3	0.71	1.15	0.67	0.41	0.66	0.37	1.44
BCS-G10-4-V1-C	3196.5	3	0.57	0.92	0.53	0.27	0.43	0.23	0.93
BCS-G10-4-V1-D	2016.8	3	0.59	0.96	0.55	0.29	0.47	0.25	1.01
BCS-G10-4-V1-D(QC)	2016.8	3	0.51	0.83	0.48	0.21	0.34	0.18	0.73
BCS-G10-5-V1-A	3137.5	2	0.54	0.88	0.51	0.24	0.39	0.21	0.84
BCS-G10-5-V1-B	2884.7	2	0.60	0.98	0.56	0.30	0.49	0.26	1.05
BCS-G10-5-V1-C	2779.4	2	0.16	0.26	0.15	-0.14	-0.23	-0.15	-0.51
BCS-G10-5-V1-D	3180.4	2	0.40	0.66	0.38	0.10	0.17	0.08	0.35
BCS-G10-6-V1-A	3409.0	3	0.35	0.58	0.33	0.05	0.09	0.03	0.17
BCS-G10-6-V1-B	3048.6	3	0.69	1.13	0.65	0.39	0.64	0.35	1.38
BCS-G10-6-V1-C	2971.4	3	0.53	0.86	0.50	0.23	0.37	0.20	0.80
BCS-G10-6-V1-D	3347.7	3	0.62	1.02	0.59	0.32	0.53	0.29	1.13
BCS-G10-7-V1-A	3069.4	2	0.97	1.58	0.91	0.67	1.09	0.61	2.38
BCS-G10-7-V1-B	2557.3	2	0.31	0.51	0.30	0.01	0.02	0.00	0.03
BCS-G10-7-V1-C	2959.3	2	0.27	0.45	0.26	-0.03	-0.04	-0.04	-0.12
BCS-G10-7-V1-D	2880.7	2	0.32	0.53	0.30	0.02	0.04	0.00	0.06
BCS-G10-8-V1-A	2951.5	3	0.55	0.89	0.51	0.25	0.40	0.21	0.86
BCS-G10-8-V1-B	2487.9	3	0.92	1.50	0.87	0.62	1.01	0.57	2.20
BCS-G10-8-V1-C	2937.0	3	0.75	1.22	0.71	0.45	0.73	0.41	1.59
BCS-G10-8-V1-D	3167.8	3	0.69	1.12	0.65	0.39	0.63	0.35	1.36
BCS-G10-9-V1-A	2888.9	2	0.58	0.95	0.55	0.28	0.46	0.25	0.99
BCS-G10-9-V1-B	2907.4	2	0.36	0.59	0.34	0.06	0.10	0.04	0.21
BCS-G10-9-V1-C	2959.1	2	0.25	0.41	0.24	-0.05	-0.08	-0.06	-0.19
BCS-G10-9-V1-D	3189.3	2	0.46	0.74	0.43	0.16	0.25	0.13	0.54
BCS-G10-9-V1-D(qc)	3189.3	2	0.26	0.43	0.25	-0.04	-0.06	-0.05	-0.16
BCS-G11-1-V1-A	2824.8	3	0.70	1.15	0.66	0.40	0.66	0.36	1.42
BCS-G11-1-V1-B	2962.5	3	0.41	0.67	0.39	0.11	0.18	0.09	0.39
BCS-G11-1-V1-C	2393.4	3	0.54	0.89	0.51	0.24	0.40	0.21	0.85
BCS-G11-1-V1-D	2775.3	3	0.50	0.81	0.47	0.20	0.32	0.17	0.68
BCS-G11-1-V1-D(qc)	2775.3	3	0.52	0.85	0.49	0.22	0.36	0.19	0.77
BCS-G11-4-V1-A	3031.7	3	0.59	0.96	0.55	0.29	0.47	0.25	1.01
BCS-G11-4-V1-B	2875.3	3	0.38	0.63	0.36	0.08	0.14	0.06	0.28
BCS-G11-4-V1-C	3146.8	3	0.31	0.50	0.29	0.01	0.01	-0.01	0.00
BCS-G11-4-V1-D	3651.6	3	0.33	0.54	0.31	0.03	0.05	0.01	0.10
BCS-G11-4-V1-D(qc)	3651.6	3	0.48	0.79	0.45	0.18	0.30	0.15	0.63
BCS-G11-7-V1-A	2889.6	2	0.29	0.47	0.27	-0.01	-0.02	-0.03	-0.07
BCS-G11-7-V1-B	2982.1	2	0.36	0.59	0.34	0.06	0.10	0.04	0.20
BCS-G11-7-V1-C	2897.1	2	0.63	1.03	0.59	0.33	0.54	0.29	1.17
BCS-G11-7-V1-D	3369.1	2	0.36	0.58	0.34	0.06	0.09	0.04	0.19
BCS-G9-2-V1-A	2839.3	2	0.95	1.55	0.89	0.65	1.06	0.59	2.31

SAMPLE #	WT. (g)	Gamma Spec Sys.	Th-232 (pCi/g)	Th-230 (pCi/g)	Th-228 (pCi/g)	Th-232 Net (pCi/g)	Th-230 Net (pCi/g)	Th-228 Net (pCi/g)	Total Net Thorium (pCi/g)
BCS-G9-2-V1-B	3100.6	2	0.55	0.90	0.52	0.25	0.41	0.22	0.87
BCS-G9-2-V1-C	2628.9	2	1.00	1.64	0.94	0.70	1.15	0.64	2.50
BCS-G9-2-V1-D	1991.8	2	0.61	0.99	0.57	0.31	0.50	0.27	1.07
BCS-G9-3-V1-A	2838.3	2	0.63	1.03	0.59	0.33	0.54	0.29	1.16
BCS-G9-3-V1-B	2443.2	2	0.80	1.30	0.75	0.50	0.81	0.45	1.75
BCS-G9-3-V1-C	2459.8	2	0.95	1.55	0.89	0.65	1.06	0.59	2.31
BCS-G9-3-V1-D	2824.5	2	0.38	0.61	0.35	0.08	0.12	0.05	0.25
BCS-G9-5-V1-A	3083.2	3	1.12	1.82	1.05	0.82	1.33	0.75	2.91
BCS-G9-5-V1-B	2271.4	3	0.89	1.46	0.84	0.59	0.97	0.54	2.10
BCS-G9-5-V1-C	3148.3	3	0.95	1.54	0.89	0.65	1.05	0.59	2.28
BCS-G9-5-V1-D	2975.3	3	0.30	0.49	0.29	0.00	0.00	-0.01	-0.01
BCS-G9-6-V1-A	2641.0	3	0.88	1.43	0.83	0.58	0.94	0.53	2.05
BCS-G9-6-V1-B	2585.0	3	0.88	1.43	0.83	0.58	0.94	0.53	2.04
BCS-G9-6-V1-C	2937.4	3	0.59	0.97	0.56	0.29	0.48	0.26	1.02
BCS-G9-6-V1-D	2312.8	3	0.63	1.03	0.59	0.33	0.54	0.29	1.17
BCS-G9-8-V1-A	2917.7	2	0.60	0.97	0.56	0.30	0.48	0.26	1.04
BCS-G9-8-V1-B	2970.1	2	0.24	0.39	0.23	-0.06	-0.10	-0.07	-0.23
BCS-G9-8-V1-C	3210.3	2	0.28	0.45	0.26	-0.02	-0.04	-0.04	-0.11
BCS-G9-8-V1-D	3116.8	2	0.39	0.64	0.37	0.09	0.15	0.07	0.30
BCS-G9-9-V1-A	3054.9	3	0.31	0.51	0.29	0.01	0.02	-0.01	0.02
BCS-G9-9-V1-B	3057.6	3	0.61	0.99	0.57	0.31	0.50	0.27	1.07
BCS-G9-9-V1-C	3201.8	3	0.49	0.79	0.46	0.19	0.30	0.16	0.64
BCS-G9-9-V1-D	3472.8	3	0.64	1.05	0.60	0.34	0.56	0.30	1.21
BCS-H10-7-V1-A	2998.9	2	0.59	0.96	0.56	0.29	0.47	0.26	1.02
BCS-H10-7-V1-B	3205.0	2	0.33	0.53	0.31	0.03	0.04	0.01	0.08
BCS-H10-7-V1-C	3027.8	2	0.51	0.83	0.48	0.21	0.34	0.18	0.72
BCS-H10-7-V1-D	2898.0	2	0.71	1.16	0.67	0.41	0.67	0.37	1.46
BCS-H10-8-V1-A	2796.3	3	0.63	1.03	0.59	0.33	0.54	0.29	1.16
BCS-H10-8-V1-B	2921.6	3	0.55	0.90	0.52	0.25	0.41	0.22	0.89
BCS-H10-8-V2-C	3396.3	2	0.42	0.68	0.39	0.12	0.19	0.09	0.41
BCS-H10-8-V1-D	3151.6	3	0.37	0.61	0.35	0.07	0.12	0.05	0.25
BCS-H10-8-V1-D (qc)	3151.6	3	0.44	0.71	0.41	0.14	0.22	0.11	0.47
BCS-H10-9-V1-A	2700.4	3	0.47	0.76	0.44	0.17	0.27	0.14	0.58
BCS-H10-9-V1-B	2882.7	3	0.58	0.94	0.54	0.28	0.45	0.24	0.97
BCS-H10-9-V1-C	3027.8	3	0.63	1.02	0.59	0.33	0.53	0.29	1.15
BCS-H10-9-V1-D	3299.8	3	0.61	0.99	0.57	0.31	0.50	0.27	1.07
BCS-H11-7-V1-A	2919.8	3	0.50	0.82	0.47	0.20	0.33	0.17	0.70
BCS-H11-7-V1-B	2679.1	3	0.64	1.04	0.60	0.34	0.55	0.30	1.18
BCS-H11-7-V1-C	3128.6	3	0.78	1.28	0.74	0.48	0.79	0.44	1.71
BCS-H11-7-V1-D	3313.8	3	0.39	0.63	0.37	0.09	0.14	0.07	0.30
BCS-H9-5-V1-A	2632.3	3	0.52	0.85	0.49	0.22	0.36	0.19	0.78
BCS-H9-5-V1-C	2700.9	3	0.47	0.77	0.45	0.17	0.28	0.15	0.60
BCS-H9-5-V1-D	2899.0	3	0.57	0.93	0.54	0.27	0.44	0.24	0.95
BCS-H9-5-V1-D(qc)	2899.0	3	0.52	0.85	0.49	0.22	0.36	0.19	0.78
BCS-H9-8-V1-A	2973.3	3	0.64	1.04	0.60	0.34	0.55	0.30	1.19

SAMPLE #	WT. (g)	Gamma Spec Sys.	Th-232 (pCi/g)	Th-230 (pCi/g)	Th-228 (pCi/g)	Th-232 Net (pCi/g)	Th-230 Net (pCi/g)	Th-228 Net (pCi/g)	Total Net Thorium (pCi/g)
BCS-H9-8-V1-B	2955.7	3	0.54	0.89	0.51	0.24	0.40	0.21	0.85
BCS-H9-8-V1-C	3076.0	3	0.70	1.15	0.66	0.40	0.66	0.36	1.42
BCS-H9-8-V1-D	2978.1	3	0.59	0.97	0.56	0.29	0.48	0.26	1.03
BCS-H9-8-V1-D(qc)	2978.1	3	0.56	0.92	0.53	0.26	0.43	0.23	0.92
BCS-H9-9-V1-A	3098.4	2	0.38	0.62	0.36	0.08	0.13	0.06	0.28
BCS-H9-9-V1-B	3070.8	2	0.64	1.04	0.60	0.34	0.55	0.30	1.18
BCS-H9-9-V1-C	3690.3	2	0.57	0.93	0.54	0.27	0.44	0.24	0.95
BCS-H9-9-V1-D	2489.8	2	0.70	1.15	0.66	0.40	0.66	0.36	1.42
Average	2509.4		0.66	1.08	0.62	0.36	0.59	0.32	1.28

Equations
Th-230 (pCi/g) = 1.63 * Th-232 (pCi/g)
Th-228 (pCi/g) = 0.94 * Th-232 (pCi/g)
Th-232 Net (pCi/g) = Th-232 (pCi/g) - 0.3
Th-230 Net (pCi/g) = Th-230 (pCi/g) - 0.49
Th-228 Net (pCi/g) = Th-228 (pCi/g) - 0.3
Total Net Thorium = Th-232 Net + Th-230 Net + Th-228 Net

Table A5

Final Gamma Exposure Rates – VA-V

Grid Number	Gross Exposure µR/hr	Net Exposure µR/hr
BCS-A10-1-V1	8	3
BCS-A10-2-V1	8	3
BCS-A10-3-V1	8	3
BCS-A10-4-V1	9	4
BCS-A10-5-V1	8	3
BCS-A10-6-V1	8	3
BCS-A10-7-V1	8	3
BCS-A10-8-V1	6	1
BCS-A11-1-V1	7	2
BCS-A11-4-V1	7	2
BCS-A8-1-V1	8	3
BCS-A8-2-V1	9	4
BCS-A8-3-V1	8	3
BCS-A8-4-V1	7	2
BCS-A8-5-V1	8	3
BCS-A8-6-V1	10	5
BCS-A8-7-V1	8	3
BCS-A8-8-V1	8	3
BCS-A8-9-V1	8	3
BCS-A9-1-V1	11	6
BCS-A9-2-V1	11	6
BCS-A9-3-V1	8	3
BCS-A9-4-V1	10	5
BCS-A9-5-V1	10	5
BCS-A9-6-V1	9	4
BCS-A9-7-V1	9	4
BCS-A9-8-V1	8	3
BCS-A9-9-V1	8	3
BCS-B10-1-V1	10	5
BCS-B10-2-V1	11	6
BCS-B10-3-V1	10	5
BCS-B10-4-V1	7	2

Grid Number	Gross Exposure µR/hr	Net Exposure µR/hr
BCS-B10-8-V1	7	2
BCS-B10-9-V1	8	3
BCS-B11-1-V1	10	5
BCS-B11-4-V1	11	6
BCS-B11-7-V1	7	2
BCS-B8-2-V1	12	7
BCS-B8-3-V1	11	6
BCS-B8-5-V1	12	7
BCS-B8-6-V1	12	7
BCS-B8-8-V1	13	8
BCS-B8-9-V1	12	7
BCS-B9-1-V1	11	6
BCS-B9-2-V1	9	4
BCS-B9-3-V1	9	4
BCS-B9-4-V1	11	6
BCS-B9-5-V1	11	6
BCS-B9-6-V1	8	3
BCS-B9-7-V1	12	7
BCS-B9-8-V1	11	6
BCS-B9-9-V1	7	2
BCS-C10-1-V1	11	6
BCS-C10-2-V1	9	4
BCS-C10-3-V1	10	5
BCS-C10-4-V1	10	5
BCS-C10-5-V1	9	4
BCS-C10-6-V1	11	6
BCS-C10-7-V1	10	5
BCS-C10-8-V1	11	6
BCS-C10-9-V1	12	7
BCS-C11-1-V1	9	4
BCS-C11-4-V1	10	5
BCS-C11-7-V1	9	4

Grid Number	Gross Exposure µR/hr	Net Exposure µR/hr	Grid Number	Gross Exposure µR/hr	Net Exposure µR/hr
BCS-B10-5-V1	8	3	BCS-C8-2-V1	10	5
BCS-B10-6-V1	10	5	BCS-C8-3-V1	10	5
BCS-B10-7-V1	9	4	BCS-C8-5-V1	10	5
BCS-C8-6-V1	10	5	BCS-E9-2-V1	9	4
BCS-C8-8-V1	10	5	BCS-E9-3-V1	9	4
BCS-C8-9-V1	11	6	BCS-F10-1-V1	7	2
BCS-C9-1-V1	11	6	BCS-F10-2-V1	8	3
BCS-C9-2-V1	11	6	BCS-F10-3-V1	8	3
BCS-C9-3-V1	10	5	BCS-F10-4-V1	7	2
BCS-C9-4-V1	10	5	BCS-F10-5-V1	7	2
BCS-C9-5-V1	10	5	BCS-F10-6-V1	7	2
BCS-C9-6-V1	10	5	BCS-F10-7-V1	9	4
BCS-C9-7-V1	12	7	BCS-F10-8-V1	9	4
BCS-C9-8-V1	10	5	BCS-F10-9-V1	7	2
BCS-C9-9-V1	10	5	BCS-F11-1-V1	7	2
BCS-D10-1-V1	8	3	BCS-F11-4-V1	8	3
BCS-D10-2-V1	9	4	BCS-F11-7-V1	7	2
BCS-D10-3-V1	10	5	BCS-F9-1-V1	10	5
BCS-D10-4-V1	9	4	BCS-F9-2-V1	10	5
BCS-D10-5-V1	10	5	BCS-F9-3-V1	8	3
BCS-D10-6-V1	10	5	BCS-F9-4-V1	10	5
BCS-D10-7-V1	9	4	BCS-F9-5-V1	9	4
BCS-D10-8-V1	10	5	BCS-F9-6-V1	9	4
BCS-D10-9-V1	9	4	BCS-F9-7-V1	10	5
BCS-D11-1-V1	10	5	BCS-F9-8-V1	9	4
BCS-D11-4-V1	9	4	BCS-F9-9-V1	9	4
BCS-D11-7-V1	10	5	BCS-G10-1-V1	6	1
BCS-D9-6-V1	9	4	BCS-G10-2-V1	6	1
BCS-D9-9-V1	10	5	BCS-G10-3-V1	6	1
BCS-E10-1-V1	9	4	BCS-G10-4-V1	7	2
BCS-E10-2-V1	9	4	BCS-G10-5-V1	6	1
BCS-E10-3-V1	8	3	BCS-G10-6-V1	6	1
BCS-E10-6-V1	8	3	BCS-G10-7-V1	6	1
BCS-E10-9-V1	10	5	BCS-G10-8-V1	8	3
BCS-E11-1-V1	7	2	BCS-G10-9-V1	9	4
BCS-E11-4-V1	9	4	BCS-G11-1-V1	7	2
BCS-E11-7-V1	9	4	BCS-G11-4-V1	7	2

Grid Number	Gross Exposure µR/hr	Net Exposure µR/hr
BCS-E9-1-V1	10	5
BCS-G9-2-V1	10	5
BCS-G9-3-V1	9	4
BCS-G9-5-V1	10	5
BCS-G9-6-V1	8	3
BCS-G9-8-V1	9	4
BCS-G9-9-V1	9	4
BCS-H10-7-V1	10	5

Grid Number	Gross Exposure µR/hr	Net Exposure µR/hr
BCS-G11-7-V1	7	2
BCS-H10-8-V1	9	4
BCS-H10-9-V1	10	5
BCS-H11-7-V1	8	3
BCS-H9-5-V1	8	3
BCS-H9-8-V1	10	5
BCS-H9-9-V1	9	4

Total Number of Sub-grids	153
Average Gross Exposure	9 µR/hr
Average Net Exposure	4 µR/hr
Background Exposure	5 µR/hr

* Net Exposure = Gross Exposure - Background Exposure

Table A6

Final Status Survey: Statistical Analysis

The following statistical relations were used to assess the database for the Bay City survey unit:

Survey Data Average ($\bar{x}$):

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

Standard Deviation (S_x):

$$S_x = \sqrt{\frac{\sum_{i=1}^{n}(\bar{x} - x_i)^2}{n-1}}$$

Determination of Number of Background data points (n_B):

$$n_B = \left[\frac{t_{95.5\%,df} S_x}{0.2 \bullet \bar{x}_B}\right]^2$$

Comparison of statistical mean ($\mu\alpha$) with guideline values:

$$\mu_\alpha = \bar{x} + t_{1-\alpha,df}\frac{S_x}{\sqrt{n}}$$

Identifying additional measurement/sampling needs:

$$\text{Estimating Factor} = \frac{C_G - \bar{x}}{S_x}$$

(Tables B-2 in NUREG/CR-5849)

Note: See chapter 8.0 of NUREG/CR-5849 for detailed discussion of above-listed statistical analyses.

Where:

X_i = measurement (analysis) at point i
n = number of measurements (analyses)
t_i - α, df = 95% confidence level from Table B-1 of Appendix B of NUREG/CR-5849
C_G = Guideline Value

Table A7

Final Status Survey: Summary Statistics

Exposure Rates							
Section	n	X (μR/h)	Sx (μR/h)	μα (μR/h)	C_G (μR/h)	Estimating Factor	No. Verification Samples Needed
VA-V	153	3.9	1.5	4.1	5.0	0.7	17
Th-232 Soil Concentrations							
Section	n	X (pCi/g)	Sx (pCi/g)	μα (pCi/g)	C_G (pCi/g)	Estimating Factor	No. Verification Samples Needed
VA-V	594	0.7	0.3	0.7	3.2	8.3	<9

Final Status Survey Report for VA-VI
Magnesium-Thorium Slag Storage Area
The Dow Chemical Company's
Bay City, Michigan Facility

Dow U.S.A.

The Dow Chemical Company
Midland, Michigan 48674

Revision 1
March 2003

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TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

1.0 BACKGROUND INFORMATION

The radioactive material at the Dow Chemical Company's Bay City site consisted primarily of foundry slag containing Thorium. This material, and similar material originally stored at Dow's Midland site, was produced in the period from 1940 to 1970 as the residual from the production of a magnesium-thorium alloy. This lightweight alloy was used for defense purposes, including aircraft engines and aeronautical structural components.

A single license (STB-527) was originally granted by the NRC in 1973 for the Bay City and Midland sites to store up to 200,000 pounds of thorium slag. The license expired in 1978, but has remained in effect under timely renewal.

The Midland site was decontaminated with the material removed and transported to Bay City for consolidation with the Bay City material and subsequent transport to the Envirocare facility in Clive, Utah. A final survey was conducted at the Midland site by Dow with the results documented in a Final Status Survey Report of March, 1997, showing that the residual contamination criteria had been met. The NRC subsequently conducted an independent survey of the Midland site and verified that the residual contamination criteria had been met.

The material transported from the Midland site to the Bay City site originally consisted of magnesium with up to two percent thorium. Portions of this process slag were mixed with soil or limited amounts of construction debris. As a result of this mixing, the thorium concentrations, as determined by Dow characterization soil sampling, varied from 2-7000 pCi/g at the Bay City Site (with an average concentration of 188 pCi/g) . A total activity of 9.7 Ci of Th-232 was originally distributed throughout approximately 52,000 cubic yards of soil, slag, and construction debris.

Initial remedial action support surveys, performed in 1996, identified wide spread areas of elevated contamination. The gamma scan surveys were conducted using a sodium iodide detector. Readings were generally higher the closer the proximity to the original thorium pile but several hot spots in the 300,000 to 600,000 cpm range were identified. Construction debris, such as drums, was removed from these areas along with the contaminated soil.

Decontamination of the Bay City site is ongoing. In accordance with NRC and Dow discussions, as confirmed in Dow's letter of June 12, 1997, verification that residual contamination criteria have been achieved on this large site is being performed in sections. This Final Status Survey Report (FSR) provides the descriptive text on the site and the parameters of the survey program and includes the analyzed verification data for Verification Area (VA) VI. As the database is acquired for subsequent VAs addendums to the Final Survey Report will be submitted to the NRC containing the analyzed database.

Supporting information on the Bay City site and decommissioning project is presented in the October, 1993 Decommissioning Work Plan, the December, 1995 Supplement to the Decommissioning Work Plan, and the March, 1996 Response to Comments.

This document is a revision to the original Final Status Survey Report for VA-VI dated June 22, 1999.

On July 13th through July 14th of 1999, after the original report submittal, the NRC Region III conducted an inspection of the VA-VI portion of the Dow Bay City facility. The primary purpose of the inspection was to conduct an independent confirmatory survey of VA-VI. This revision to the original report is provided to include the findings of the NRC confirmatory surveys documented in NRC Report No. 040-00017/99001 (DNMS) dated August 5, 1999.

Additionally, this revision to the original report is provided to address deficiencies identified by NRC staff in a letter to Dow dated August 16, 2002 (Review of Final Status Survey Reports for the Previously Remediated Areas VA-I through VA-VI, Dow Chemical Company's Bay City, MI, SDMP Site (TAC# L60463)).

2.0 SITE INFORMATION

2.1 SITE DESCRIPTION

The Bay City thoriated material storage site is on a Dow facility near the Town of Bay City, Michigan about one-mile south of Saginaw Bay. The Bay City site (pile) is shown on Figure 2-1 in relation to adjacent land features and other facilities.

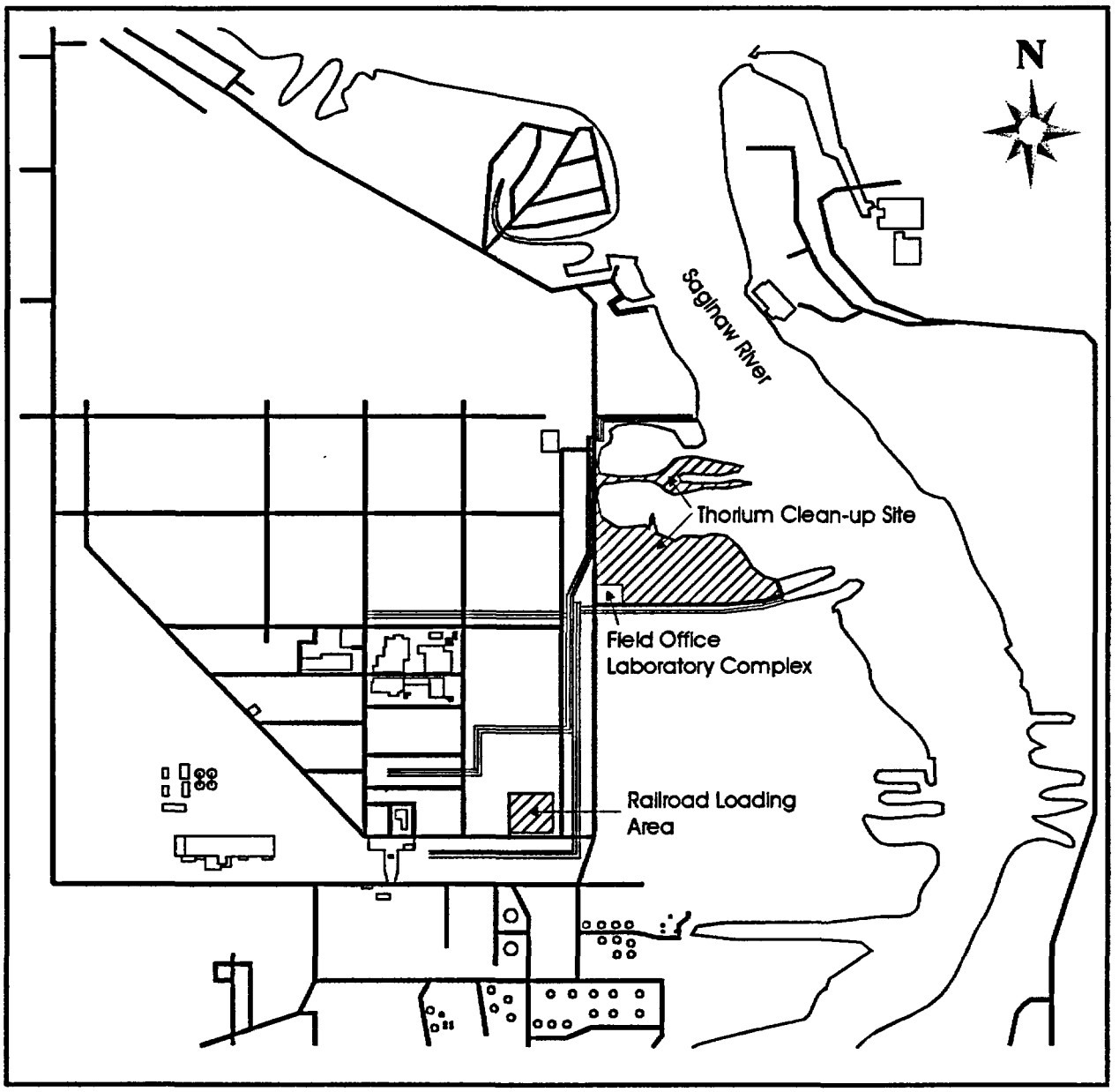
The thoriated material site is located adjacent to and north of an inlet canal, which enters the Saginaw River to the east. The Saginaw River is located to the north and east of the material. Access to the Dow manufacturing facility is restricted to authorized personnel. The storage site within the facility is posted as a radiation control area and delineated with a fence.

The area surrounding the material is relatively level, with some marshy areas and ponds. Any sediments containing elevated levels of thorium are being excavated as part of the decontamination program.

The affected area of the Bay City storage site was initially based on knowledge of the operating history, and subsequently on radiological characterization surveys. While areas immediately surrounding the Bay City storage area were included in the affected area, some further outward adjustment of the affected area boundary was required during site remediation to encompass surface and subsurface contamination uncovered during remedial operations.

Figure 2-1

Bay City Thorium Disposal Site



2.2 SITE CONDITIONS AT TIME OF FINAL SURVEY

The decommissioning activities at the Bay City site involve excavation of the contaminated soil, loading on to trucks, onsite transportation of the material to the stockpile at the railhead, loading on to the rail cars, and transport of the material to the Envirocare burial site in Clive, Utah. Soil removal is to varying depths continuing until sample analysis showed residual concentrations to be within NRC defined limits. Final verification samples were taken in the VA and analyzed on site through gamma spectroscopy. When the gamma spectral analysis results showed the Th-232 levels to be less than the guideline value, a conversion factor was applied to the Th-232 concentration to obtain the Th-230 and Th-228 concentrations. After the net total thorium concentration was determined, five percent of all final verification soil samples were sent to Dow Chemical's radioanalytical laboratory, Freeport, Texas, where the samples were monitored by the Dow Quality Assurance coordinator.

2.3 IDENTITY OF POTENTIAL CONTAMINANTS AND RELEASE GUIDELINES

Based on the knowledge of the process that generated the slag material, and the results of the characterization survey, the significant radiological contaminants were determined to be Th-232, Th-230, and Th-228. The above background residual soil concentration measurements used as a basis for the final verification for all the verification samples analyzed to date at Bay City provided the average soil activity ratios at Bay City of approximately:

Th-232	-	22%
Th-230	-	60%
Th-228	-	18%

Using the approach described in Section 3.1 ("Release Criteria") of the December, 1995 Supplement to the Decommissioning Work Plan and response No. 8 of the Response to Comments (on the Work Plan) of March, 1996, in conjunction with the methodology in Appendix A of NUREG/CR 5849 gives a residual soil gross activity guideline of 14.5 pCi/g total

thorium. The site-specific guideline levels for each of the contributory radionuclides is thus 3.2 pCi/g for Th-232, 2.6 pCi/g for Th-228, and 8.7 pCi/g for Th-230.

The gross activity guideline is determined as follows:

$$\textit{Gross Activity Guideline} = \frac{1}{\frac{0.22}{10} + \frac{0.18}{10} + \frac{0.60}{21}} = 14.5\ pCi/g$$

where Th-232, Th-230, and Th-228 are present in net activity ratios of 0.22, 0.60, and 0.18 respectively in the residual soil. The guideline concentrations for Th-232 plus Th-228 are 10 pCi/g and 21 pCi/g for Th-230 (see March, 1996 Response to Comments).

3.0 FINAL STATUS SURVEY OVERVIEW

3.1 SURVEY OBJECTIVES

The purpose of the final status survey was to demonstrate that the residual radiological concentrations in the soil at the Bay City thorium storage site satisfy the NRC guidelines (see 2.3 above) and that the storage site can, therefore, be released for future use without radiological controls. Specifically, the final status survey soil database should show that:

- Average residual radionuclide concentrations are at or below the soil guideline values defined in Section 2.3. Averaging is based on a 100 m^2 (10m x 10m) grid area. Note an actual grid size of 33.3 ft. x 33.3 ft. was used for convenience in measuring rather than 10m x 10m (32.8 ft. x 32.8 ft.).

- Reasonable efforts have been made to identify, evaluate, and remove, if necessary, areas of residual activity exceeding the guideline values. Areas of residual activity exceeding the guideline value (elevated areas) may be acceptable provided they do not exceed the guideline value by greater than a factor of $(100/A)^{1/2}$, where A is the area of residual

activity in m^2, and provided the activity level at any location does not exceed three times the guideline values.

In addition, exposure rates should not exceed 5 μR/h above background at 1 m above the soil surface. Exposure rates may be averaged over a 100 m^2 grid area. Maximum exposure rates over any discrete area may not exceed 10 μR/h above background.

A 95% minimum level of confidence that the above conditions have been met was to be demonstrated. The entire Section VI of the Bay City storage area (affected area) is treated as a single survey unit, and the 95% level of confidence was applied to the entire survey unit.

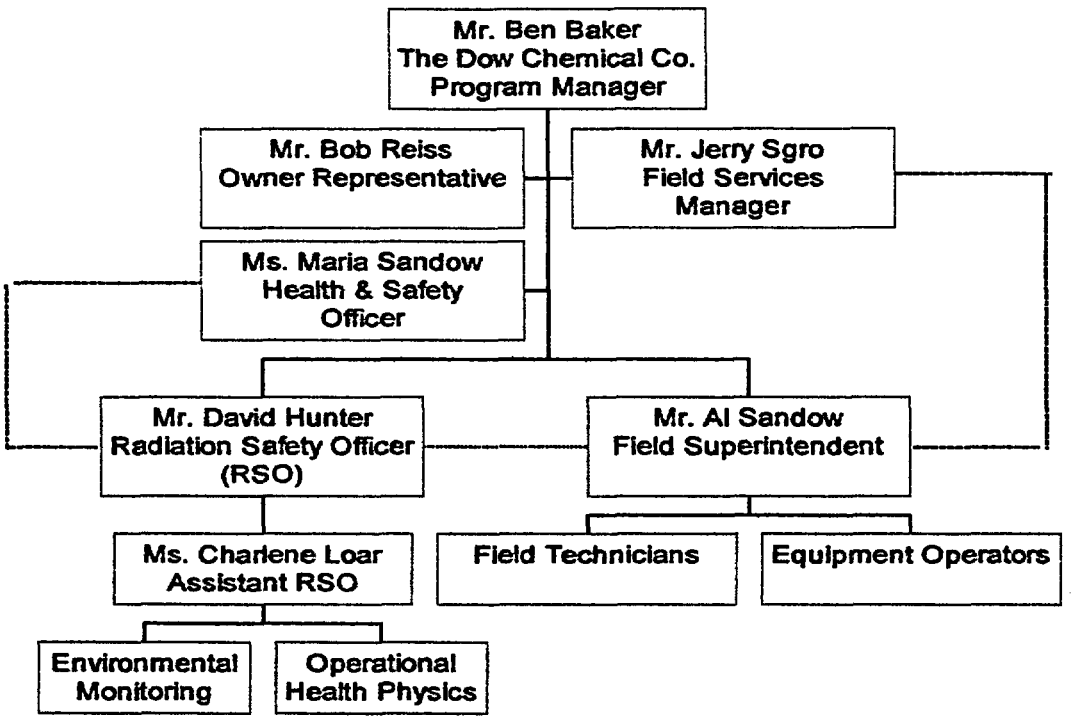
3.2 ORGANIZATION AND RESPONSIBILITIES

The final status survey was conducted by the same qualified Dow and subcontractor personnel who had conducted the characterization survey, and remediation control survey. The Project Organization is shown in Figure 3-1.

The sampling and analysis methods to be used during the remediation control survey was designed to achieve the sampling sensitivity and elevated activity guidelines defined in NUREG/CR-5849 relative to the site specific residual contamination criteria. The approach consisted of first performing a gamma scan survey of the remediated area to determine if any localized areas of elevated activity remained. Elevated areas of activity identified by the scan survey were remediated. If no areas of elevated activity were identified, composite soil samples were then collected and analyzed in the field laboratory using a NaI crystal coupled to the MCA to provide rapid turnaround on the Th-232 levels. If the Th-232 level exceeded the guideline value, further remediation was performed. The soil sample results of the analysis of the final samples collected, that demonstrated that the administrative cleanup level had been achieved, were then used as input into the final status survey.

Figure 3-1

Project Organization for Remediation of the Midland and Bay City Storage Sites



3.3 INSTRUMENTATION

Table 3-2 lists the field radiological monitoring instrumentation used on the project inclusive of the specific use of each instrumentation and detection sensitivities. Each instrument was initially calibrated to NIST-traceable standards prior to use on the project, and then checked for radiation response and efficiency prior to daily use.

Table 3-1

Field Radiological Monitoring Instrumentation

Instrument	Measures	Detector Efficiency*	LLD/MDA
Ludlum Model 43-5 w/ Ludlum Model 12	Alpha Surface	15%	22 dpm
Ludlum Model 43-90 w/ Ludlum Model 2221	Alpha Surface	22%	12 dpm
Ludlum Model 44-9 w/ Ludlum Model 12	Alpha, Beta, Gamma	12% alpha 15% beta 1% gamma	
Ludlum Model 43-10 w/ Ludlum 1000	Alpha (air filters, smears)	43%	0.04 dpm
Ludlum Model 19	Exposure Rate		1 microR/h
Air Particulate			
Eberline RAS-1 Air Pump	Flow Rate = 40-100 lpm		
MSA Escort Lapel Sampler	Flow Rate = 2-3 lpm		
General Metal Works–2000 High Vol Sampler	Flow Rate = 30-60 cfm		
Test/Calibration Equipment			
Ludlum Model 500 Pulser	NIST Traceable		
AFC-85L Air Flow Calibrator	NIST Traceable		
GMW-Calibrator Orifice for High Vol Sampler	NIST Traceable		
MSA Optiflow 660 Air Flow Calibrator	NIST Traceable		
Field Laboratory Equipment			
Canberra Gamma Spectrometer	Soil Th-232 Concentration		0.8 pCi/g

* Detector efficiencies are approximate and appropriate for Th-230, Tc-99, and Co-60

3.4 SURVEY PROCEDURES

Survey planning and procedures are consistent with the methods described in the Decommissioning Plan. The soil survey procedures are summarized in this section and can be found in greater detail in Appendices D-2 and D-3 of the March, 1996 Response to Comments.

3.4.1 Area Classification

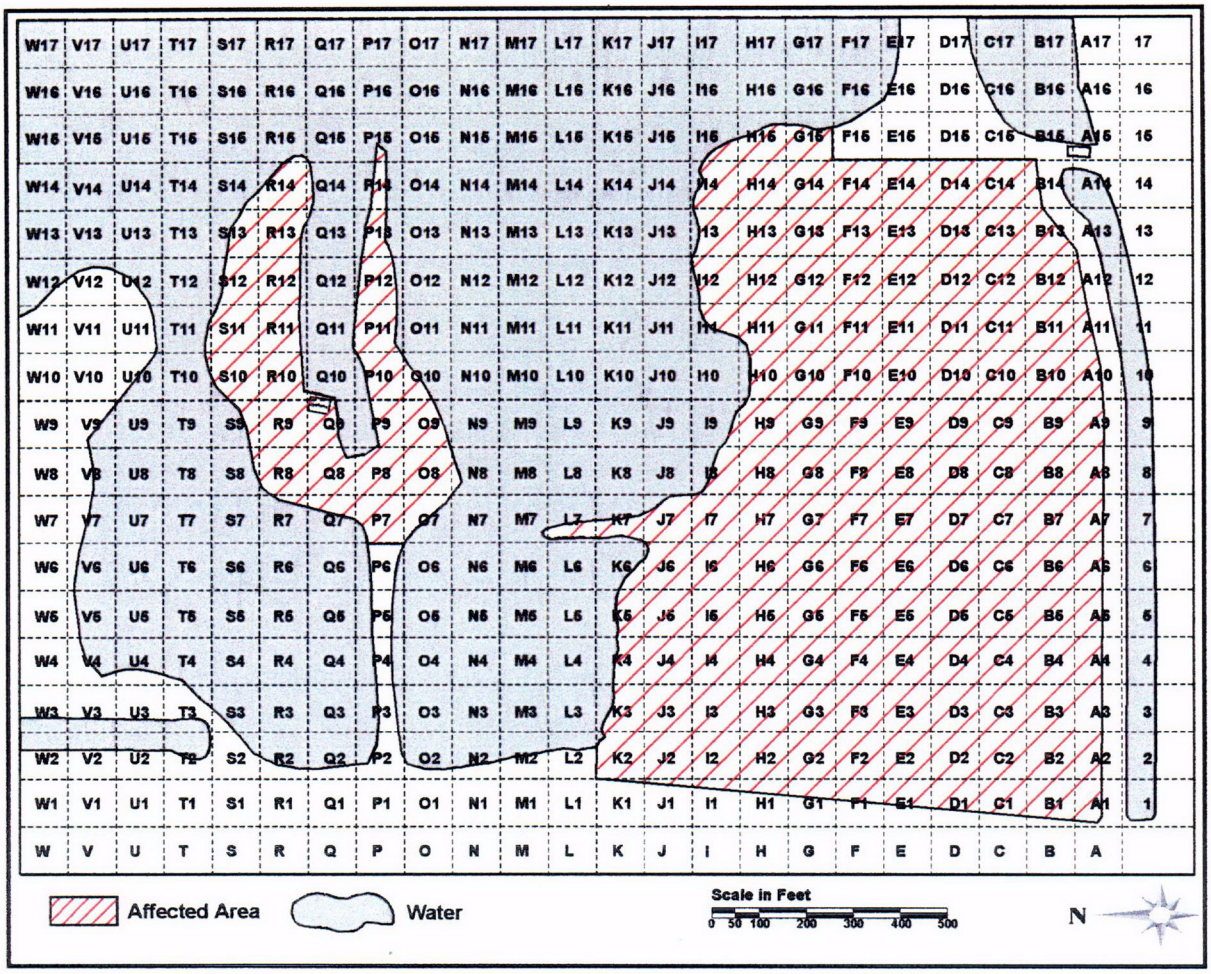
The Bay City storage site was divided into affected and unaffected areas to establish the sampling pattern and frequency. The basis for the affected and unaffected classification, as applied to the Bay City site are:

- **Affected Area** – As shown in Figure 3-2, the thorium material storage area and region immediately surrounding the storage area was defined as the affected area based on both historical records and prior characterization surveys. This location had known thorium contamination in the soil that had been placed there via backfill operations and storage.

- **Unaffected Area** – The region surrounding the affected area (see Figure 3-2) was treated as unaffected since it did not contain residual radioactivity.

Figure 3-2

Bay City Site Affected Areas



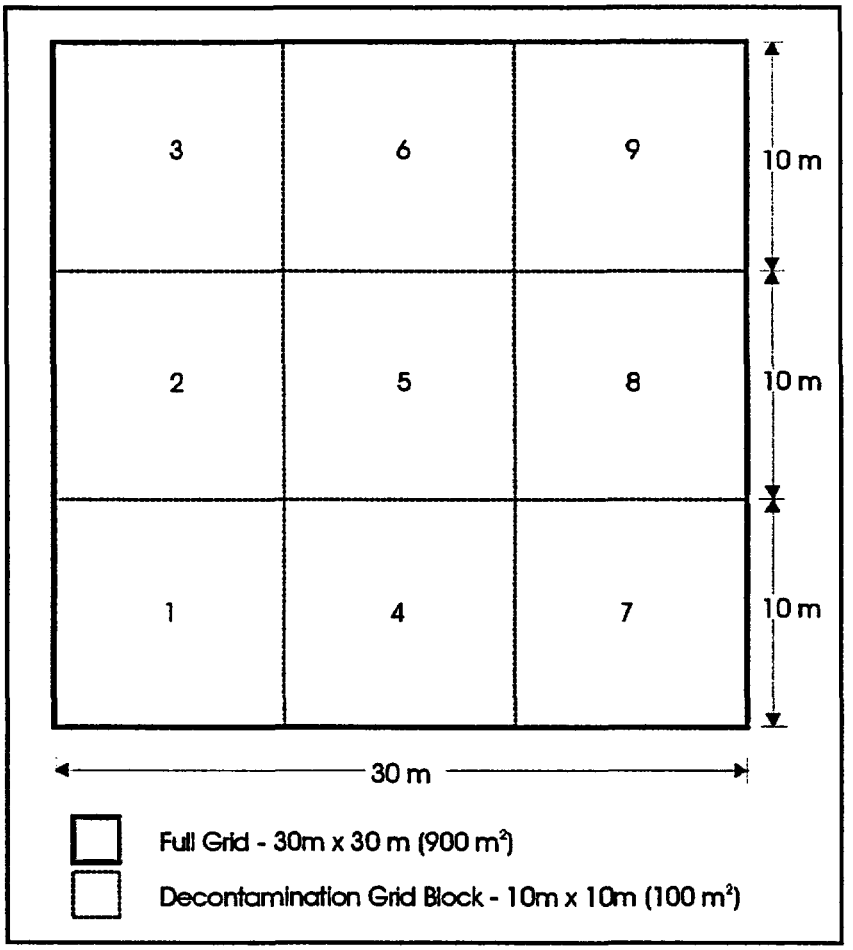
3.4.2 Reference Grid

A grid was established over the affected area upon completion of material excavation for the purpose of referencing locations of samples and measurements (see Figure 3-2). These full grids were 30m x 30m (900 m^2) in size. Each full grid was then divided into nine 10m x 10m sub-grids (100 m^2 each). Each sub-grid was marked into 5-meter increments to establish the four quadrants (A-D) where soil samples were taken to obtain four composite samples per sub-grid. Figure 3-3 depicts the breakdown of the reference grid system. As previously noted, the entire Section VI (affected area) constituted the survey unit.

C15

Figure 3-3

Reference Grid System



3.4.3 Surface Scans

One hundred percent of the soil surface was initially scanned to identify locations of elevated activity. The gamma scans were conducted in accordance with procedure SOP 1.5, Measurement of Gamma-Ray Fields using a Sodium Iodide (NaI) Detector. As soil was removed, additional gamma scans were conducted to identify remaining locations of contaminated soil. After completion of contaminated soil removal, a final scan was performed of the soil surface prior to obtaining final verification soil samples.

3.4.4 Soil sampling

Final survey soil samples consisted of 4 composite samples (approximately 2 kg each) from each sub-grid (see Figure 3-4). This sampling method differs from the method used in VA-I through VA-IV where nine individual samples were combined into one composite sample for each sub-grid. The modification to the sampling procedure was made by the RSO to be more consistent with NUREG/CR-5849. The sampling method used in VA-V and VA-VI is conservative relative to that used in VA-I – VA-IV in that a minimum of 3 soil samples from each 25 m^2 quadrant were composited, providing a total of 12 individual samples from each 100 m^2 sub-grid. This exceeds the decommissioning plan requirement of 9 soil samples (composited into 1) in each 100 m^2 sub-grid. One of the three individual samples from each quadrant was collected at the location with the highest scan reading. The remaining two sample locations were randomly selected.

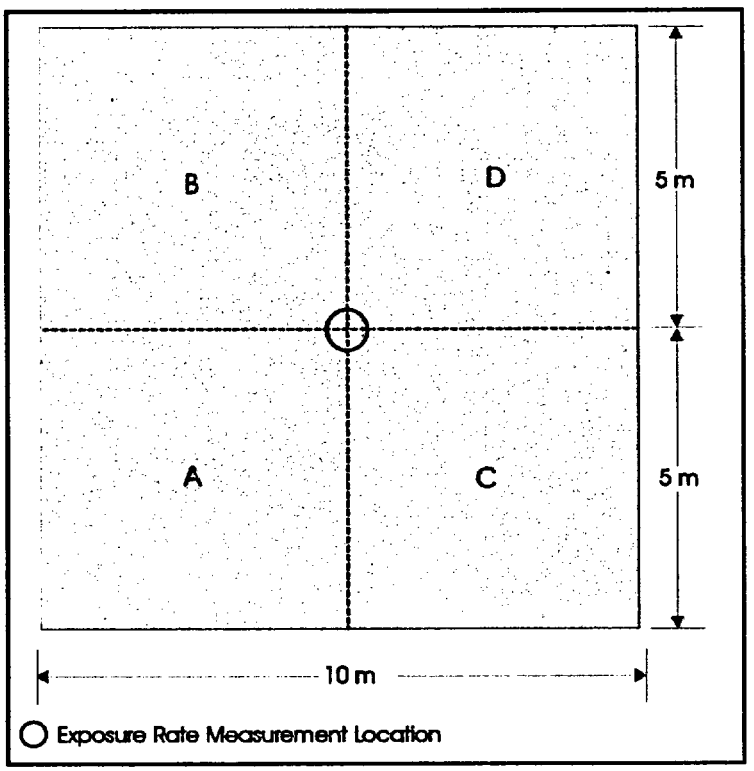
The samples were collected after gamma levels were measured to preliminarily determine that all contaminated soil had been removed. Each of the twelve locations where the individual samples were collected was scanned prior to soil sampling to validate that elevated levels did not exist (>3 times background). These final verification soil samples were analyzed on site through gamma spectroscopy. When the analytical results for Th-232 were less than the guideline value, a conversion factor was applied to the Th-232 concentration to obtain the Th-230 and Th-228 concentrations. After the net total thorium concentration was determined, five percent of all final verification soil samples were sent to Dow Chemical's radioanalytical laboratory in Freeport, Texas for duplicate QA analyses. Soil sample collection was performed in accordance with procedure SOP 1.8, Guide to the Handling, Packaging and Shipping of Samples, and SOP 1.9, Sample Control and Documentation.

3.4.5 Exposure Rate Measurements

Gamma exposure rates were measured in the affected area at 1 meter above the soil surface at the center of each sub-grid (see Figure 3-4). Exposure rate measurements were obtained using a Ludlum Model 19 MicroR meter.

Figure 3-4

Sub-grid Quadrant Designation

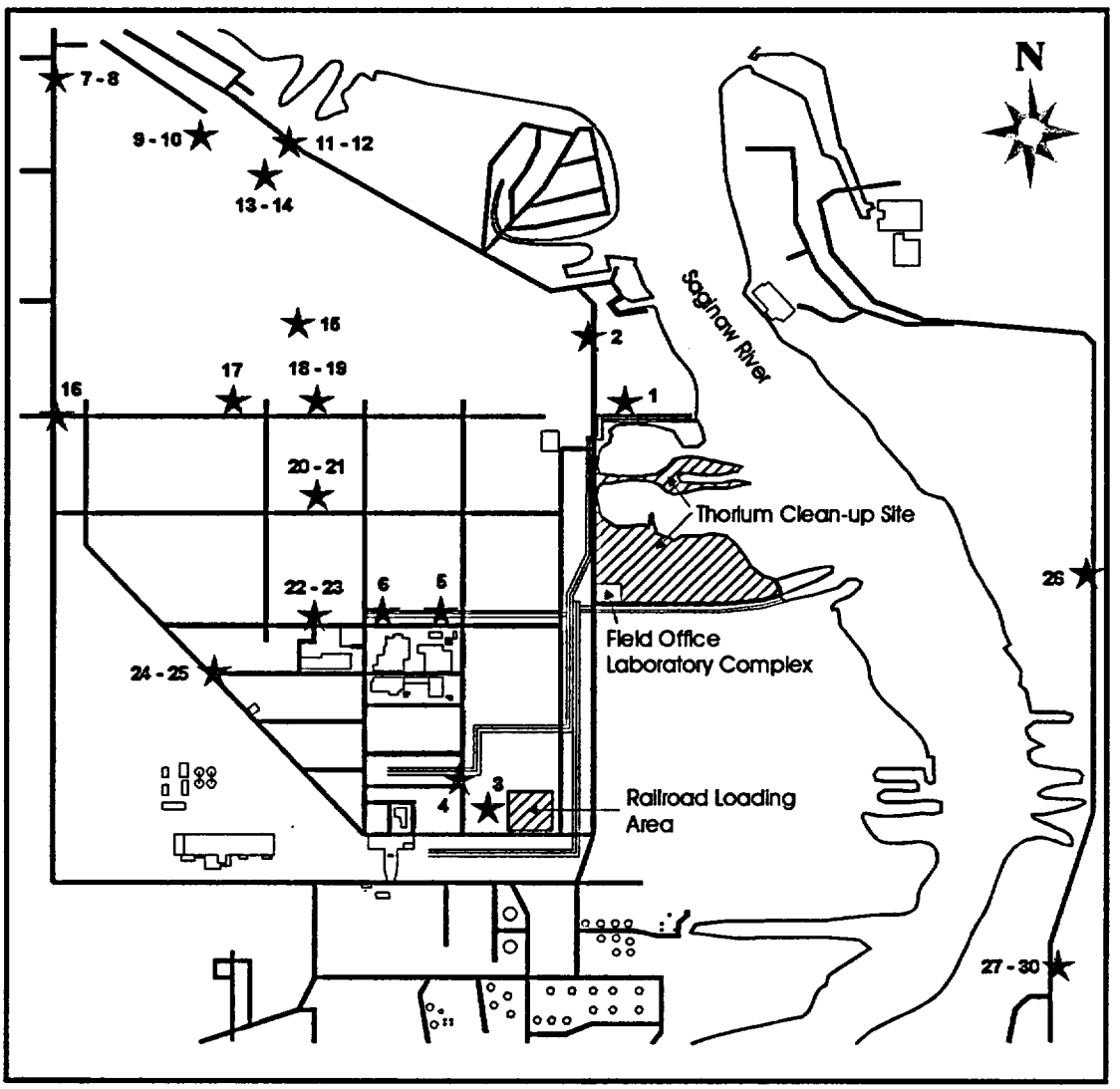


3.5 BACKGROUND LEVEL DETERMINATION

Background soil samples were collected from 30 locations in the unaffected area (Figure 3-5), and 29 samples analyzed for Th-230, Th-232, and Th-228 concentrations in the Freeport Laboratory (sample no. 14 was lost in transit). Sample numbers 1-25 were collected from locations on Dow property that were not impacted by site operations. Sample numbers 26-30 were collected from locations east of the Dow property, across the Saginaw River. Background exposure rates were measured at the same locations as the soil samples. Statistical procedures described in NUREG/CR-5849 (see Table A6) were used to assure that the average thorium concentrations determined were representative of true average background levels.

Figure 3-5

Background Sample Locations



3.6 SAMPLE ANALYSIS

Final survey soil samples were analyzed for Th-232 in the field laboratory using the NaI detector coupled to the MCA. Soil samples were analyzed in accordance with "Procedure for Counting Soil Samples for EOP Characterization". Th-228 and Th-230 concentrations were determined by multiplying the Th-232 result by 0.94 and 1.63, respectively. Five percent of the FSS samples were analyzed for Th-232, Th-230, and Th-228 using gamma and alpha spectroscopy in the

Freeport Laboratory to satisfy QA requirements. The onsite analytical methods were determined to be acceptable by NRC as documented in Inspection Report 040-00017/99001.

3.7 DATA INTERPRETATION

Soil sample locations and survey results for fixed measurements were recorded on data sheets. The data conversion and statistical analysis techniques in NUREG/CR-5849 (Chapter 8.0) were used to convert the reported data into a form that permitted a direct comparison with residual contamination guidelines and thus assess if remediation goals were met. The statistical relationships are shown with the analyzed data in Appendix A (Tables A6, A7). Soil concentrations were converted into units of pCi/g and exposure rates to μR/h. The reported affected area data in Appendix A has been adjusted by subtracting the natural background levels.

Additional soil removal was performed when the remediation control survey measurements showed that residual contamination guidelines were not being met.

3.8 RECORDS

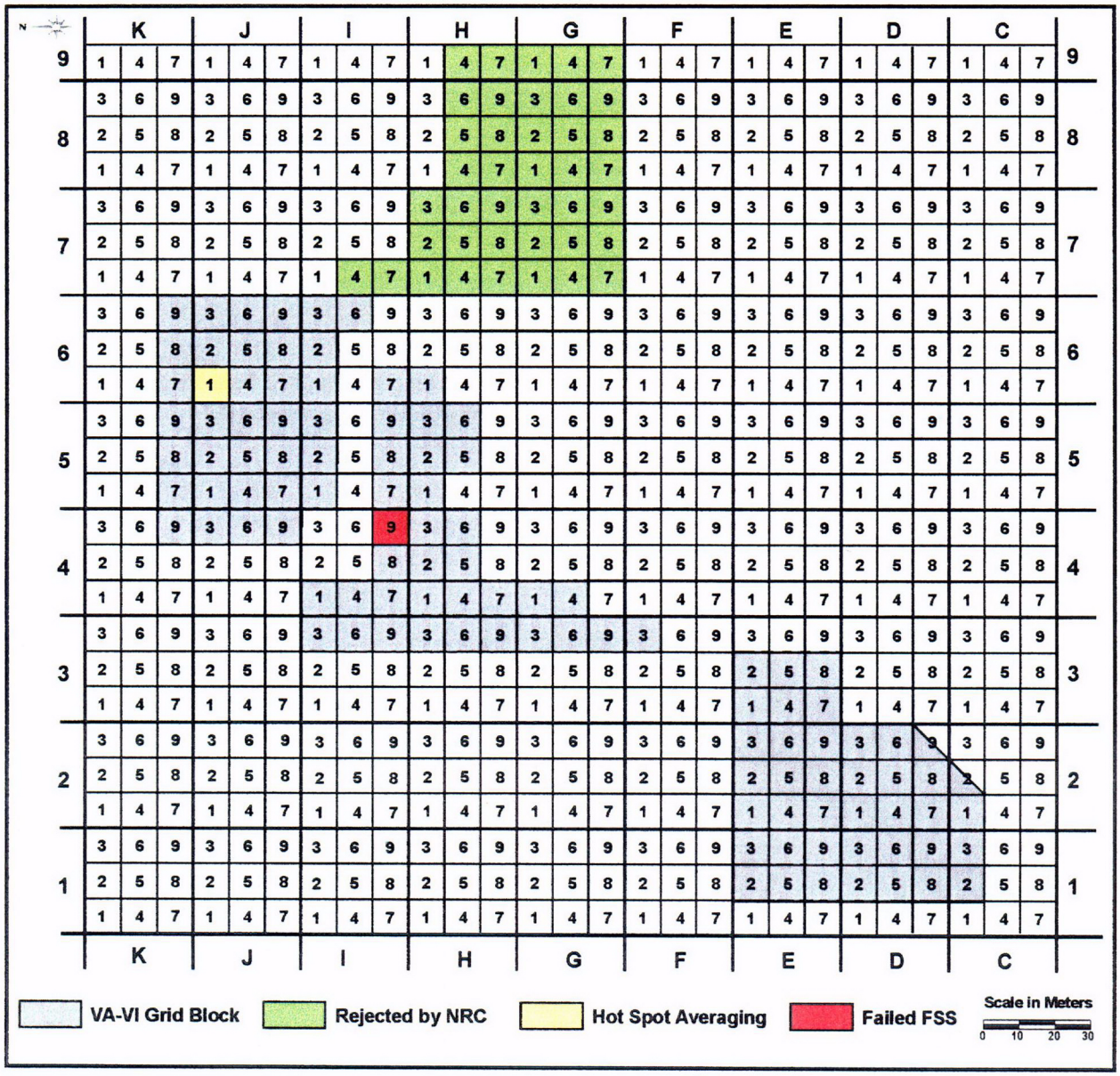
All soil samples, original survey data records, and log-books have been archived at the Dow Bay City facility and will be held until after license termination.

4.0 SURVEY FINDINGS AND RESULTS

Appendix A contains the radiological database collected during the final status survey for VA-VI (as defined in Figure 4-1) that provides the basis for verifying that the residual contamination objectives have been achieved for this area at the Bay City thorium site. Summary Tables, data interpretations and statistical comparisons with residual contamination guidelines in VA-VI are included in Appendix A.

Figure 4-1

Grid Locations for VA-VI



4.1 BACKGROUND LEVELS

Background soil concentrations (Table A1) averaged 0.30 pCi/g for Th-232, 0.49 pCi/g for Th-230, and 0.31 pCi/g for Th-228. Background exterior exposure rates averaged 5 μR/h (Table A2). Both the number of data points collected to obtain the average background soil concentrations and exposure rates are more than sufficient to meet the test for demonstrating that

C16

the measured average background is within ± 20% of the true average at the 95% confidence level.

4.2 GROUND SURVEYS

4.2.1 Scans

Surface scans were used during the remediation control survey to identify locations of elevated gamma radiation to guide the excavation of the material and locate remaining hot spots. There were 41 sub-grids with discreet areas of elevated activity identified during the verification scan survey. These areas were remediated and re-scanned with satisfactory results.

4.2.2 Thorium Concentrations in Soil

The results of the analyses of the verification soil samples from VA-VI are provided in Table A3, and related to the grid locations shown in Figure 4-1. QA soil analyses, performed by Dow's Freeport Laboratory on duplicate analysis of 5 percent of the FSS samples, are also shown in Table A3. Numerous soil samples contained concentrations in excess of the guideline value in grids G7, G8, G9, H7, H8, H9 and I7. These grids failed the final status survey and were removed from Table A3. These areas will be remediated and re-surveyed as part of a future VA. For the remainder of the grids within the scope of this report, two of the FSS samples and none of the QA samples contained total thorium concentrations in excess of the soil residual activity guideline (see Section 2.3).

Table A3 shows the final verification soil concentrations in the 2 sub-grid quadrants that exceed the total net thorium guideline value of 14.5 pCi/g (BCS-J6-1-A was 14.83 pCi/g and BCS-I4-9-C was 33.60 pCi/g).

As stated in Section 3.1 of this report, areas of elevated activity between one and three times the site guideline value may be tested to ensure that the average concentration is less than (100 /

A)$^{1/2}$ times the guideline value, where A is the area of the elevated activity in m^2. Also, the average over each 100 m^2 sub-grid must be less than the guideline value.

Samples J6-1-A and I4-9-C were both composited over a 25 m^2 area and therefore, the formula is applied as follows:

$$\text{Activity} \leq (100 / 25)^{1/2} \times 14.5 \text{ pCi/g} = 29 \text{ pCi/g}$$

The sample concentration for J6-1-A was 14.83 pCi/g which is less than the averaging criteria of 29 pCi/g and the overall average over sub-grid J6-1 is less than the guideline value. Therefore, sample J6-1-A passes the final status survey. The sample concentration for I4-9-C was 33.60 pCi/g which is greater than the averaging criteria of 29 pCi/g and therefore, the sample fails the final status survey. Sub-grid I4-9 has been removed from the scope of VA-VI and will be remediated, or additional samples collected to demonstrate compliance with the averaging criteria, at a later date and the results reported in a subsequent FSSR.

Discounting the soil sample result for sub-grid I4-9 which exceeded the guideline value and was removed from this survey unit and soil sample J6-1-A which passed the final status survey through use of the averaging technique, the maximum total residual thorium concentrations (above background) as measured in sample BCS-J4-9-C was 14.42 pCi/g which is less than the residual guideline of 14.5 pCi/g.

Analysis of the mean concentration of Th-232 shows that the concentration meets the guideline value at the 95% confidence level (Table A6, A7). The number of samples collected (401 in VA-VI) is much greater than the number (<9) statistically required to demonstrate that the concentrations satisfies the guideline value at the 95% confidence level (Table A6, A7).

All of the verification soil samples in VA-VI (with the exception of sub-grid I4-9) meet the criteria that the sum of the ratios of the concentration of each radionuclide to its respective guideline must not exceed 1 (Appendix A of NUREG/CR-5849).

4.2.3 Exposure Rates

Exposure rate measurements of the remediated VA-VI areas (Figure 4-1) and for each grid block are provided in Table A5. Exposure rates ranged from 0 to 8 μR/h above background. All individual values are within the guideline levels of 5 μR/h above background with the exception of 16 sub-grids. The average exposure rate over 100 m^2 for each of the sub-grids is less than 5 μR/h and no individual exposure rate exceeded 10 μR/h, thus meeting the release criteria. Analysis of the statistical mean also shows that the exposure rates in VA-VI meet the guideline at the 95% confidence level (Table A6, A7). The number of measurements (109) is in excess of the number required (11) to demonstrate that the exposure rate satisfies the guideline value at the 95% confidence level (Table A6, A7).

4.2.4 NRC Confirmatory Surveys

The NRC performed an inspection of VA-VI on July 13th and July 14th of 1999. This inspection included the performance of a confirmatory survey. Approximately 50% of VA-VI was scanned using a sodium iodide detector. Grids H7, H8, H9, I7, G7, G8 and G9 indicated radiation levels in various locations which exceeded three times background. These grids, as well as sub-grid I4-9, have been deleted from the VA-VI final status survey database and will be remediated and re-surveyed at a later date. Dow personnel collected 19 soil samples, per NRC staff direction, at the 19 individual scan locations having the highest scan readings. The soil samples were analyzed for Th-232 at the Bay City field laboratory, under inspector observation, following QA/QC and calibration checks of the counting systems. When analyzed, no activity above release guidelines was found in any of the samples. Exposure rate measurements were also conducted with all readings in the acceptable ranges.

5.0 SUMMARY

Decontamination of the affected area by soil removal at Dow's Bay City facility is an ongoing process. Since the affected area is quite large it is more efficient for Dow to verify that residual contamination criteria have been met in sections, and for the NRC to subsequently validate each

section. Thus area VA-VI has been verified and the evaluated database from the final status survey provided in the Appendix. Remediation control surveys were performed to guide the decontamination effort, and a final status survey conducted of VA-VI during June 1999. Independent QA analysis of soil samples was performed. Results of the final status survey demonstrate that the decontamination program successfully reduced residual activity in VA-VI to within the NRC limits for unrestricted use with the exception of sub-grid I4-9. As each subsequent VA is surveyed, a FSSR will be submitted to NRC.

6.0 REFERENCES

6.1 Dow Decommissioning Work Plan, October 1993

6.2 Supplement to the Decommissioning Work Plan, December 1995

6.3 Letter from Dow to NRC, Response to Comments, March 1996

6.4 NUREG/CR-5849, Manual for Conducting Radiological Surveys in Support of License Termination (Draft for Comment), December 1993

6.5 NRC Inspection Report No. 040-00017/97002 (DNMS), August 14, 1997

6.6 Letter from NRC to Dow, Review of Final Status Survey Reports for the Previously Remediated Areas VA-I through VA-VI, Dow Chemical Company's Bay City, MI, SDMP Site (TAC# L60463), August 16, 2002

6.7 Dow "Background Radiological Survey", October 11-13, 1989

6.8 Dow Bay City Site Procedures

- 6.8.1 SOP 1.1, Access Control Procedures
- 6.8.2 SOP 1.2, Total Alpha Surface Contamination Measurements
- 6.8.3 SOP 1.3, External Dosimetry Procedure
- 6.8.4 SOP 1.4, Beta-Gamma Radiation Measurements using a Geiger-Muller Detector
- 6.8.5 SOP 1.5, Measurement of Gamma-Ray Fields using a Sodium Iodide (NaI) Detector
- 6.8.6 SOP 1.6, Intermediate Volume Air Particulate Sampling
- 6.8.7 SOP 1.7, Sampling for Removable Alpha Contamination
- 6.8.8 SOP 1.8, Guide to the Handling, Packaging and Shipping of Samples
- 6.8.9 SOP 1.9, Sample Control and Documentation
- 6.8.10 SOP 1.10, Radiation Work Permits
- 6.8.11 SOP 1.11, Respiratory Protection Program
- 6.8.12 "Procedure for Counting Soil Samples for EOP Characterization"
- 6.8.13 Dow Central Research Index Report, CRI-TSP-92-076, "Radiological Analysis of Soil Samples from the Madison, Illinois Storage Facility Utilizing a Revised Alpha Spectroscopic Method"

Appendix A

Final Status Survey

Verification Measurements / Analyses

Table A1

BACKGROUND SOIL CONCENTRATIONS							
Bay City							
Sample Name	^{232}Th (pCi/G)	Error (2σ)	MDA (pCi/G)	^{230}Th (pCi/G)	Error (2σ)	^{228}Th (pCi/G)	Error (2σ)
BCBKG01	0.39	0.08	0.13	1.04	0.84	0.48	0.44
BCBKG02	0.36	0.07	0.14	0.46	0.34	0.41	0.31
BCBKG03	0.28	0.08	0.11	0.38	0.31	0.35	0.29
BCBKG04	0.44	0.10	0.13	0.80	0.91	0.62	0.74
BCBKG05	0.43	0.10	0.15	0.70	0.51	0.52	0.40
BCBKG06	0.51	0.18	0.13	0.68	0.47	0.48	0.35
BCBKG07	0.38	0.19	0.13	2.30	3.69	0.77	1.38
BCBKG08	0.16	0.08	0.11	0.37	0.48	0.12	0.20
BCBKG09	0.13	0.07	0.10	0.21	0.25	0.09	0.12
BCBKG10	0.26	0.09	0.13	0.38	0.39	0.23	0.26
BCBKG11	0.19	0.07	0.11	0.04	0.04	0.14	0.10
BCBKG12	0.18	0.08	0.14	0.18	0.14	0.11	0.09
BCBKG13	0.18	0.08	0.14	0.21	0.12	0.19	0.11
BCBKG15	0.23	0.07	0.11	0.12	0.15	0.32	0.31
BCBKG16	0.56	0.12	0.16	0.76	0.51	0.66	0.46
BCBKG17	0.41	0.10	0.16	0.30	0.47	0.30	0.47
BCBKG18	0.10	0.08	0.12	0.18	0.21	0.16	0.19
BCBKG19	0.12	0.06	0.10	0.15	0.14	0.06	0.07
BCBKG20	0.14	0.07	0.11	0.29	0.25	0.09	0.09
BCBKG21	0.19	0.07	0.15	0.23	0.17	0.13	0.11
BCBKG22	0.20	0.07	0.10	0.36	0.39	0.13	0.18
BCBKG23	0.15	0.06	0.11	0.24	0.24	0.30	0.29
BCBKG24	0.12	0.08	0.11	0.13	0.16	0.05	0.08
BCBKG25	0.22	0.07	0.08	0.93	0.89	0.72	0.70
BCBKG26	0.32	0.09	0.13	0.27	0.23	0.16	0.15
BCBKG27	0.56	0.20	0.20	0.93	0.69	0.90	0.67
BCBKG28	0.68	0.24	0.20	0.41	0.45	0.07	0.14
BCBKG29	0.43	0.19	0.21	0.65	1.22	0.43	0.89
BCBKG30	0.34	0.08	0.15	0.44	0.45	0.10	0.16
AVERAGE	0.30			0.49		0.31	
St. Dev.	0.16			0.44		0.24	

Table A2

Background Exposure Rates – Bay City

Sample	Value (μR/hr)
BCBKG1	5
BCBKG2	7
BCBKG3	5
BCBKG4	6
BCBKG5	4
BCBKG6	4
BCBKG7	5
BCBKG8	5
BCBKG9	5
BCBKG10	6
BCBKG11	5
BCBKG12	6
BCBKG13	5
BCBKG14	5
BCBKG15	7
BCBKG16	5
BCBKG17	4
BCBKG18	5
BCBKG19	5
BCBKG20	4
BCBKG21	4
BCBKG22	4
BCBKG23	4
BCBKG24	3
BCBKG25	3
ACROSS THE RIVER	
BCBKG26(1)	3
BCBKG27(2)	5
BCBKG28(3)	5
BCBKG29(4)	4
BCBKG30(5)	5

Number of measurements: 30
Average: 5 μR/hr
Standard Deviation: 1.3 μR/hr (≅ 1.0 μR/hr)

Table A3

Final Verification Soil Concentrations – VA-VI

Sample #	Weight (g)	Gamma Spec Sys.	Th-232 (pCi/g)	Th-230 (pCi/g)	Th-228 (pCi/g)	Th-232 Net (pCi/g)	Th-230 Net (pCi/g)	Th-228 Net (pCi/g)	Total Net Thorium (pCi/g)
BCS-C1-2-A&C	3051.3	2	0.60	0.97	0.56	0.30	0.48	0.26	1.04
BCS-C1-2-B	3122.9	2	0.99	1.61	0.93	0.69	1.12	0.63	2.44
BCS-C1-2-D	3313.7	2	2.07	3.38	1.95	1.77	2.89	1.65	6.31
BCS-C1-2-D(DUP)	3313.7	2	2.07	3.37	1.94	1.77	2.88	1.64	6.29
BCS-C1-3-A	2966	3	1.30	2.12	1.22	1.00	1.63	0.92	3.56
BCS-C1-3-B	2989	3	1.36	2.22	1.28	1.06	1.73	0.98	3.77
BCS-C1-3-C	3087	3	1.19	1.93	1.12	0.89	1.44	0.82	3.15
BCS-C1-3-D	2901	3	0.54	0.88	0.50	0.24	0.39	0.20	0.83
BCS-C2-1-A	2828	3	1.16	1.90	1.09	0.86	1.41	0.79	3.07
BCS-C2-1-B	3201	3	0.52	0.84	0.48	0.22	0.35	0.18	0.75
BCS-C2-1-C	2786	3	0.34	0.56	0.32	0.04	0.07	0.02	0.13
BCS-C2-1-D	2939	3	0.33	0.54	0.31	0.03	0.05	0.01	0.10
BCS-C2-2-A	2825	3	0.64	1.04	0.60	0.34	0.55	0.30	1.18
BCS-C2-2-B&C	3003.5	3	0.63	1.03	0.59	0.33	0.54	0.29	1.17
BCS-D1-2-B	2845.5	3	0.33	0.53	0.31	0.03	0.04	0.01	0.07
BCS-D1-2-D	3030.5	3	1.61	2.63	1.51	1.31	2.14	1.21	4.66
BCS-D1-3-A	2703.7	3	0.41	0.66	0.38	0.11	0.17	0.08	0.36
BCS-D1-3-B	2570.4	3	0.37	0.60	0.35	0.07	0.11	0.05	0.23
BCS-D1-3-C	2791.4	3	1.35	2.20	1.27	1.05	1.71	0.97	3.72
BCS-D1-3-D	2790.6	3	1.58	2.58	1.49	1.28	2.09	1.19	4.55
BCS-D1-5-B	2545.3	3	0.77	1.25	0.72	0.47	0.76	0.42	1.65
BCS-D1-5-D	2636.9	3	1.00	1.63	0.94	0.70	1.14	0.64	2.47
BCS-D1-5-D(DUP)	2636.9	3	1.11	1.82	1.05	0.81	1.33	0.75	2.89
BCS-D1-6-A	3264.7	3	0.33	0.53	0.31	0.03	0.04	0.01	0.07
BCS-D1-6-B	2939.8	3	1.28	2.09	1.20	0.98	1.60	0.90	3.48
BCS-D1-6-C	2971.6	3	1.71	2.79	1.61	1.41	2.30	1.31	5.02
BCS-D1-6-D	3101.3	3	0.80	1.31	0.75	0.50	0.82	0.45	1.77
BCS-D1-8-B	2882.5	3	0.90	1.46	0.84	0.60	0.97	0.54	2.11
BCS-D1-8-D	2845.5	3	0.92	1.50	0.87	0.62	1.01	0.57	2.20
BCS-D1-9-A	3010.7	3	0.95	1.55	0.90	0.65	1.06	0.60	2.31
BCS-D1-9-B	3141.3	3	1.74	2.84	1.64	1.44	2.35	1.34	5.12
BCS-D1-9-C	2779.6	3	1.71	2.79	1.61	1.41	2.30	1.31	5.03
BCS-D1-9-D	3245	3	1.20	1.96	1.13	0.90	1.47	0.83	3.21
BCS-D2-1-A	2713.2	3	0.75	1.22	0.70	0.45	0.73	0.40	1.58
BCS-D2-1-B	2607.9	3	2.20	3.59	2.07	1.90	3.10	1.77	6.77
BCS-D2-1-C	2988	3	1.30	2.12	1.22	1.00	1.63	0.92	3.56
BCS-D2-1-D	2734.6	3	2.28	3.72	2.15	1.98	3.23	1.85	7.06
BCS-D2-1-D(DUP)	2734.6	3	1.93	3.15	1.82	1.63	2.66	1.52	5.81
BCS-D2-2-A	2810.6	2	0.85	1.38	0.80	0.55	0.89	0.50	1.94
BCS-D2-2-B	2832	2	1.40	2.29	1.32	1.10	1.80	1.02	3.92

Sample #	Weight (g)	Gamma Spec Sys.	Th-232 (pCi/g)	Th-230 (pCi/g)	Th-228 (pCi/g)	Th-232 Net (pCi/g)	Th-230 Net (pCi/g)	Th-228 Net (pCi/g)	Total Net Thorium (pCi/g)
BCS-D2-2-C	2807.7	2	1.89	3.09	1.78	1.59	2.60	1.48	5.67
BCS-D2-2-D	3120.9	2	1.21	1.97	1.14	0.91	1.48	0.84	3.23
BCS-D2-3-A	3362.2	3	0.51	0.83	0.48	0.21	0.34	0.18	0.72
BCS-D2-3-B	2851.1	3	1.03	1.68	0.97	0.73	1.19	0.67	2.58
BCS-D2-3-C	2899	3	0.63	1.03	0.60	0.33	0.54	0.30	1.17
BCS-D2-3-D	3400.6	3	0.30	0.50	0.29	0.00	0.01	-0.01	0.00
BCS-D2-4-A	3413.8	3	1.09	1.78	1.03	0.79	1.29	0.73	2.81
BCS-D2-4-B	3030	3	2.11	3.44	1.98	1.81	2.95	1.68	6.44
BCS-D2-4-C	3688.3	3	1.02	1.66	0.96	0.72	1.17	0.66	2.55
BCS-D2-4-D	3550.3	3	1.50	2.45	1.41	1.20	1.96	1.11	4.27
BCS-D2-5-A	3091.1	3	0.67	1.08	0.63	0.37	0.59	0.33	1.28
BCS-D2-5-B	3157.9	3	0.39	0.64	0.37	0.09	0.15	0.07	0.30
BCS-D2-5-C	3095.8	3	0.40	0.65	0.38	0.10	0.16	0.08	0.34
BCS-D2-5-D	3341	3	0.47	0.76	0.44	0.17	0.27	0.14	0.58
BCS-D2-5D(DUP)	3341	3	0.55	0.90	0.52	0.25	0.41	0.22	0.88
BCS-D2-6-A	2665.9	3	0.39	0.64	0.37	0.09	0.15	0.07	0.32
BCS-D2-6-B	2888.3	3	0.41	0.68	0.39	0.11	0.19	0.09	0.39
BCS-D2-6-C	2862.7	3	1.76	2.87	1.66	1.46	2.38	1.36	5.20
BCS-D2-6-D	3017.8	3	0.16	0.26	0.15	-0.14	-0.23	-0.15	-0.52
BCS-D2-7-A	3680.6	3	0.75	1.23	0.71	0.45	0.74	0.41	1.60
BCS-D2-7-B	3585.9	3	1.64	2.67	1.54	1.34	2.18	1.24	4.76
BCS-D2-7-C	2925.8	3	0.95	1.54	0.89	0.65	1.05	0.59	2.29
BCS-D2-7-D	3424.4	3	0.36	0.59	0.34	0.06	0.10	0.04	0.21
BCS-D2-7-D(DUP)	3424.4	3	0.38	0.62	0.36	0.08	0.13	0.06	0.26
BCS-D2-8-A	3254.8	3	1.29	2.10	1.21	0.99	1.61	0.91	3.51
BCS-D2-8-A	3254.8	3	1.29	2.11	1.22	0.99	1.62	0.92	3.53
BCS-D2-8-B	3610.8	3	1.09	1.78	1.03	0.79	1.29	0.73	2.81
BCS-D2-8-C	3259.1	3	0.61	0.99	0.57	0.31	0.50	0.27	1.08
BCS-D2-8-D	3245.4	3	0.45	0.73	0.42	0.15	0.24	0.12	0.52
BCS-D2-9-A	3344.1	2	0.53	0.87	0.50	0.23	0.38	0.20	0.81
BCS-D2-9-B&C	3399.3	2	0.30	0.49	0.28	0.00	0.00	-0.02	-0.01
BCS-E1-2-B&D	1819.7	3	0.44	0.72	0.42	0.14	0.23	0.12	0.50
BCS-E1-3-A	2081.3	3	0.61	0.99	0.57	0.31	0.50	0.27	1.07
BCS-E1-3-B	2083.2	3	0.75	1.23	0.71	0.45	0.74	0.41	1.60
BCS-E1-3-C	2115	3	0.33	0.53	0.31	0.03	0.04	0.01	0.07
BCS-E1-3-D	2089.3	3	0.60	0.98	0.56	0.30	0.49	0.26	1.05
BCS-E1-3-D(DUP)	2089.3	3	0.50	0.81	0.47	0.20	0.32	0.17	0.69
BCS-E1-5-B&D	2593.6	3	0.17	0.28	0.16	-0.13	-0.21	-0.14	-0.47
BCS-E1-6-A	2748	3	0.34	0.55	0.32	0.04	0.06	0.02	0.12
BCS-E1-6-B	2430.4	3	0.28	0.46	0.27	-0.02	-0.03	-0.03	-0.07
BCS-E1-6-C	2621.6	3	0.43	0.70	0.40	0.13	0.21	0.10	0.44
BCS-E1-6-D	2515.8	3	0.19	0.32	0.18	-0.11	-0.17	-0.12	-0.39
BCS-E1-8-B&D	2377.9	3	0.50	0.82	0.47	0.20	0.33	0.17	0.71
BCS-E1-9-A	2821	3	0.39	0.63	0.37	0.09	0.14	0.07	0.30
BCS-E1-9-B	2537.9	3	0.36	0.59	0.34	0.06	0.10	0.04	0.21

Sample #	Weight (g)	Gamma Spec Sys.	Th-232 (pCi/g)	Th-230 (pCi/g)	Th-228 (pCi/g)	Th-232 Net (pCi/g)	Th-230 Net (pCi/g)	Th-228 Net (pCi/g)	Total Net Thorium (pCi/g)
BCS-E1-9-C	2714.3	3	0.37	0.60	0.34	0.07	0.11	0.04	0.21
BCS-E1-9-D	2892.3	3	0.50	0.82	0.47	0.20	0.33	0.17	0.71
BCS-E1-9-D(DUP)	2892.3	3	0.57	0.92	0.53	0.27	0.43	0.23	0.93
BCS-E2-1-A	2244.5	2	0.14	0.23	0.13	-0.16	-0.26	-0.17	-0.59
BCS-E2-1-B	1885.5	2	0.69	1.12	0.64	0.39	0.63	0.34	1.36
BCS-E2-1-C	2256.3	2	3.37	5.50	3.17	3.07	5.01	2.87	10.96
BCS-E2-1-D	1921.3	2	1.02	1.66	0.96	0.72	1.17	0.66	2.55
BCS-E2-2-A	2189.1	2	0.61	0.99	0.57	0.31	0.50	0.27	1.08
BCS-E2-2-B	1834.3	2	0.46	0.75	0.43	0.16	0.26	0.13	0.55
BCS-E2-2-B(DUP)	1834.3	2	0.24	0.39	0.23	-0.06	-0.10	-0.07	-0.23
BCS-E2-2-C	2190.6	2	0.74	1.20	0.69	0.44	0.71	0.39	1.54
BCS-E2-2-D	1846.9	2	0.33	0.53	0.31	0.03	0.04	0.01	0.07
BCS-E2-3-A	2856	3	0.35	0.57	0.33	0.05	0.08	0.03	0.16
BCS-E2-3-B	2808	3	0.52	0.84	0.48	0.22	0.35	0.18	0.75
BCS-E2-3-C	2881	3	0.60	0.99	0.57	0.30	0.50	0.27	1.07
BCS-E2-3-D	2913	3	0.64	1.05	0.60	0.34	0.56	0.30	1.20
BCS-E2-4-A	2177.8	3	0.60	0.97	0.56	0.30	0.48	0.26	1.04
BCS-E2-4-B	2402.1	3	0.65	1.07	0.61	0.35	0.58	0.31	1.25
BCS-E2-4-C	2230.4	3	0.42	0.68	0.39	0.12	0.19	0.09	0.40
BCS-E2-4-D	2345.2	3	0.47	0.76	0.44	0.17	0.27	0.14	0.58
BCS-E2-4-D(DUP)	2345.2	3	0.61	1.00	0.58	0.31	0.51	0.28	1.10
BCS-E2-5-A	2571.6	3	0.74	1.21	0.70	0.44	0.72	0.40	1.55
BCS-E2-5-B	2913.8	3	0.54	0.89	0.51	0.24	0.40	0.21	0.86
BCS-E2-5-C	2654.3	3	0.42	0.69	0.40	0.12	0.20	0.10	0.43
BCS-E2-5-D	3039.6	3	0.55	0.89	0.52	0.25	0.40	0.22	0.87
BCS-E2-6-A	3531	2	0.75	1.23	0.71	0.45	0.74	0.41	1.59
BCS-E2-6-B	3436.9	2	0.17	0.28	0.16	-0.13	-0.21	-0.14	-0.47
BCS-E2-6-C	3226.3	2	0.95	1.54	0.89	0.65	1.05	0.59	2.29
BCS-E2-6-D	3267.2	2	0.68	1.11	0.64	0.38	0.62	0.34	1.33
BCS-E2-6-D(DUP)	3267.2	2	0.62	1.02	0.59	0.32	0.53	0.29	1.14
BCS-E2-7-A	2473.4	3	0.39	0.64	0.37	0.09	0.15	0.07	0.32
BCS-E2-7-B	2308.5	3	0.30	0.49	0.29	0.00	0.00	-0.01	-0.01
BCS-E2-7-C	2299.2	3	0.65	1.06	0.61	0.35	0.57	0.31	1.23
BCS-E2-7-D	2396.5	3	0.59	0.96	0.56	0.29	0.47	0.26	1.02
BCS-E2-8-A	3193.2	2	0.79	1.29	0.74	0.49	0.80	0.44	1.74
BCS-E2-8-B	3232.9	2	0.55	0.89	0.51	0.25	0.40	0.21	0.86
BCS-E2-8-C	3059.3	2	0.68	1.10	0.64	0.38	0.61	0.34	1.32
BCS-E2-8-D	3035.2	2	0.62	1.01	0.58	0.32	0.52	0.28	1.12
BCS-E2-9-A	2979.2	3	1.39	2.26	1.31	1.09	1.77	1.01	3.87
BCS-E2-9-B	2816	3	0.97	1.59	0.92	0.67	1.10	0.62	2.39
BCS-E2-9-C	3080.5	3	3.22	5.25	3.03	2.92	4.76	2.73	10.42
BCS-E2-9-D	3038.8	3	0.85	1.39	0.80	0.55	0.90	0.50	1.96
BCS-E2-9-D(DUP)	3038.8	3	0.66	1.08	0.62	0.36	0.59	0.32	1.28
BCS-E3-1-A	2564.1	3	0.25	0.42	0.24	-0.05	-0.07	-0.06	-0.18
BCS-E3-1-B	2453.9	3	0.59	0.96	0.55	0.29	0.47	0.25	1.00

Sample #	Weight (g)	Gamma Spec Sys.	Th-232 (pCi/g)	Th-230 (pCi/g)	Th-228 (pCi/g)	Th-232 Net (pCi/g)	Th-230 Net (pCi/g)	Th-228 Net (pCi/g)	Total Net Thorium (pCi/g)
BCS-E3-1-C	2834.4	3	0.39	0.63	0.37	0.09	0.14	0.07	0.30
BCS-E3-1-D	2499.7	3	0.21	0.34	0.20	-0.09	-0.15	-0.10	-0.34
BCS-E3-2-A	2604	3	0.38	0.62	0.36	0.08	0.13	0.06	0.26
BCS-E3-2-B	3049	3	0.54	0.88	0.51	0.24	0.39	0.21	0.85
BCS-E3-2-C	2575	3	0.34	0.56	0.32	0.04	0.07	0.02	0.13
BCS-E3-2-D	3025	3	0.31	0.50	0.29	0.01	0.01	-0.01	0.02
BCS-E3-4-A	2923	3	0.21	0.35	0.20	-0.09	-0.14	-0.10	-0.33
BCS-E3-4-B	2977.5	3	0.51	0.84	0.48	0.21	0.35	0.18	0.75
BCS-E3-4-C	3138	3	0.32	0.52	0.30	0.02	0.03	0.00	0.05
BCS-E3-4-D	2965.3	3	0.33	0.53	0.31	0.03	0.04	0.01	0.07
BCS-E3-5-A	2832	3	0.33	0.54	0.31	0.03	0.05	0.01	0.10
BCS-E3-5-B	2933	3	0.24	0.39	0.22	-0.06	-0.10	-0.08	-0.24
BCS-E3-5-C	3071	3	0.98	1.60	0.92	0.68	1.11	0.62	2.42
BCS-E3-5-D	2940	3	0.90	1.46	0.84	0.60	0.97	0.54	2.11
BCS-E3-7-A	2989.9	3	0.68	1.11	0.64	0.38	0.62	0.34	1.34
BCS-E3-7-B	3092.6	3	0.28	0.46	0.26	-0.02	-0.03	-0.04	-0.09
BCS-E3-7-C	2519.1	3	0.39	0.64	0.37	0.09	0.15	0.07	0.32
BCS-E3-7-D	2461.7	3	0.25	0.41	0.24	-0.05	-0.08	-0.06	-0.19
BCS-E3-8-A	2979	3	0.41	0.67	0.39	0.11	0.18	0.09	0.37
BCS-E3-8-B	3089.1	3	0.33	0.53	0.31	0.03	0.04	0.01	0.08
BCS-E3-8-C	3102.7	3	0.66	1.07	0.62	0.36	0.58	0.32	1.25
BCS-E3-8-D	3009.8	3	0.32	0.52	0.30	0.02	0.03	0.00	0.05
BCS-F3-3	NA	In-situ	0.6	0.98	0.56	0.30	0.49	0.26	1.05
BCS-G3-3	NA	In-situ	0.6	0.98	0.56	0.30	0.49	0.26	1.05
BCS-G3-6	NA	In-situ	0.6	0.98	0.56	0.30	0.49	0.26	1.05
BCS-G3-9-A	3211.5	3	0.32	0.52	0.30	0.02	0.03	0.00	0.05
BCS-G3-9-B	3439.6	3	0.25	0.41	0.24	-0.05	-0.08	-0.06	-0.19
BCS-G3-9-C	3401.2	3	0.09	0.14	0.08	-0.21	-0.35	-0.22	-0.78
BCS-G3-9-D	3422.3	3	0.33	0.54	0.31	0.03	0.05	0.01	0.10
BCS-G4-1	NA	In-situ	0.9	1.47	0.85	0.60	0.98	0.55	2.12
BCS-G4-4	NA	In-situ	0.8	1.30	0.75	0.50	0.81	0.45	1.77
BCS-H3-3-A	3230.8	3	0.27	0.44	0.26	-0.03	-0.05	-0.04	-0.12
BCS-H3-3-B	3546.7	3	0.47	0.76	0.44	0.17	0.27	0.14	0.57
BCS-H3-3-C	2677	3	0.52	0.85	0.49	0.22	0.36	0.19	0.78
BCS-H3-3-D	3439.2	3	0.68	1.10	0.64	0.38	0.61	0.34	1.33
BCS-H3-6-A	2951.9	2	0.56	0.91	0.53	0.26	0.42	0.23	0.91
BCS-H3-6-B	2864.3	2	0.33	0.54	0.31	0.03	0.05	0.01	0.08
BCS-H3-6-C	2765.6	2	0.45	0.73	0.42	0.15	0.24	0.12	0.50
BCS-H3-6-D	2505.4	2	0.51	0.83	0.48	0.21	0.34	0.18	0.73
BCS-H3-9-A	2979.5	2	0.51	0.84	0.48	0.21	0.35	0.18	0.75
BCS-H3-9-B	2473	3	0.94	1.53	0.88	0.64	1.04	0.58	2.25
BCS-H3-9-C	2826	3	1.39	2.26	1.31	1.09	1.77	1.01	3.87
BCS-H3-9-D	3312.2	2	0.43	0.71	0.41	0.13	0.22	0.11	0.46
BCS-H4-1-A	3582	3	0.62	1.02	0.59	0.32	0.53	0.29	1.14
BCS-H4-1-B	3069.7	3	0.47	0.77	0.44	0.17	0.28	0.14	0.59

Sample #	Weight (g)	Gamma Spec Sys.	Th-232 (pCi/g)	Th-230 (pCi/g)	Th-228 (pCi/g)	Th-232 Net (pCi/g)	Th-230 Net (pCi/g)	Th-228 Net (pCi/g)	Total Net Thorium (pCi/g)
BCS-H4-1-C	2817.6	3	0.31	0.50	0.29	0.01	0.01	-0.01	0.00
BCS-H4-1-D	3341.6	3	0.43	0.69	0.40	0.13	0.20	0.10	0.43
BCS-H4-2-A	3509.4	3	0.45	0.74	0.42	0.15	0.25	0.12	0.52
BCS-H4-2-B	2728.6	3	0.28	0.46	0.26	-0.02	-0.03	-0.04	-0.09
BCS-H4-2-C	3255.8	3	0.44	0.71	0.41	0.14	0.22	0.11	0.47
BCS-H4-2-D	2999.5	3	0.24	0.40	0.23	-0.06	-0.09	-0.07	-0.22
BCS-H4-3-A	3026.4	3	0.21	0.34	0.20	-0.09	-0.15	-0.10	-0.34
BCS-H4-3-B	3482.4	3	0.47	0.76	0.44	0.17	0.27	0.14	0.58
BCS-H4-3-C	2588.7	3	0.46	0.75	0.43	0.16	0.26	0.13	0.55
BCS-H4-3-D	2556.2	3	0.34	0.55	0.32	0.04	0.06	0.02	0.11
BCS-H4-4-A	2912	3	0.50	0.81	0.47	0.20	0.32	0.17	0.68
BCS-H4-4-B	2975.8	3	0.29	0.47	0.27	-0.01	-0.02	-0.03	-0.07
BCS-H4-4-C	2301.3	3	0.33	0.55	0.31	0.03	0.06	0.01	0.10
BCS-H4-4-D	2979.9	3	0.16	0.26	0.15	-0.14	-0.23	-0.15	-0.52
BCS-H4-5-A	2537.5	2	0.47	0.76	0.44	0.17	0.27	0.14	0.58
BCS-H4-5-B	3083.1	2	0.41	0.67	0.39	0.11	0.18	0.09	0.38
BCS-H4-5-C	2728.1	2	0.39	0.64	0.37	0.09	0.15	0.07	0.32
BCS-H4-5-D	2898.9	2	0.42	0.69	0.40	0.12	0.20	0.10	0.42
BCS-H4-5-D(DUP)	2898.9	2	0.29	0.47	0.27	-0.01	-0.02	-0.03	-0.06
BCS-H4-6-A	3087	2	0.42	0.69	0.40	0.12	0.20	0.10	0.42
BCS-H4-6-B	2716	2	0.27	0.44	0.25	-0.03	-0.05	-0.05	-0.14
BCS-H4-6-C	3028.5	2	0.31	0.50	0.29	0.01	0.01	-0.01	0.00
BCS-H4-6-D	2601	2	0.15	0.25	0.15	-0.15	-0.24	-0.15	-0.54
BCS-H4-7-A	2751.1	3	0.96	1.56	0.90	0.66	1.07	0.60	2.33
BCS-H4-7-B	3089.7	3	0.61	1.00	0.57	0.31	0.51	0.27	1.09
BCS-H4-7-C	3069	3	1.21	1.97	1.14	0.91	1.48	0.84	3.22
BCS-H4-7-D	2602.5	3	1.46	2.38	1.37	1.16	1.89	1.07	4.11
BCS-H5-1-A	3229.5	2	0.33	0.54	0.31	0.03	0.05	0.01	0.10
BCS-H5-1-B	3145.1	2	0.61	1.00	0.58	0.31	0.51	0.28	1.10
BCS-H5-1-C	3202.4	2	0.38	0.63	0.36	0.08	0.14	0.06	0.28
BCS-H5-1-D	2448.8	2	0.32	0.51	0.30	0.02	0.02	0.00	0.04
BCS-H5-2-A	2691.5	2	0.50	0.81	0.47	0.20	0.32	0.17	0.68
BCS-H5-2-B	2810.9	2	0.69	1.13	0.65	0.39	0.64	0.35	1.38
BCS-H5-2-C	3284.3	2	0.21	0.34	0.20	-0.09	-0.15	-0.10	-0.34
BCS-H5-2-D	2915	2	0.37	0.60	0.34	0.07	0.11	0.04	0.22
BCS-H5-3-A	3302	3	0.37	0.60	0.35	0.07	0.11	0.05	0.22
BCS-H5-3-B	2727.4	3	0.51	0.83	0.48	0.21	0.34	0.18	0.72
BCS-H5-3-C	3165.3	3	0.29	0.47	0.27	-0.01	-0.02	-0.03	-0.06
BCS-H5-3-D	2977.7	3	0.51	0.83	0.48	0.21	0.34	0.18	0.72
BCS-H5-5-A	2945.8	3	0.37	0.61	0.35	0.07	0.12	0.05	0.24
BCS-H5-5-B	2548.7	3	0.46	0.75	0.43	0.16	0.26	0.13	0.55
BCS-H5-5-C	2745.4	2	2.34	3.82	2.20	2.04	3.33	1.90	7.27
BCS-H5-5-D	2813.8	3	0.65	1.06	0.61	0.35	0.57	0.31	1.24
BCS-H5-6-A	3137.8	3	0.33	0.54	0.31	0.03	0.05	0.01	0.10
BCS-H5-6-B	2474.5	3	0.41	0.67	0.38	0.11	0.18	0.08	0.37

Sample #	Weight (g)	Gamma Spec Sys.	Th-232 (pCi/g)	Th-230 (pCi/g)	Th-228 (pCi/g)	Th-232 Net (pCi/g)	Th-230 Net (pCi/g)	Th-228 Net (pCi/g)	Total Net Thorium (pCi/g)
BCS-H5-6-C	2880.8	3	0.99	1.61	0.93	0.69	1.12	0.63	2.44
BCS-H5-6-D	2306.5	3	0.39	0.63	0.36	0.09	0.14	0.06	0.29
BCS-H6-1-A	3467.1	3	0.26	0.43	0.25	-0.04	-0.06	-0.05	-0.14
BCS-H6-1-B	3314.9	3	0.90	1.47	0.85	0.60	0.98	0.55	2.12
BCS-H6-1-C	3036	3	0.43	0.71	0.41	0.13	0.22	0.11	0.46
BCS-H6-1-D	3207.5	3	0.52	0.84	0.49	0.22	0.35	0.19	0.76
BCS-I3-3-A	2516.7	3	0.79	1.29	0.74	0.49	0.80	0.44	1.74
BCS-I3-3-B	3004.1	3	0.77	1.25	0.72	0.47	0.76	0.42	1.65
BCS-I3-3-C	3255.1	3	0.61	1.00	0.58	0.31	0.51	0.28	1.10
BCS-I3-3-D	3426.7	3	0.47	0.77	0.44	0.17	0.28	0.14	0.60
BCS-I3-6-A	2072.3	2	3.46	5.64	3.25	3.16	5.15	2.95	11.26
BCS-I3-6-B	2775.8	2	0.51	0.83	0.48	0.21	0.34	0.18	0.73
BCS-I3-6-C	2585.6	2	0.50	0.81	0.47	0.20	0.32	0.17	0.68
BCS-I3-6-D	1862.8	2	0.86	1.40	0.81	0.56	0.91	0.51	1.97
BCS-I3-9-A	3190.2	3	0.47	0.76	0.44	0.17	0.27	0.14	0.58
BCS-I3-9-B	2809.1	3	1.03	1.67	0.96	0.73	1.18	0.66	2.57
BCS-I3-9-C	2695.6	3	0.93	1.52	0.88	0.63	1.03	0.58	2.24
BCS-I3-9-D	3011.5	3	0.77	1.26	0.73	0.47	0.77	0.43	1.66
BCS-I3-9-D(DUP)	3011.5	3	0.85	1.39	0.80	0.55	0.90	0.50	1.94
BCS-I4-1-A	3101.7	3	0.80	1.31	0.75	0.50	0.82	0.45	1.77
BCS-I4-1-B	2814.5	3	0.53	0.87	0.50	0.23	0.38	0.20	0.81
BCS-I4-1-C	2879.8	3	0.57	0.94	0.54	0.27	0.45	0.24	0.96
BCS-I4-1-D	2783.8	3	0.75	1.22	0.70	0.45	0.73	0.40	1.58
BCS-I4-4-A	2724.8	3	0.85	1.38	0.80	0.55	0.89	0.50	1.93
BCS-I4-4-B	2725.1	3	0.82	1.33	0.77	0.52	0.84	0.47	1.83
BCS-I4-4-C	2711.5	3	0.45	0.73	0.42	0.15	0.24	0.12	0.52
BCS-I4-4-D	2817.5	3	0.71	1.16	0.67	0.41	0.67	0.37	1.45
BCS-I4-7-A	2355.6	2	0.35	0.57	0.33	0.05	0.08	0.03	0.15
BCS-I4-7-B	2379.4	2	0.83	1.36	0.78	0.53	0.87	0.48	1.89
BCS-I4-7-C	2655.2	2	2.39	3.90	2.25	2.09	3.41	1.95	7.44
BCS-I4-7-D	2845.6	2	0.33	0.53	0.31	0.03	0.04	0.01	0.08
BCS-I4-8-A	2348.4	3	0.23	0.37	0.22	-0.07	-0.12	-0.08	-0.27
BCS-I4-8-B	1993.7	3	0.48	0.78	0.45	0.18	0.29	0.15	0.63
BCS-I4-8-C	2293.6	3	0.45	0.74	0.43	0.15	0.25	0.13	0.53
BCS-I4-8-D	2544.7	3	0.57	0.92	0.53	0.27	0.43	0.23	0.94
BCS-I4-9-A	2271.2	2	0.89	1.46	0.84	0.59	0.97	0.54	2.10
BCS-I4-9-B	2522.7	2	0.92	1.50	0.86	0.62	1.01	0.56	2.19
BCS-I4-9-C	2126.5	2	9.72	15.84	9.13	9.42	15.35	8.83	33.60
BCS-I4-9-D	1914.6	2	0.87	1.41	0.81	0.57	0.92	0.51	2.00
BCS-I5-1-A	2945.6	2	1.16	1.89	1.09	0.86	1.40	0.79	3.06
BCS-I5-1-B	3417	2	0.53	0.86	0.50	0.23	0.37	0.20	0.80
BCS-I5-1-C	2798.9	2	0.69	1.13	0.65	0.39	0.64	0.35	1.38
BCS-I5-1-D	3093.9	2	0.62	1.02	0.59	0.32	0.53	0.29	1.14
BCS-I5-2-A	2997.6	2	0.61	0.99	0.57	0.31	0.50	0.27	1.07
BCS-I5-2-B	3264.5	2	0.15	0.24	0.14	-0.15	-0.25	-0.16	-0.56

Sample #	Weight (g)	Gamma Spec Sys.	Th-232 (pCi/g)	Th-230 (pCi/g)	Th-228 (pCi/g)	Th-232 Net (pCi/g)	Th-230 Net (pCi/g)	Th-228 Net (pCi/g)	Total Net Thorium (pCi/g)
BCS-I5-2-C	2833.6	2	0.49	0.79	0.46	0.19	0.30	0.16	0.64
BCS-I5-2-D	3141.1	2	0.50	0.81	0.47	0.20	0.32	0.17	0.69
BCS-I5-3-A	3313.1	3	0.43	0.69	0.40	0.13	0.20	0.10	0.43
BCS-I5-3-B	3038.1	3	0.78	1.28	0.74	0.48	0.79	0.44	1.71
BCS-I5-3-C	3178.2	3	0.11	0.18	0.10	-0.19	-0.31	-0.20	-0.70
BCS-I5-3-D	3368	3	0.30	0.48	0.28	0.00	-0.01	-0.02	-0.03
BCS-I5-7-A	3456.3	2	0.48	0.78	0.45	0.18	0.29	0.15	0.61
BCS-I5-7-B	3210.4	2	1.27	2.06	1.19	0.97	1.57	0.89	3.43
BCS-I5-7-C	3364.7	2	1.53	2.50	1.44	1.23	2.01	1.14	4.38
BCS-I5-7-D	3225.9	2	0.69	1.12	0.64	0.39	0.63	0.34	1.36
BCS-I5-8-A	3462.2	2	0.72	1.18	0.68	0.42	0.69	0.38	1.49
BCS-I5-8-B	2652.1	2	0.29	0.48	0.28	-0.01	-0.01	-0.02	-0.04
BCS-I5-8-C	3865.6	2	0.51	0.83	0.48	0.21	0.34	0.18	0.74
BCS-I5-8-D	3168.6	2	0.37	0.60	0.35	0.07	0.11	0.05	0.22
BCS-I5-9-A	1977.6	3	0.70	1.13	0.65	0.40	0.64	0.35	1.39
BCS-I5-9-B	2312.6	3	0.32	0.52	0.30	0.02	0.03	0.00	0.05
BCS-I5-9-C	2235	3	0.50	0.82	0.47	0.20	0.33	0.17	0.71
BCS-I5-9-D	2269.6	3	0.59	0.96	0.56	0.29	0.47	0.26	1.02
BCS-I6-1-A	2829.1	3	0.66	1.07	0.62	0.36	0.58	0.32	1.26
BCS-I6-1-B	2936.1	3	1.46	2.37	1.37	1.16	1.88	1.07	4.11
BCS-I6-1-C	3071.2	3	0.68	1.11	0.64	0.38	0.62	0.34	1.34
BCS-I6-1-D	3321.1	3	0.71	1.16	0.67	0.41	0.67	0.37	1.44
BCS-I6-2-A	3109.7	3	1.58	2.57	1.48	1.28	2.08	1.18	4.55
BCS-I6-2-B	2351.5	3	0.71	1.15	0.66	0.41	0.66	0.36	1.43
BCS-I6-2-C	2679	3	1.75	2.85	1.65	1.45	2.36	1.35	5.16
BCS-I6-2-D	2558.7	3	3.64	5.93	3.42	3.34	5.44	3.12	11.89
BCS-I6-3-A	3070.8	3	2.73	4.46	2.57	2.43	3.97	2.27	8.67
BCS-I6-3-B	2777	3	2.09	3.41	1.96	1.79	2.92	1.66	6.37
BCS-I6-3-C	2645.7	3	2.33	3.79	2.19	2.03	3.30	1.89	7.21
BCS-I6-3-D	2249.6	3	2.29	3.73	2.15	1.99	3.24	1.85	7.07
BCS-I6-6-A	3219.4	3	1.56	2.54	1.46	1.26	2.05	1.16	4.47
BCS-I6-6-B	3265	3	2.19	3.58	2.06	1.89	3.09	1.76	6.74
BCS-I6-6-C	2654.3	3	0.58	0.94	0.54	0.28	0.45	0.24	0.98
BCS-I6-6-D	2515.2	3	1.67	2.72	1.57	1.37	2.23	1.27	4.87
BCS-I6-7-A	3291.5	2	0.47	0.77	0.44	0.17	0.28	0.14	0.59
BCS-I6-7-B	3052.2	2	0.63	1.02	0.59	0.33	0.53	0.29	1.15
BCS-I6-7-D	3332.3	2	0.73	1.18	0.68	0.43	0.69	0.38	1.50
BCS-I6-7-D(DUP)	3332.3	2	0.73	1.19	0.69	0.43	0.70	0.39	1.51
BCS-J4-3-A	3163.9	3	0.43	0.70	0.40	0.13	0.21	0.10	0.45
BCS-J4-3-B	2678.1	3	0.72	1.17	0.68	0.42	0.68	0.38	1.48
BCS-J4-3-C	3090	3	1.90	3.10	1.79	1.60	2.61	1.49	5.71
BCS-J4-3-D	3214.6	3	0.56	0.91	0.53	0.26	0.42	0.23	0.91
BCS-J4-6-A	3052.5	3	0.63	1.03	0.59	0.33	0.54	0.29	1.16
BCS-J4-6-B	3276.2	3	0.55	0.90	0.52	0.25	0.41	0.22	0.88
BCS-J4-6-C	2897.8	3	0.59	0.96	0.56	0.29	0.47	0.26	1.02

Sample #	Weight (g)	Gamma Spec Sys.	Th-232 (pCi/g)	Th-230 (pCi/g)	Th-228 (pCi/g)	Th-232 Net (pCi/g)	Th-230 Net (pCi/g)	Th-228 Net (pCi/g)	Total Net Thorium (pCi/g)
BCS-J4-6-D	3008.3	3	0.72	1.17	0.67	0.42	0.68	0.37	1.46
BCS-J4-9-A	2603.6	3	1.74	2.84	1.64	1.44	2.35	1.34	5.13
BCS-J4-9-B	3063.7	3	0.63	1.03	0.60	0.33	0.54	0.30	1.17
BCS-J4-9-C	2447.8	3	4.35	7.08	4.08	4.05	6.59	3.78	14.42
BCS-J4-9-D	2586.4	3	1.85	3.02	1.74	1.55	2.53	1.44	5.51
BCS-J4-9-D(DUP)	2586.4	3	1.78	2.90	1.67	1.48	2.41	1.37	5.27
BCS-J5-1-A	2900.2	3	0.75	1.22	0.70	0.45	0.73	0.40	1.57
BCS-J5-1-B	3260.6	3	0.67	1.09	0.63	0.37	0.60	0.33	1.30
BCS-J5-1-C	3203	3	0.72	1.18	0.68	0.42	0.69	0.38	1.48
BCS-J5-1-D	3245.3	3	0.76	1.24	0.72	0.46	0.75	0.42	1.63
BCS-J5-2-A	3699.4	3	0.73	1.18	0.68	0.43	0.69	0.38	1.50
BCS-J5-2-B	3473.2	3	0.58	0.95	0.55	0.28	0.46	0.25	0.98
BCS-J5-2-C	3705.8	3	0.55	0.90	0.52	0.25	0.41	0.22	0.88
BCS-J5-2-D	3604.6	3	0.38	0.61	0.35	0.08	0.12	0.05	0.25
BCS-J5-3-A	2928.9	3	1.47	2.40	1.38	1.17	1.91	1.08	4.16
BCS-J5-3-B	2661	3	2.06	3.35	1.93	1.76	2.86	1.63	6.25
BCS-J5-3-C	2906.7	3	1.19	1.94	1.12	0.89	1.45	0.82	3.16
BCS-J5-3-D	2946.8	3	1.47	2.39	1.38	1.17	1.90	1.08	4.15
BCS-J5-3-D(DUP)	2946.8	3	1.49	2.44	1.40	1.19	1.95	1.10	4.25
BCS-J5-4-A	3443	3	0.66	1.07	0.62	0.36	0.58	0.32	1.26
BCS-J5-4-B	2998.4	3	0.51	0.83	0.48	0.21	0.34	0.18	0.72
BCS-J5-4-C	3353.3	3	0.67	1.10	0.63	0.37	0.61	0.33	1.32
BCS-J5-4-D	3579.2	3	0.56	0.91	0.52	0.26	0.42	0.22	0.90
BCS-J5-5-A	2552.1	3	0.85	1.38	0.80	0.55	0.89	0.50	1.94
BCS-J5-5-B	3225.1	3	0.69	1.13	0.65	0.39	0.64	0.35	1.38
BCS-J5-5-C	3823.9	3	0.69	1.13	0.65	0.39	0.64	0.35	1.38
BCS-J5-5-D	3547	3	3.03	4.93	2.84	2.73	4.44	2.54	9.71
BCS-J5-6-A	3531	2	1.01	1.64	0.95	0.71	1.15	0.65	2.50
BCS-J5-6-B	3688	2	0.30	0.49	0.28	0.00	0.00	-0.02	-0.03
BCS-J5-6-C	3863.7	2	0.68	1.10	0.64	0.38	0.61	0.34	1.33
BCS-J5-6-D	3841.2	2	0.63	1.02	0.59	0.33	0.53	0.29	1.15
BCS-J5-7-A	2883.3	2	0.49	0.80	0.46	0.19	0.31	0.16	0.66
BCS-J5-7-B	3733	2	0.42	0.68	0.39	0.12	0.19	0.09	0.41
BCS-J5-7-C	2439	2	0.77	1.25	0.72	0.47	0.76	0.42	1.66
BCS-J5-7-D	3037	2	0.57	0.92	0.53	0.27	0.43	0.23	0.93
BCS-J5-8-A	3738.8	2	0.82	1.34	0.77	0.52	0.85	0.47	1.84
BCS-J5-8-B	3089.2	2	0.67	1.09	0.63	0.37	0.60	0.33	1.29
BCS-J5-8-C	3013	2	0.72	1.18	0.68	0.42	0.69	0.38	1.49
BCS-J5-8-D	3707.1	2	0.61	0.99	0.57	0.31	0.50	0.27	1.07
BCS-J5-8-D(DUP)	3707.1	2	0.44	0.72	0.41	0.14	0.23	0.11	0.48
BCS-J5-9-A	3645.8	3	0.57	0.93	0.54	0.27	0.44	0.24	0.94
BCS-J5-9-B	3627.3	3	0.57	0.93	0.54	0.27	0.44	0.24	0.95
BCS-J5-9-C	3592.1	3	0.92	1.50	0.86	0.62	1.01	0.56	2.19
BCS-J5-9-D	3669.8	3	0.32	0.52	0.30	0.02	0.03	0.00	0.06
BCS-J6-1-A	2722	3	4.46	7.27	4.19	4.16	6.78	3.89	14.83

Sample #	Weight (g)	Gamma Spec Sys.	Th-232 (pCi/g)	Th-230 (pCi/g)	Th-228 (pCi/g)	Th-232 Net (pCi/g)	Th-230 Net (pCi/g)	Th-228 Net (pCi/g)	Total Net Thorium (pCi/g)
BCS-J6-1-B	3044.2	3	1.10	1.79	1.03	0.80	1.30	0.73	2.83
BCS-J6-1-C	3035.4	3	0.57	0.92	0.53	0.27	0.43	0.23	0.93
BCS-J6-1-D	3007.7	3	0.91	1.48	0.85	0.61	0.99	0.55	2.15
BCS-J6-2-A	3232.7	3	0.68	1.11	0.64	0.38	0.62	0.34	1.33
BCS-J6-2-B	2930.5	3	0.44	0.71	0.41	0.14	0.22	0.11	0.47
BCS-J6-2-C	3357.5	3	0.32	0.53	0.31	0.02	0.04	0.01	0.07
BCS-J6-2-D	3444.9	3	0.27	0.44	0.25	-0.03	-0.05	-0.05	-0.13
BCS-J6-2-D(DUP)	3444.9	3	0.26	0.42	0.24	-0.04	-0.07	-0.06	-0.17
BCS-J6-3-A	3089.1	3	1.83	2.98	1.72	1.53	2.49	1.42	5.44
BCS-J6-3-B	3189.2	3	1.09	1.78	1.03	0.79	1.29	0.73	2.81
BCS-J6-3-C	3071.4	3	0.85	1.39	0.80	0.55	0.90	0.50	1.95
BCS-J6-3-D	3341.2	3	0.72	1.17	0.67	0.42	0.68	0.37	1.46
BCS-J6-4-A	3743.5	3	0.57	0.92	0.53	0.27	0.43	0.23	0.93
BCS-J6-4-B	3956.7	3	0.79	1.28	0.74	0.49	0.79	0.44	1.72
BCS-J6-4-C	3767.6	3	0.77	1.26	0.73	0.47	0.77	0.43	1.67
BCS-J6-4-D	3859.7	3	0.62	1.01	0.58	0.32	0.52	0.28	1.12
BCS-J6-5-A	3284.9	3	0.53	0.87	0.50	0.23	0.38	0.20	0.81
BCS-J6-5-B	3248.7	3	0.19	0.30	0.17	-0.11	-0.19	-0.13	-0.43
BCS-J6-5-C	3413.1	3	0.50	0.82	0.47	0.20	0.33	0.17	0.70
BCS-J6-5-D	3253.8	3	0.59	0.96	0.56	0.29	0.47	0.26	1.02
BCS-J6-6-A	2760.8	3	0.80	1.30	0.75	0.50	0.81	0.45	1.76
BCS-J6-6-B	3364.7	3	0.36	0.59	0.34	0.06	0.10	0.04	0.21
BCS-J6-6-C	3020.5	3	0.37	0.60	0.34	0.07	0.11	0.04	0.21
BCS-J6-6-D	2729.5	3	0.56	0.91	0.52	0.26	0.42	0.22	0.90
BCS-J6-7-A	3576.2	2	0.76	1.25	0.72	0.46	0.76	0.42	1.64
BCS-J6-7-B	3526.6	2	0.92	1.51	0.87	0.62	1.02	0.57	2.21
BCS-J6-7-C	3719.6	3	0.23	0.37	0.21	-0.07	-0.12	-0.09	-0.28
BCS-J6-7-D	3571.4	3	1.38	2.25	1.30	1.08	1.76	1.00	3.84
BCS-J6-8-A	3357.6	3	0.45	0.74	0.42	0.15	0.25	0.12	0.52
BCS-J6-8-B	3311.7	3	0.59	0.97	0.56	0.29	0.48	0.26	1.03
BCS-J6-8-C	3263.1	3	0.65	1.07	0.61	0.35	0.58	0.31	1.24
BCS-J6-8-D	3564.1	3	0.97	1.58	0.91	0.67	1.09	0.61	2.38
BCS-J6-9-A	3031.2	3	0.46	0.75	0.43	0.16	0.26	0.13	0.56
BCS-J6-9-B	3050.4	3	0.88	1.44	0.83	0.58	0.95	0.53	2.07
BCS-J6-9-C	3235.4	3	1.00	1.64	0.94	0.70	1.15	0.64	2.49
BCS-J6-9-D	2752.3	3	1.85	3.02	1.74	1.55	2.53	1.44	5.52
BCS-K4-9-A	3448.8	2	0.58	0.94	0.54	0.28	0.45	0.24	0.96
BCS-K4-9-B	3167.9	2	0.46	0.76	0.44	0.16	0.27	0.14	0.56
BCS-K4-9-C	3162.5	2	0.58	0.94	0.54	0.28	0.45	0.24	0.98
BCS-K4-9-D	3543.7	2	0.43	0.71	0.41	0.13	0.22	0.11	0.46
BCS-K5-7-A	3303.6	2	0.62	1.01	0.58	0.32	0.52	0.28	1.12
BCS-K5-7-B	3346.5	2	0.58	0.94	0.54	0.28	0.45	0.24	0.97
BCS-K5-7-C	2849.1	2	0.40	0.65	0.38	0.10	0.16	0.08	0.34
BCS-K5-7-D	3271	2	0.70	1.13	0.65	0.40	0.64	0.35	1.39
BCS-K5-8-A	3010.1	3	0.80	1.30	0.75	0.50	0.81	0.45	1.77

Sample #	Weight (g)	Gamma Spec Sys.	Th-232 (pCi/g)	Th-230 (pCi/g)	Th-228 (pCi/g)	Th-232 Net (pCi/g)	Th-230 Net (pCi/g)	Th-228 Net (pCi/g)	Total Net Thorium (pCi/g)
BCS-K5-8-B	3141.6	3	0.74	1.20	0.69	0.44	0.71	0.39	1.54
BCS-K5-8-C	3472.8	3	1.23	2.01	1.16	0.93	1.52	0.86	3.31
BCS-K5-8-D	2716	3	1.02	1.66	0.96	0.72	1.17	0.66	2.55
BCS-K5-9-A	3383.1	2	0.44	0.71	0.41	0.14	0.22	0.11	0.47
BCS-K5-9-B	3587.7	2	0.50	0.81	0.47	0.20	0.32	0.17	0.68
BCS-K5-9-C	3060.5	2	2.10	3.42	1.97	1.80	2.93	1.67	6.39
BCS-K5-9-D	3028.4	2	1.29	2.10	1.21	0.99	1.61	0.91	3.50
BCS-K5-9-D(DUP)	3028.4	2	1.18	1.93	1.11	0.88	1.44	0.81	3.13
BCS-K6-7-A	3017.8	3	0.66	1.07	0.62	0.36	0.58	0.32	1.26
BCS-K6-7-B	3313.3	3	0.60	0.97	0.56	0.30	0.48	0.26	1.04
BCS-K6-7-C	3297.6	3	1.28	2.09	1.21	0.98	1.60	0.91	3.49
BCS-K6-7-D	3475.5	3	0.40	0.65	0.38	0.10	0.16	0.08	0.34
BCS-K6-7-D(DUP)	3475.5	3	0.47	0.76	0.44	0.17	0.27	0.14	0.58
BCS-K6-8-A	3296.4	2	0.43	0.70	0.40	0.13	0.21	0.10	0.43
BCS-K6-8-B	3288.4	2	0.68	1.11	0.64	0.38	0.62	0.34	1.33
BCS-K6-8-C	3474	2	0.40	0.65	0.38	0.10	0.16	0.08	0.34
BCS-K6-8-D	3249.5	2	1.11	1.80	1.04	0.81	1.31	0.74	2.86
BCS-K6-9-A	3319.8	2	0.46	0.75	0.43	0.16	0.26	0.13	0.54
BCS-K6-9-B	3471	2	0.36	0.58	0.33	0.06	0.09	0.03	0.18
BCS-K6-9-C	3076.3	2	0.93	1.52	0.88	0.63	1.03	0.58	2.24
BCS-K6-9-D	2743.6	2	0.80	1.30	0.75	0.50	0.81	0.45	1.75
Average	**2976.5**		**0.80**	**1.30**	**0.75**	**0.50**	**0.81**	**0.45**	**1.75**
Median	**3011.1**		**0.6**	**1.0**	**0.6**	**0.3**	**0.5**	**0.3**	**1.1**
Standard Deviation	**418.7**		**0.7**	**1.2**	**0.7**	**0.7**	**1.2**	**0.7**	**2.6**

Equations
Th-230 (pCi/g) = 1.63 * Th-232 (pCi/g)
Th-228 (pCi/g) = 0.94 * Th-232 (pCi/g)
Th-232 Net (pCi/g) = Th-232 (pCi/g) - 0.3
Th-230 Net (pCi/g) = Th-230 (pCi/g) - 0.49
Th-228 Net (pCi/g) = Th-228 (pCi/g) - 0.3
Total Net Thorium = Th-232 Net + Th-230 Net + Th-228 Net

Table A5

Final Gamma Exposure Rates – VA-VI

Sample #	Gross Exposure µR/hr	Net Exposure µR/hr
BCS- C1-2 -V1	10	5
BCS- C1-3 -V1	11	6
BCS- C2-1 -V1	9	4
BCS- C2-2 -V1	12	7
BCS- D1-2 -V1	8	3
BCS- D1-3 -V1	8	3
BCS- D1-5 -V1	10	5
BCS- D1-6 -V1	11	6
BCS- D1-8 -V1	11	6
BCS- D1-9 -V1	12	7
BCS- D2-1 -V1	11	6
BCS- D2-2 -V1	13	8
BCS- D2-3 -V1	10	5
BCS- D2-4 -V1	11	6
BCS- D2-5 -V1	9	4
BCS- D2-6 -V1	10	5
BCS- D2-7 -V1	12	7
BCS- D2-8 -V1	10	5
BCS- D2-9 -V1	8	3
BCS- E1-2 -V1	8	3
BCS- E1-3 -V1	7	2
BCS- E1-5 -V1	7	2
BCS- E1-6 -V1	7	2
BCS- E1-8 -V1	6	1
BCS- E1-9 -V1	7	2
BCS- E2-1 -V1	8	3
BCS- E2-2 -V1	8	3
BCS- E2-3 -V1	9	4
BCS- E2-4 -V1	7	2
BCS- E2-5 -V1	9	4
BCS- E2-6 -V1	11	6
BCS- E2-7 -V1	7	2

Sample #	Gross Exposure µR/hr	Net Exposure µR/hr
BCS- E3-5 -V1	12	7
BCS- E3-7 -V1	8	3
BCS- E3-8 -V1	11	6
BCS- F3-3 -V1	9	4
BCS- G3-3 -V1	8	3
BCS- G3-6 -V1	7	2
BCS- G3-9 -V1	8	3
BCS- G4-1 -V1	9	4
BCS- G4-4 -V1	9	4
BCS- H3-3 -V1	8	3
BCS- H3-6 -V1	8	3
BCS- H3-9 -V1	8	3
BCS- H4-1 -V1	8	3
BCS- H4-2 -V1	8	3
BCS- H4-3 -V1	9	4
BCS- H4-4 -V1	8	3
BCS- H4-5 -V1	9	4
BCS- H4-6 -V1	9	4
BCS- H4-7 -V1	10	5
BCS- H5-1 -V1	8	3
BCS- H5-2 -V1	8	3
BCS- H5-3 -V1	7	2
BCS- H5-5 -V1	7	2
BCS- H5-6 -V1	7	2
BCS- H6-1 -V1	8	3
BCS- I3-3 -V1	8	3
BCS- I3-6 -V1	7	2
BCS- I3-9 -V1	9	4
BCS- I4-1 -V1	9	4
BCS- I4-4 -V1	9	4
BCS- I4-7 -V1	9	4
BCS- I4-8 -V1	8	3

Sample #	Gross Exposure µR/hr	Net Exposure µR/hr
BCS- E2-8 -V1	10	5
BCS- E2-9 -V1	11	6
BCS- E3-1 -V1	9	4
BCS- E3-2 -V1	11	6
BCS- E3-4 -V1	10	5
BCS- I5-8 -V1	7	2
BCS- I5-9 -V1	7	2
BCS- I6-1 -V1	7	2
BCS- I6-2 -V1	9	4
BCS- I6-3 -V1	11	6
BCS- I6-6 -V1	11	6
BCS- I6-7 -V1	7	2
BCS- J4-3 -V1	8	3
BCS- J4-6 -V1	9	4
BCS- J4-9 -V1	9	4
BCS- J5-1 -V1	8	3
BCS- J5-2 -V1	9	4
BCS- J5-3 -V1	8	3
BCS- J5-4 -V1	8	3
BCS- J5-5 -V1	10	5
BCS- J5-6 -V1	7	2
BCS- J5-7 -V1	8	3
BCS- J5-8 -V1	9	4

Sample #	Gross Exposure µR/hr	Net Exposure µR/hr
BCS- I4-9 -V1	9	4
BCS- I5-1 -V1	7	2
BCS- I5-2 -V1	8	3
BCS- I5-3 -V1	7	2
BCS- I5-7 -V1	9	4
BCS- J5-9 -V1	9	4
BCS- J6-1 -V1	9	4
BCS- J6-2 -V1	8	3
BCS- J6-3 -V1	8	3
BCS- J6-4 -V1	8	3
BCS- J6-5 -V1	8	3
BCS- J6-6 -V1	8	3
BCS- J6-7 -V1	9	4
BCS- J6-8 -V1	9	4
BCS- J6-9 -V1	9	4
BCS- K4-9 -V1	8	3
BCS- K5-7 -V1	8	3
BCS- K5-8 -V1	7	2
BCS- K5-9 -V1	8	3
BCS- K6-7 -V1	8	3
BCS- K6-8 -V1	8	3
BCS- K6-9 -V1	7	2

Total Number of Sub-Grids	109
Average Gross Exposure Rate	9 µR/h
Average Net Exposure Rate	4 µR/h
Background Exposure Rate	5 µR/h

* Net Exposure = Gross Exposure - Background Exposure

Table A6

Final Status Survey: Statistical Analysis

The following statistical relations were used to assess the database for the Bay City survey unit:

Survey Data Average ($\bar{x}$):

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

Standard Deviation (S_x):

$$S_x = \sqrt{\frac{\sum_{i=1}^{n}(\bar{x} - x_i)^2}{n-1}}$$

Determination of Number of Background data points (n_B):

$$n_B = \left[\frac{t_{95.5\%,df} S_x}{0.2 \bullet \bar{x}_B}\right]^2$$

Comparison of statistical mean ($\mu\alpha$) with guideline values:

$$\mu_\alpha = \bar{x} + t_{1-\alpha,df}\frac{S_x}{\sqrt{n}}$$

Identifying additional measurement/sampling needs:

$$\text{Estimating Factor} = \frac{C_G - \bar{x}}{S_x}$$

(Tables B-2 in NUREG/CR-5849)

Note: See chapter 8.0 of NUREG/CR-5849 for detailed discussion of above-listed statistical analyses.

Where:

X_i = measurement (analysis) at point i
n = number of measurements (analyses)
t_i - α, df = 95% confidence level from Table B-1 of Appendix B of NUREG/CR-5849
C_G = Guideline Value

Table A7

Final Status Survey: Summary Statistics

Exposure Rates							
Section	n	X (μR/h)	Sx (μR/h)	μα (μR/h)	C_G (μR/h)	Estimating Factor	No. Verification Samples Needed
VA-VI	109	3.7	1.4	3.9	5.0	0.9	11
Th-232 Soil Concentrations							
Section	n	X (pCi/g)	Sx (pCi/g)	μα (pCi/g)	C_G (pCi/g)	Estimating Factor	No. Verification Samples Needed
VA-VI	401	0.8	0.5	0.9	3.2	4.8	<9