CONNECTICUT YANKEE ATOMIC POWER COMPANY

HADDAM NECK PLANT
362 INJUN HOLLOW ROAD • EAST HAMPTON, CT 06424-3099

DEC - 6 2005
Docket No. 50-213
CY-05-239

Re: 10 CFR 50.82(a)(11)

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, DC 20555-0001

Haddam Neck Plant
Response to NRC Staff Comments/Questions
On Final Status Survey (FSS) Final Report – Phase II

In a letter dated March 8, 2005,[(1)] Connecticut Yankee Atomic Power Company (CYAPCO) submitted the FSS Final Report – Phase II. The Phase II FSS Final Report addresses fourteen (14) land area Survey Units and one (1) subsurface soil Survey Unit within the east mountainous and low land survey areas of the Haddam Neck Plant (HNP) site. The report contains a compilation of all fifteen (15) Survey Unit Release Records that are within the Phase II scope. The purpose of this submittal is to provide a response to each of the NRC questions on the FSS Final Report – Phase II. These responses were discussed during the June 14, 2005, August 4, 2005 and September 22, 2005 conference calls between the NRC Staff and CYAPCO personnel. Attachment 1 provides those responses.

There are no regulatory commitments contained in this submittal.

If you should have any questions regarding this submittal, please contact Mr. G.P. van Noordennen at (860) 267-3938.

Sincerely,

J. F. Bourassa — 12/6/05 Date
Director, Nuclear Safety/Regulatory Affairs

(1) J. F. Bourassa (CYAPCO) letter to US NRC, "Haddam Neck Plant, Final Status Survey (FSS) Final Report – Phase II", dated March 8, 2005.

NMSS01

Attachment 1: Response to NRC Staff Comments/Questions on the HNP Final Status Survey (FSS) Final Report – Phase II

cc: S. J. Collins, Region I Administrator
M. T. Miller, Branch Chief, Decommissioning Branch, Region I
T. B. Smith, Project Manager, Haddam Neck Plant
E. L. Wilds, Jr., Director, CT DEP Monitoring and Radiation Division

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Attachment 1
Haddam Neck Plant
Responses to NRC Staff Comments/Questions on
Final Status Survey (FSS) Final Report – Phase II

December 2005

Responses to NRC STAFF COMMENTS/QUESTIONS ON Haddam Neck Plant (HNP) FINAL STATUS SURVEY REPORT - Phase II

INTRODUCTION

On March 8, 2005, Connecticut Yankee Atomic Power Company (CYAPCO) submitted the Final Status Survey (FSS) Report - Phase II for the Haddam Neck Plant (HNP). The following NRC staff Comments/Questions on the HNP Final Status Survey (FSS) Report - Phase II were discussed during the June 14, 2005, August 4, 2005 and September 22, 2005 conference calls between the NRC staff and CYAPCO Staff. A response to each of the questions discussed during the conference calls is provided below.

A *First Series of Comments/Questions Received on June 10, 2005*

GENERAL COMMENTS

1. Overall Good First Impression.

The NRC staff notes that from all Survey Units in Phase II, none of the sample results appear to exceed the DCGL, which is more than required, and may indicate a relatively low likelihood of problems for these survey units.

In addition, the staff notes that the FSS Reports are written clearly and in a manner that is easy to read and follow. This makes the NRC staff review relatively easier.

Notwithstanding the generally positive impression, staff does have some comments/questions, given below.

1. Response:

No Response is required.

2. Classification of Class 3 Survey Units.

Reference: Book 1 of 16.

Table 5-1 summarizes results from all the Survey Units of Phase II. Based on this table, some Survey Units have mean Cs-137 concentrations of 0.007 to 0.2 pCi/g, which appears to provide an indication of the background concentrations of Cs-137. Of the Class 3 areas, 3 of 5 (Survey Units 9523-0000, 9526-0000, and 9528-0000) Survey Units have mean concentrations significantly greater than 0.2 pCi/g, and 4 of 5 have maximum concentrations significantly greater than 0.2 pCi/g. In addition, the Class 3 areas have an overall average (non area-weighted) concentration of Cs-137 that is greater than that of the Class 2 areas overall. These may be indications that some of the Class 3 areas have residual radioactivity at more than a small fraction the DCGL and thus should have been classified as Class 2 areas.

2. Response

An evaluation of the data shows several distributions. Survey Units 9806, 9537, 9536, 9535-0001, and 9525 should not be considered "as a typical background examples" since some of these Survey Units underwent Resource Conservation and Recovery Act (RCRA) or radiological remediation which required backfill and extensive disturbance of the soils; or is a subsurface area (Survey Unit 9806); or is a paved roadway (Survey Unit 9525).

Elimination of the non-typical areas provides two distributions, one of which is open lands and the other, major landmasses, which are wooded. Survey Units 9524, 9528-0003, 9528-0004, 9535-0002, and 9538-000 are open, and mostly excavated areas subject to runoff and leaching and exhibit similar backgrounds.

Survey Units 9523, 9526, and 9528; exhibit apparent "elevated" or higher concentrations of Cs-137. These areas are wooded, show little signs of recent disturbance and are not readily accessible. Survey Unit 9523 also includes tidal influenced wet lands that rise rapidly to rocky slopes. Characterization data to support Final Status Survey (FSS) and final classification did not identify Cs-137 in concentrations exceeding site specific Class 3 criterion.

Data from the FSS of these three (3) areas was evaluated and found not to have exceeded the investigation criterion for a Class 3 area as specified in Section 5.5.3 of the Haddam Neck Plant (HNP) License Termination Plan (LTP) (i.e., perform investigation when samples exceed 0.5 times the DCGL). Therefore, no investigation was necessary and reclassification is not required per the HNP LTP. CYAPCO did choose to perform additional sampling based on lower administrative criteria in an effort to understand the extent and mechanism for the apparent elevated Cs-137 concentration. Based upon our data research and conclusions these areas were classified properly.

3. Regarding the Determination of Relative Shift.

Reference: Book 11 of 16; Appendix A10, Survey Unit 9535-0001, Southeast Landfill Area.

The assumptions or approach for determining the numbers of samples are not entirely clear. On Page 9, CYAPCO describes the selection of the 15-sample set for the Survey Unit 9535-0001 for Cs-137 using the applicable procedure RPM 5.1-12, *Determination of the Number of Surface Samples for FSS*. The LBGR was adjusted from 0.5 to 0.91 to maintain the relative shift in the 1 - 3 range. The resultant number of samples was 15. Also, Page 12, in Table 4 - *Synopsis of the Survey Design*, CYAPCO indicates that alpha = beta = 0.05, and that the relative shift was set at 2 per procedure (RPM 5.1-12), and the LBGR adjusted to 0.91.

The value of sigma for this calculation could not be determined. What is the source of the data used to provide the sigma value? What does procedure RPM 5.1-12 describe for determining the LBGR and relative shift?

3. Response

The assumptions to determine the number of samples and the method to calculate the sigma value are contained in RPM 5.1-12. The appropriate sections of the procedure are hereby enclosed (Enclosure 1). Calculation of the LBGR was performed in accordance with procedure RPM 5.1-12.

There is a minor discrepancy between the standard deviation on the sample calculation sheet (Enclosure 1) and the standard deviation in Table 3 of the Final Status Survey Plan (Enclosure 1). The difference is that the DCGL for Cs-137 was lowered during the calculation of samples from 3.16 pCi/g to 2.82 pCi/g to account for the surrogate relationships. The difference is trivial in that the number of required samples would remain at fifteen.

4. Regarding the technical basis for Cs-137 as surrogate for Hard-To-Detects.

Reference: Book 11 of 16; Appendix A10, Survey Unit 9535-0001, Southeast Landfill Area.

On page 9, CYAPCO also indicates that Cs-137 is acceptable as a surrogate for the Hard-to-Detect (HTD) radionuclides (i.e., Sr-90, C-14 & Ni-63). Radio-analytical laboratory results are provided in Appendix A10, and the data do not seem to have a reasonably consistent ratio (HTD/Cs137).

The data, (which are referred to) based on which the ratios that were developed have not been provided. Also, the surrogate ratios used have not been provided. A review cannot be readily completed without these data.

Were you able to identify a reasonably consistent ratio of Cs-137 to HTD materials using Cs-137 as a surrogate? What ratio (Cs-137 and HTD) did you use?

4. Response

Appropriate sections of the Final Status Survey Plan (FSSP) are enclosed (Enclosure 1).

Three samples were collected during remediation from locations showing the highest levels of activity as identified during scanning. The samples where sent off-site for analysis to determine type and concentration of HTD radionuclides. Remediation of the landfill continued until only very low levels of Cs-137 were identified. During FSS design Co-60 was considered as a surrogate for the activation products C-14 and Ni-63. However, the remedial action data indicates that Co-60 will likely be reported at concentrations below the minimum detection criteria and will not provide a meaningful relationship. Therefore, Cs-137 was considered acceptable as the surrogate since it was likely to be the only easy-to-detect radionuclide of concern present in sufficient quantities at the time of FSS.

The percentage coefficient of variation (%CV) was higher than desired for the three (3) samples collected during remediation. The range of %CV was 40% to 57%. More samples would have been desirable to reduce variance. However, radiological conditions were now different following remediation. The FSS design could have deselected HTD radionuclides based on individual and aggregate concentrations not exceeding 5% and 10% of the DCGL respectively. This would have required additional sampling and off-site analysis to confirm. To expedite the FSS, surrogates were developed around Cs-137 using the concentrations reported for the three (3) samples. A representative mix was determined from the three (3) samples and the 95% upper bound of the surrogate ratios was used to account for the variability and level of uncertainty in the data. This approach is consistent with the MARSSIM and is expected to produce a conservative value for the surrogate ratios as they are based on very high concentrations of activity that are not expected to be present in the landfill based on the remedial action survey data.

Additional information is provided in the second series of comments/questions received on August 3, 2005. This discussion shows that although surrogate ratios were developed, they were not needed in the final status survey as analysis for HTD radionuclides was performed as part of the final status survey.

5. Regarding the Handling of Data Outliers.

Reference: Book 11 of 16; Appendix A10, Survey Unit 9535-0001, Southeast Landfill Area.

On page 16, the discussion in the Data Quality Assessment (DQA) section indicates that statistical analysis revealed three positive outliers, and attributes the 0.313 pCi/g data point to natural variations of environmental soil at offsite locations with inductions from topographical and geological features.

CYAPCO has not provided any data to indicate that the results were invalid. If the data are valid, then the results should not be excluded, and should not be considered outliers.

How does CYAPCO handle outliers? Are they excluded from the data set for data analysis? How were these three outliers handled?

In addition, Appendices discuss "Anomalies," in Section 12 of each appendix. For clarification, what does CYAPCO mean by anomalies?

5. Response

The outliers are used in the data analysis and considered valid. The outliers are considered as a "datum point that may not fit the typical distribution." Outliers may prompt an evaluation of the sample method or sample location, further review of the data, prompt investigations if limits are exceeded, and are included in the data analysis.

'Anomalies' are events or unexpected results that occur during the FSS. This may include data loss, instrument failure, readings that are higher than expected but can't be confirmed, lab results not meeting quality, unusual readings, such as NORMs, invalid results, data that indicates fallout from weapons testing or other non-CYAPCO origins.

6. DCGL Terminology.

The Staff has observed the use of the following terms: DCGL or DCGLw; Administrative DCGL; Operational DCGL; and Surrogate DCGL or Surrogate-adjusted DCGL. The use of multiple terms is sometimes confusing, especially when the values being used are not always provided.

6. Response

DCGL or DCGLw is used as described in the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM). The term Administrative DCGL is the 10mR/yr level in areas with no potential for "Future GW" dose. Operational DCGL is the limit applied for field results. This was developed when two or more radionuclides were part of the FSS Plan. It was applied later to the DCGL used for the FSS Plan limits. All DCGL terms refer to the 10 mR/yr limit. Surrogate DCGL is the limit of the analog that will meet the summation limit. This variation in nomenclature reflects the program changes that occurred over the last 4 year period. Standardized nomenclature will be used in future reports.

7. Survey Unit Locations Map.

CYAPCO has provided a map of the Survey Units, in Figure 1-1 of Book 1 of 16. This map is useful in our reviews. However, the map would be even more useful if it were a large scale map, and if it could include the topography information as well. If that would be easy to create in a large scale (perhaps separate from the reports), it would be useful to the NRC staff.

7. Response

A large size map was provided separately to the NRC.

SURVEY-UNIT SPECIFIC COMMENTS

1. Appendix A1, Survey Unit 9523-0000

Tables 12 and 13 appear to refer to SU 9532-0000 instead of Survey Unit 9523-0000.

Classification question and concerns (see also general comment). One Cs-137 sample result is 3.8 pCi/g. A confirmatory sample was taken for Cs-137 with results of 1.44 pCi/g. Investigation samples in Table 13, 14 and 15 indicate Cs-137 sample results in the 1 - 3 pCi/g range. It appears to be residual radioactivity at a significant fraction of the DCGL, perhaps indicating that this SU should have been Class 2.

1. Response

Tables 12 and 13 have typographical errors and should refer to 9523-0000.

Characterization was performed to support FSS and final characterization. Forty-eight (48) samples were collected and evaluated prior to classification.
Cs-137 was reported in a range of 2.77E-02 pCi/g to 7.41E-01 pCi/g. Co-60 was reported in a range of -1.40E-02 pCi/g to 6.23E-2 pCi/g. Characterization data did not identify Cs-137 or Co-60 in concentrations exceeding LTP specified Class 3 criterion for investigation and reclassification.

The 3.8 pCi/g was below the investigation criteria in Section 5.5.3 of the HNP LTP and did not require additional sampling or reclassification of this survey unit by the HNP LTP. This sample result was included in the data calculations and assessment as designed by the FSS Plan.

The means for the data presented in Tables 13 through Table 16 is 1.8 pCi/g, which is higher than what is generally observed, but can be explained by the use of truncated data sets (these were sample points biased around four (4) apparent elevated areas. The samples with elevated activity were associated with areas containing large amounts of organic material. The distance from the site facility (about one mile) and the absence of other licensed radioactivity material in significant quantities suggests a source other than site operation. Mechanical (washout and runoff) and organic accumulation of fallout (Cs-137) is the expected source.

2. Subdivision of Survey Unit 9523-0000

Reference: Book 2 of 16, Appendix A1

Page 4 indicates that the Survey Unit (SU) was split, with a new SU added: 9106-0000. This new SU is not shown on the map, and the split is not shown on the drawing, Figure 1-1, of Book 1, which still shows the survey unit as including the canal road and up to the canal edge.

2. Response

The "split" is minor with the boundary of SU 9523 along the Discharge Canal moved from one side of the road nearest to the canal to the opposite side of the road. The evaluation of this move determined that the integrity of the FSS area could be maintained and would provide isolation from future Discharge Canal activities. The scale of the map cannot show this minor change. All other plots indicate the correct location of this boundary on the Survey Unit side of the road.

This should read Survey Unit 9106, which is the Discharge Canal area. No new Survey Unit was created. Area from 9523 was added to existing Survey Units not yet ready for FSS.

3. Appendix A4, Survey Unit 9526-0000

The rationale for the Classification for this Survey Unit is questioned. Page 4 indicates that this area was impacted by two radiological events - (1) a 1979 stack release where short-lived radioactive materials were identified east of this area. CYAPCO indicates that after the 1979-era release and subsequent remediation, essentially all of Survey Unit 9526 was radiologically surveyed in 1980; and (2) the 1997 characterization survey identified Cs-137 in the area. In addition, the results for this SU do not appear to be much different from results from SU 9526-0001 and SU 9526-0002.

What is the basis for the areas chosen for gamma-scanning? Is it based on past events or judgmental based on site terrain or other judgmental factor?

3. Response

Although discrete spots of radioactive materials had been identified in this Survey Unit in the past, soil sampling and scanning results from 1997 as well as the time between 1979 to the present date (approximately 4 half-lives for Co-60) make it unlikely that the average residual radioactivity would exceed 5% of the 25 mR/yr DCGL.

The exact location of the "discrete" spots cannot be determined from historical records. The resultant samples for Survey Unit 9526-0000 show a mean of 0.08 or 8% of the 25 mR/yr DCGL, which is consistent with the survey design. This amount is consistent with fallout related background.

The area where the Co-60 was found was subdivided into Survey Units 0001 and 0002, and re-classified. Survey Units 0001 and 0002 were classified and created prior to the HNP LTP approval with concurrence from the NRC Inspector at the time. Additional details are provided in the appropriate reports.

The selection of the areas for scanning took into consideration the adjacent Survey Units, terrain, judgmental and available history. Area 5 was selected because of a possible pathway from the Stack release. Other areas were selected because of possible run-off collection points, pathways, and access.

4. Mean and Standard Deviation for SU 9535-0001

Reference - Book 1 of 16; Page 51, Table 5-1, Summary of Statistical Analysis.

The mean or average and the standard deviation for Cs-137 for the Survey Unit 9535-0001 appear to be in error. The calculated mean (0.642) and standard deviation (0.508) exceed the maximum value (0.313) in the 15-sample data set. Please explain how you calculated the mean and standard deviation since the results doesn't seem to be attributable to a misplaced decimal point.

4. Response

This is a data entry error (typo) and should be a mean of 0.0992 with a standard deviation of 0.065.

5. Appendix A10, SU 9535-0001, Table 6, Sample Numbers

The sample numbers sometimes include an "F" at the end, and sometimes do not. Are these the same samples? If so, the nomenclature should be consistent. This may apply to more than just the Table.

5. Response

This nomenclature change reflects changes in reporting protocol over a 3 or 4 year period. "F" will indicate final status survey samples, which are used in Table 6. Sample numbers are not "reused" in FSSs, sample 9535-0001-002 is the same as 9535-0001-002F.

B. Second Series of Comments/Questions Received on August 3, 2005

1. Use of Surrogates in detecting Hard-to-Detect Radionuclides

References: Book 11/16, 9535-0001 survey unit; Book 16/16, 9806-0000 survey unit, (or subsurface of 9535-0001 and 9535-0002 survey units); Health Physics Procedure GP-GGGR - R5112-001-Rev. CY-0001, attachment B.

The HNP License Termination Plan and several final status surveys reports refer to the use of surrogates for detecting hard-to-detect radionuclides. The referenced documents indicate that surrogates were used in detecting HTD radionuclides, but do not appear to provide any specific details or results.

The 9535-00001 final status survey records indicate that a surrogate relationship was developed for Cs-137 and Sr-90, Ni-63 and C-14. The records indicate that three samples were analyzed for the full suite of Easy to Detect (ETD) and HTD radionuclides by the offsite laboratory, and Ni-63 and Sr-90 were identified.

Sample calculation sheet (dated 4/19/2004) provides an activity ratio $f_{DTD:ETD}$ for Sr-90, Ni-63 and C-14 that doesn't seem to be consistent with the sample data results in the final status survey record.

The 9806-0000 final status survey records indicate that surrogates were developed for HTD radionuclides, and indicates that three (3) samples collected during landfill remedial actions were analyzed at offsite laboratory for the full suite of Easy-To-Detects and HTDs - identifying Cs-137, Co-60, Sr-90, Ni-63 and C-14.

Regarding Survey Units 9535-0001 and 9806-000, could CYAPCO provide specific information on the data used to establish the Cs-137/HTD ratio or ratios? Also, would CYAPCO describe how the surrogate ratio or ratios were used in these survey units?

1. Response

Surrogate relationships have been developed on only two (2) occasions, but they were not needed. In both cases, they corresponded with the same physical location at the landfill. This location contained a surface and a subsurface Survey Unit, referred to as 9535-0001 and 9806-0000 respectively. The specific information on how surrogate relationships were used for these areas is contained in the applicable Final Status Survey Plan (FSSP) for the two (2) Survey Units.

The following paragraphs from the applicable FSSPs will provide the necessary background information and rationale behind the use of surrogates for the two (2) Survey Units. It is noted that the surrogate relationship was assumed to be the same for both Survey Units since both Survey Units occupied the same physical location. For this reason, the two (2) Survey Units will be collectively referred to as "the survey area."

A remedial action plan was developed and implemented from July 30, 2003 through October 21, 2003 in the survey area. Soil was removed by an excavator and placed in containers for eventual transport and disposition. Soil remediation was followed by remedial action surveys conducted under an approved survey and sampling work plan and subsequent addendums. Remedial action surveys included scans with gamma sensitive equipment for elevated radioactivity and soil samples. Additional soil was removed when elevated areas of radioactivity were identified during the remedial action surveys.

During the course of remedial action, three (3) samples were collected and sent to an approved off-site laboratory for radionuclide specific analysis. These three (3) samples were associated with localized areas yielding the highest response to the gamma sensitive survey equipment. The requested analyses were for the full suite of easy-to-detect and hard-to-detect radionuclides. The gamma spectroscopy results reported maximum concentrations of 2.21 pCi/g and 52.9 pCi/g for Co-60 and Cs-137, respectively. The hard-to-detect analyses identified Sr-90, Ni-63 and C-14 as well in maximum concentrations of 2.74E-02 pCi/g, 1.6E+01 pCi/g and 6.29E-01 pCi/g, respectively.

The remedial action was completed on October 21, 2003, based on the final results of the final remedial action survey. About forty (40) containers (four thousand cubic feet (4,000 ft^3)) of material (including the soil from which the three (3) samples were collected) were removed from the area and shipped off-site as waste. The final remedial action survey in the survey area did not identify elevated areas of activity. Samples collected and analyzed following remediation did not identify plant-related radioactivity other than low-levels of cesium-137. Sample results for Cs-137 reported a maximum concentration of 8.35E-02 pCi/g, which is one percent (1%) of the soil DCGL.

Surrogate relationships were considered using the Data Quality Objective (DQO) process during the survey and sampling design phase of FSS. The final remedial action survey data provided sufficient evidence that Cs-137 concentrations would be well below the DCGL. Furthermore, the data led to the conclusion that Co-60, Sr-90, Ni-63 and C-14 would likely have been completely removed during the remedial action. Nevertheless, given that there was some uncertainty that remediation might not have removed all the suspect material, a surrogate relationship was established to be conservative.

Cs-137 was selected as the surrogate for the three hard-to-detect radionuclides. This was not the first choice for the FSSP designer. The FSSP designer would have preferred to empirically establish a correlation from the remedial action surveys. However, the remedial action left virtually no residual radioactivity by which to establish consistent ratios. For example, Co-60 would have been considered as a surrogate for the activation product Ni-63. However, the remedial action data indicated that Co-60 would likely be reported at concentrations below the minimum detection criteria and would not provide a meaningful relationship.

Therefore, Cs-137 was established as the surrogate for all the hard-to-detect radionuclides since it was likely to be the only easy-to-detect radionuclide present in sufficient quantities at the time of FSS. The FSSP identified three (3) samples for measurements to include analysis for hard-to-detects. This was twenty percent (20%) of the measurements used to demonstrate compliance which is more than the ten percent (10%) recommended by MARSSIM.

The surrogate ratios were determined from the three (3) samples previously discussed. A representative mix was determined from the three samples processed off-site and the 95% upper bound of the surrogate ratios was used to account for the variability and level of uncertainty in the data. This approach is consistent with the MARSSIM and is expected to produce a conservative value for the surrogate ratios as they are based on very high concentrations of activity that are not expected to be present in the landfill based on the remedial action survey data.

The general use of the surrogate relationship is explained by Section 5.4.7.3 of the HNP LTP. This section also provides a formula for performing the calculation for singular radionuclide relationships. The surrogate relationship can also be used for multiple radionuclides using an adaptation of the same relationship. The following equations show the derivation of a simple recurrence formula based on the surrogate relationship described by the LTP.

$$\frac{C_{ETD}}{DCGL_{Surrogate}} = \frac{C_{ETD}}{DCGL_{ETD}} + \frac{C_1}{DCGL_1} + \frac{C_2}{DCGL_2} + \frac{C_3}{DCGL_3}$$

Equation 1

or, for simplification

$$\frac{C_E}{D_{Surrogate}} = \frac{C_E}{D_E} + \frac{C_1}{D_1} + \frac{C_2}{D_2} + \frac{C_3}{D_3}$$

Equation 2

$$\frac{C_E}{D_{Surrogate}} = \frac{(C_E D_1 D_2 D_3) + (C_1 D_E D_2 D_3) + (C_2 D_E D_1 D_3) + (C_3 D_E D_1 D_2)}{(D_E D_1 D_2 D_3)}$$

Equation 3

$$\frac{DCGL_{Surrogate}}{C_E} = \frac{(D_E D_1 D_2 D_3)}{(C_E D_1 D_2 D_3) + (C_1 D_E D_2 D_3) + (C_2 D_E D_1 D_3) + (C_3 D_E D_1 D_2)}$$

Equation 4

$$DCGL_{Surrogate} = \frac{(D_E D_1 D_2 D_3)}{(D_1 D_2 D_3) + (\frac{C_1}{C_E} C_1 D_E D_2 D_3) + (\frac{C_2}{C_E} C_2 D_E D_1 D_3) + (\frac{C_3}{C_E} C_3 D_E D_1 D_2)}$$

Equation 5

$$DCGL_{Surrogate} = \frac{(D_E D_1 D_2 D_3)}{(D_1 D_2 D_3)+(f_1 D_E D_2 D_3)+(f_2 D_E D_1 D_3)+(f_3 D_E D_1 D_2)}$$

Equation 6

where
D_E ≡ the DCGL for the easy-to-detect radionuclide
D_1 ≡ the DCGL for the first hard-to-detect radionuclide
D_2 ≡ the DCGL for the second hard-to-detect radionuclide
D_3 ≡ the DCGL for the third hard-to-detect radionuclide
f_1 ≡ the activity ratio of the first hard-to-detect radionuclide to the easy-to-detect radionuclide
f_2 ≡ the activity ratio of the second hard-to-detect radionuclide to the easy-to-detect radionuclide
f_3 ≡ the activity ratio of the third hard-to-detect radionuclide to the easy-to-detect radionuclide

The FSSP further reduced the Cs-137 DCGL by 60% to achieve the administrative level of ten millirem in a year (10 mR/year) Total Effective Dose Equivalent (TEDE).

A review of the FSS data from Book 11 of 16 shows that Cs-137 was detected in low concentrations in all fifteen (15) samples used to demonstrate compliance. The sample results for Cs-137 reported a mean concentration of 9.92E-02 pCi/g; which compares well to the maximum concentration reported following remedial action (8.35E-3 pCi/g). Again, the mean value for Cs-137 represents one percent (1%) of the soil DCGL.
The FSS data from Book 11 of 16 also shows that Sr-90, Ni-63 and C-14 were reported at low concentrations. As expected, the final ratios are somewhat different that those assumed during design of the FSSP given the low-levels of reported Cs-137. Using the final ratios in conjunction with Equation 6 above and assuming all three (3) hard-to-detect radionuclides are present yields a Cs-137 surrogate DCGL of 1.22 pCi/g. This value is forty-three percent (43%) of the Cs-137 surrogate DCGL specified by the FSSP. However, the FSS data clearly shows the mean Cs-137 concentration to be well below the lower surrogate DCGL value of 1.22 pCi/g.

Surrogate relationships were not necessary in this survey area given the low levels of residual radioactivity following remedial action. The decision to perform sufficient hard-to-detect analyses during FSS was consistent with the recommendation of the MARSSIM. The reported mean Cs-137 concentration was well below the retrospective surrogate DCGL determined using methodology from the HNP LTP.

2. Final Status Survey Documents and Links to Past Contamination Events

References: Final Report Phase II, Book 1/16

The reference indicates that 2 of 140 identified events at the HNP had the potential to result in contamination of plant property. These two events listed are the December 1979 stack release and the waste materials disposed in the Southeast Landfill area.

Three (3) Survey Unit 9535-0001, 9535-0002 and 9806-0000 (for Survey Unit 9535 subsurface) final status surveys documents are provided for the Southeast Landfill surface and subsurface areas. The Southeast Landfill Area was remediated during July - October 2003. The final status survey records for the Southeast Landfill area appear to be adequately documented.

The December 1979 event is described in the HNP License Termination Plan, but adequate references are not provided in the Final Status Survey Reports, and CYAPCO had not linked its final status surveys efforts to the identification of the scope and extent of the 1979 event.

Does CYAPCO identify the areas undergoing final status surveys that may have been impacted by the December 1979 release? Were there areas in Phase II of the final status survey efforts that may have been impacted? If not already addressed, it may be appropriate to overlay the footprints of any past releases over the map or locations of current final status survey efforts, and discuss and/or link those past and present survey efforts.

2. Response

The Haddam Neck Plant (HNP) LTP identifies all known events, including the 1979 releases, for the Survey Units undergoing FSS. This is done during the final classification process where events impacting a Survey Unit are identified using the *10CFR 50.75(g)(1)* database and historical files and other site specific records (e.g., Historical Site Assessment Supplement). The impact of radiological events is evaluated during the design phase of the FSSP using the DQO process. Outputs of the DQO process could include additional scanning and biased sampling.

There were areas impacted by the 1979 releases. These are identified in the Release Records under the section for the classification basis. For example, for Survey Unit 9526-0000 in Book 5 of 16, the classification basis which starts on page three (3) and continues through page five (5) provides information on the 1979 release events. Other impacted Survey Units in areas of the Phase II include Survey Units 9526-0001, and 9526-0002 and 9525-0000.

3. Survey Unit Classification and Comparison of FSS Data with Cs-137 Background Study

References: HPD Technical Support Document BCY-HP-0063, Revision 0, *Background Cs-137 Concentration in Soil*; Table 5-1 in Book 1/16; Tables 6, 13, 14, & 15 in Book 2/16

NRC still has concerns about the classification of Survey Units. Several Survey Units have Cs-137 soil concentrations approaching a significant fraction of the administrative DCGL. The classification of an area as a Class 3 Survey Unit versus a Class 2 Survey Unit may result in a survey design that may not detect applicable radionuclides. Also, there appears to be a basic difference between the Cs-137 background study data and several FSS data since a number of samples in the FSS (Survey Units 9523-0000, 9526-0000) exceed the expected upper bounds of the background study.

NRC has reviewed the HPD Technical Support Document BCY-HP-0063, Revision 0, '*Background Cs-137 Concentration in Soil*'. The Cs-137 data in Book 1/16, Table 5-1, and Book 2/16, Tables 6, 13, 14, 15 appear to be significantly different from the Cs-137 background study data. The criteria that CYAPCO has used in the FSS has been the administrative DCGL, and the criteria do not appear to have been exceeded. But some of the Cs-137 final status survey data exceeded the expected upper bounds of the Cs-137 background study, and raises questions about Cs-137 background in several Survey Units.

Does CYAPCO consider the Cs-137 soil concentrations identified in several Survey Units release records (i.e., Survey Unit 9523-0000, Survey Unit 9526-0000) to be consistent with the Cs-137 background study data? If CYAPCO considers the Cs-137 background study to be representative of the Cs-137 in the Phase II Survey Units then a more detailed explanation is needed since some of the final status survey data clearly exceed the expected upper bounds of the Cs-137 background study.

3. Response

The background study was generated to provide a basis for the evaluation and disposition of soil at off-site locations during the Off-site Material Recovery Program (OMRP). Accordingly, it was used to support the final survey of property not owned or controlled under the HNP License. Nevertheless, the study has been a useful tool to compare and evaluate on-site soil data during the DQO process for the design phase of the FSSP. The range of Cs-137 concentrations provided by the background study help identify outliers in on-site sample results.

Investigation levels are established in the FSSP to identify when a measurement begins to deviate from expected norms and to confirm that Survey Units have been properly classified. Measurements approaching investigation levels, which the HNP LTP defines as fractions of the DCGLs, are reviewed to see if reclassification of the Survey Unit is necessary. The HNP LTP establishes the investigation level at fifty percent (50%) of the DCGL for Class 3 units. The HNP LTP required investigation level would therefore be 3.96 pCi/g for Survey Unit 9523-0000.

The FSSP established the investigation criteria for Cs-137 in soil at 1.58 pCi/g, based on achieving the administrative level of ten (10) mrem a year (mR/yr) TEDE. The investigation level is lower than the HNP LTP required investigation level and the 98th percentile value for Cs-137 (1.68 pCi/g) provided by the background study BCY-HP-0063.

The apparent elevated Cs-137 soil concentrations found during the FSSs of Survey Units 9523-0000 and 9526-0000 are outliers and are not consistent with the background study described by BCY-HP-0063. The apparent elevated concentrations have not exceeded the investigation criteria for Class 3 area as specified in Section 5.5.3 of the HNP LTP (i.e., perform investigation when samples exceed 0.5 times the DCGL). Therefore, no investigation or reclassification was necessary by the HNP LTP.

References: Book 1/16, on pages 31 and 53

These pages contain statements regarding the explanation of Cs-137 levels identified in final status surveys, and these statements appear to need additional explanation and/or clarification in the documentation.

Page 31 in Identification of Potential Contaminants, indicates that a majority of the Cs-137 soil concentrations were below or at the Cs-137 background study concentrations. However, some of the Cs-137 data does not appear to be consistent with the Cs-137 background study data since the FSS data exceeds the expected upper bounds of the study data.

Page 53 in Comparison of Findings with DCGLs, indicates that Cs-137 soil concentrations in wetlands and rocky slopes reflect a mechanism for concentrating the radionuclide of concern, and additional sampling would only produce the same results. Also, CYAPCO indicates that this event has been researched and this type of occurrence is common and well documented in other regions of the United States.

Would CYAPCO provide the applicable reference(s) that link the Cs-137 concentration phenomenon identified at the HNP with similar phenomena in other areas of the USA? NRC also believes that additional explanation and/or clarification is needed for these statements in the final status survey reports.

4. Response

Research studies for the United States Department of Agriculture include using Cs-137 redistribution to measure soil movement due to erosion and deposition[2]. The same group, Agricultural Research Service (ARS) provides a very detailed bibliography of Cs-137 studies related to soil erosion and sediment studies[3]. The bibliography includes studies performed in the United States[4].

Another publication, a paper published by the Health Physics Society in 2002[5], discusses several mechanical processes that, "effect the movement of radionuclides in the temperate environments post-deposition." Included in these processes is the weathering of radionuclides into deeper soil layers from the soil surface. While the paper limits scope to vertical migration into a vertical column of soil, the concept of "weathering" and gravitation settling can be applied to the phenomena we have identified here. The accumulation and concentration of Cs-137, which has been observed at the HNP, can be explained by washout due to heavy rains from steep rocky crags and ledges to low-lying areas with well defined vegetation and root systems.

Although data were not provided, the principle is clear. Cs-137 concentrations will be less where there is erosion and Cs-137 concentrations will be higher where there is deposition. The amount of erosion and deposition would be dependent on the permeability of the soil and the slope of the land. The Release Record for Survey Unit 9523-0000 describes the topography on page 3 as ranging from "low, flat wetlands to steep, rock hillsides." These physical features would be expected to enhance the conditions by which runoff occurs. The outcome is redistribution and accumulation of Cs-137 as was identified during the FSS.

The highest Cs-137 concentration identified during the FSS of Survey Unit 9523-0000 was 3.83 pCi/g. This concentration is less than the investigation level of 3.96 pCi/g required by the HNP LTP. Therefore, no investigation or reclassification was required or necessary per the HNP LTP. The Survey Unit is properly designated as Class 3.

CY Technical Support Document BCY-HP-0063

In CY technical support document BCY-HP-0063, rev. 0, Background Cs-137 Concentration in Soil, page 5 states that for survey areas with results between 1.68 and 2.6 pC/g, CYAPCO will apply the WRS test (Scenario B version) to test if the concentrations are indistinguishable from background.

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[2]http://www.ars.usda.gov/research/publications/Publications.htm?seq_no_115=146981.
[3] http://hydrolab.arsusda.gov/cesium/BiblioCs1372005.pdf.
[4]McHenry, J.R., J.C. Ritchie, and G.B. Bubenzer. 1978. Redistribution of Cs-137 due to erosional processes in a Wisconsin watershed. pp. 495-503. In: D.C. Adriano and I.L. Brisbin Jr. (eds.), Environmental Chemistry and cycling processes. USDOE CONF-760429, US Department of Energy, Washington, DC.
[5]L. Anspaugh, S. Simon, K. Gordeev, I. Likhtarov, R. Maxwell, and S. Shimlaavey – 2002 Movement of Radionuclides in Terrestrial Ecosystems by Physical Processes.

This test was not described in the FSSR for Survey Unit 9523 (this reviewer did not see it).

5. Response

The background study was generated to provide a basis for the evaluation and disposition of soil at off-site locations during the Off-site Material Recovery Program (OMRP). Accordingly, the study was used to support the final survey of property not owned or controlled under the HNP license. The goal of the OMRP was to demonstrate that no plant licensed material that was distinguishable from background was present at the off-site locations whereas the HNP LTP criteria are different. The background study does use the term "survey areas"; however, it is important to distinguish the difference between an off-site survey area as described by the background study and a licensee controlled survey unit described by the HNP LTP.

The background study does not explicitly or implicitly provide requirements with regard to final status survey design. The HNP LTP alone provides the process for performing FSS and the method for demonstrating that the site meets the criteria for release for unrestricted use.

C. Third Series of Comments/Questions discussed on September 22, 2005

Comment 1(Reference - response to question 1 received on August 3, 2005)

The NRC was unable to determine from the previous response if surrogate ratios were developed and/or used for some Survey Units.

Response 1

Surrogate relationships have been developed on only two (2) occasions, but they were not needed or used. Please refer to earlier response to NRC Question #1 under "Second Series of Comments/Questions Received on August 3, 2005."

Comment 2 (Reference - response to question 4 received on August 3, 2005)

Applicable reference(s) are needed that address Cs-137 observed disposition patterns in the northeast United States.

Response 2

The applicable references are provided in the earlier response to NRC Question #4 under "Second Series of Comments/Questions Received on August 3, 2005."

Comment 3 (Reference - response to question 3 received on August 3, 2005)

Cs-137 Background Study, TSD-BCY-HP-0063, contains information that suggests that further analysis of Cs-137 data in the 1.68 to 2.6 pCi/g range will be done. Please clarify the purpose of the Cs-137 Background Study and the purpose of the data analysis referenced.

Response 3

Health Physics Technical Support Document (TSD) BCY-HP-0063, *"Background Cs-137 Concentration in Soil"*, was developed in support of the OMRP to evaluate the presence of Cs-137 at off-site locations for the purpose of recovering plant-related radionuclides from the properties. During the historical site assessment of the Haddam Neck Plant, it was identified that low levels of radioactive material were inappropriately released from the site. The radioactive material in the form of concrete shield blocks, soil and other miscellaneous materials were removed from the site by CYAPCO employees and used/stored on their private properties. CYAPCO management committed to removing the licensed radioactive material from the impacted properties. Due to the presence of Cs-137 in background from fallout of atmospheric nuclear testing of atomic weapons and reactor accidents, the TSD was developed to ensure that the removal of the radioactive material was limited to the licensed activity and not the background cesium. The TSD develops a method for evaluation of Cs-137 concentrations in soil between 1.68 pCi/g and 2.6 pCi/g. Because the requirement of the OMRP was to determine if the contamination levels at the off-site property are indistinguishable from background (Scenario B of MARSSIM, NUREG-1575), the use of the Wilcoxon Rank Sum statistical test is required. The HNP LTP implements the requirements of 10CFR20.1402 which states in part:

> *"A site will be considered acceptable for unrestricted use if the residual radioactivity that is distinguishable from background radiation results in a TEDE to an average member of the critical group that does not exceed 25 mrem (0.25mSv) per year..."*

The primary difference between the two methods is license termination allows residual radioactivity to be present above background and the OMRP was to demonstrate that residual radioactivity was indistinguishable from background. The Final Status Survey Final Report Phase II addresses background in several sections. Section 2.2, Survey Design, discusses Cs-137 and Sr-90 background as a portion of the total concentration identified in soil samples. The section describes the DQO process as used in the survey design which determined that background subtraction would not be applied during the survey of the land areas included in the submittal. Section 4.3, Background Determination, states that background for soil samples was not calculated nor included in the DCGL comparisons to sample data. The TSD was provided as reference for this section; however, the last statement of the first paragraph of the section reiterates that none of the radionuclide concentrations believed to be non-HNP derived were subtracted from the DCGL comparisons for Phase II Survey Units.

In practice, these statements commit CYAPCO to performing the statistical testing of the Phase II Survey Units using the uncorrected data collected from the Survey Units. The background levels that could be attributed to fallout are conservatively considered to be CYAPCO derived and are included in the compliance measurements for each Survey Unit. This allows CYAPCO to perform the Sign Test as described in the survey design DQOs and the HNP LTP. This practice is consistent with the guidance of Section 5.5.2.3 of NUREG-1575, MARSSIM, which states in part:

"For the situations where the contamination is not present in background or is present at such a small fraction of the $DCGL_W$ *as to be considered insignificant, a background reference area is not necessary. Instead, the contamination levels are compared directly with the DCGL value."*

The Administrative Level DCGL value selected for the Phase II Survey Units for Cs-137 is 3.16 pCi/g. This concentration is 40% of the 25 mrem/year DCGL of 7.91 pCi/g. The decision by CYAPCO to declare all concentrations of Cs-137 identified in the Phase II Survey Units as plant derived establishes a substantially conservative decision for declaring the survey units satisfy the release criteria. The use of the Wilcoxon Rank Sum (WRS) statistical test if used in subsequent Phase Survey Units will be evaluated and reported in the appropriate Final Report.

It is appropriate to reference this TSD in the Phase II Reports as the sample data contained therein is applicable. The TSD states that it was developed for the OMRP which makes the requirement to use the WRS test only applicable to the OMRP.

Docket No. 50-213
CY-05-239

Enclosure 1
Haddam Neck Plant
Response to NRC Staff Comments/Questions on
Final Status Survey (FSS) Final Report – Phase II

1. Appropriate Sections of Procedure RPM 5.1-12 (page 5) and sample calculation sheet
2. Appropriate Sections of FSS Plan – GPP-GGGR-R5111 (pages 7 through 11)

December 2005

Sample Number Calculation Sheet – Multiple Radionuclides

Survey Area Number: 9535				
Survey Unit Number: 0001				
Classification: 1				
INPUT PARAMETERS FROM DQOs	*VALUE(S)*			
Type I error (α)	0.05			
Type II error (β)	0.05			
Easy to detect radionuclides:	Cs-137			Co-60
Radioactive concentration variability (Standard Deviation (σ)) Source Document: Remedial Action Plan BCY-SSWP-03-07-003 final results (see attached sheet (1))	1.21E-01			6.15E-03
Difficult to detect radionuclides (see attached sheet (1):	Sr-90	Ni-63	C-14	N/A
Activity ratio ($f_{DTD:ETD}$):	0.0103	1.02	0.0255	N/A
CALCULATIONS	*VALUE(S)*			
DCGL	3.16			1.52
Surrogate DCGLs:	2.82			N/A
Radioactive concentration variance of the weighted sum (Standard Deviation (σ)):	4.31E-02			
RESULTS	*VALUE*			
Operational DCGL	1.0			
LBGR	0.5			
Shift (Δ)	0.5			
Calculated Relative Shift (Δ/σ)	12			
Adjusted Relative Shift (refer to Step 3.4.7) when required, otherwise N/A	2			
Adjusted LBGR (refer to Step 3.4.8) when required, otherwise N/A	0.91			
Number of samples (N)	15			

Performed by: Jack McCarthy [signature] Date: 4/19/2004

Independent Review by: [signature] Date: 4/19/04

rRELIMINARY DATA REVIEW FORM

Survey Plan No. :	BCY-SSWP-03-07-003
WP&IR No. :	N/A
Survey Unit :	9535-0001
Survey Unit Name :	Southeast Landfill Area
Classification :	1
Survey Media :	Soil
Type of Survey :	Remedial Action Survey
Type of Measurement :	Radionuclide Specific
Number of Measurements :	6

BASIC STATISTICAL QUANTITIES

		Cs-137	Co-60
RANGE	Minimum Value :	8.35E-02	1.49E-03
RANGE	Maximum Value :	4.08E-01	1.56E-02
	Mean :	2.11E-01	7.15E-03
	Median :	1.82E-01	4.87E-03
	Standard Deviation :	1.21E-01	6.15E-03

	RADIONUCLIDE CONCENTRATION (pCi/g)			
NUMBER	Cs-137	ID?	Co-60	ID?
9535-0001-042R	4.080E-01	Y	2.138E-03	
9535-0001-043R	1.776E-01	Y	1.395E-02	
9535-0001-044R	2.963E-01	Y	1.557E-02	
9535-0001-045R	1.140E-01	Y	1.485E-03	
9535-0001-046R	8.348E-02	Y	6.378E-03	
9535-0001-047R	1.870E-01	Y	3.360E-03	

Comments: Contains all third phase remedial action sample results. No elevated readings identified during survey of 100% of impacted area.

[signature] 4/1/04
Submitted by/Date

3.4.4 IF not already performed during the DQO process, THEN CALCULATE the measurement standard deviation of the weighted sum (σ) using the following formula AND RECORD the result in the space provided.

$$\sigma = \sqrt{\sum_{1}^{n}\left(\frac{\sigma_i}{DCGL_i}\right)^2}$$

where:

n ≡ total number of radionuclides of interest
σ_i ≡ standard deviation of the ith radionuclide
$DCGL_i$ ≡ DCGL of the ith radionuclide or DCGL of surrogate

NOTE
The Operational DCGL is set to one (1) for using the unity rule.

3.4.5 OBTAIN the LBGR from the FSSP and RECORD in the space provided.

3.4.6 CALCULATE the Shift (Δ) by subtracting the LBGR from the DCGL and RECORD in the space provided.

3.4.7 DETERMINE the Relative Shift (Δ/σ).

a. DIVIDE the Shift (Δ) by the measurement standard deviation of the weighted sum for the radionuclides of interest.

b. RECORD the result in the space provided.

c. IF the resulting Relative Shift is between one (1) and three (3), THEN GO TO Step 3.4.10. OTHERWISE PROCEED to the next step.

d. IF the Relative Shift is greater than three (3), THEN RECORD a value of two (2) as the adjusted Relative Shift in the space provided AND GO TO Step 3.4.8.

e. IF the Relative Shift is less than one (1), THEN STOP AND RETURN to the DQO process to determine the cause and/or make adjustments to the DQOs.

3.4.8 CALCULATE the adjusted LBGR by multiplying the measurement standard deviation of the weighted sum times two (2), then subtracting the product from the DCGL.

3.4.9 RECORD the adjusted LBGR value in the space provided.

5 Pages

Table 3 – Basic statistical quantities for cesium-137 and cobalt-60 from the population data set obtained during the characterization survey. Cesium-137 was identified in 6 of the 6 samples. Cobalt-60 was not identified in any of the samples.

	Cesium-137 (pCi/g)	Cobalt-60 (pCi/g)
Minimum Value:	8.35E-02	1.49E-03
Maximum Value:	4.08E-01	1.56E-02
Mean:	2.11E-01	7.15E-03
Median:	1.82E-01	4.87E-03
Standard Deviation:	1.21E-01	6.15E-03
Radioactive concentration variance of the weighted sum(1):	7.27E-02	

(1) MARSSIM Section I.11.3 describes the use of the radioactive concentration variance of the weighted sum when measured concentrations of the various radionuclides are assumed to be uncorrelated (i.e., there is no fixed ratio between the concentrations).

The scoping, characterization and remedial action survey data indicates that five of the twenty listed radionuclides may be potentially present in this survey unit at the time of FSS. It is unlikely that the other fifteen radionuclides will be identified or the aggregate concentration will exceed 10%. Furthermore, cesium-137 attributed to past atmospheric nuclear weapons testing will be assumed to be present in the sampling media for the purpose of survey design. The "Base Case" DCGLs for cesium-137 and cobalt-60 will be reduced by 60% to achieve the administrative level of 10 mrem/year TEDE. Since there are multiple radionuclides in the survey unit, compliance with the release criteria will be assessed through use of the unity rule, also known as the sum of the fractions. The unity rule, represented by Equation 2, is satisfied when radionuclide mixtures yield a combined fractional concentration limit that is less than or equal to one.

$$1 \geq \frac{C_1}{DCGL_1} + \frac{C_2}{DCGL_2} + \ldots + \frac{C_n}{DCGL_n}$$ *Equation 2*

Surrogate relationships will be used to relate easy-to-detect concentrations to strontium-90, carbon-14 and nickel-63. Cesium-137 will be the surrogate for the three hard-to-detect radionuclides. Cobalt-60 was considered as a surrogate for the activation products carbon-14 and nickel-63. However, the remedial action data indicates that cobalt-60 will likely be reported at concentrations below the minimum detection criteria and will not provide a meaningful relationship. Therefore, cesium-137 is considered acceptable as the surrogate since it is likely to be the only easy-to-detect radionuclide of concern present in sufficient quantities at the time of final status survey. The surrogate ratios were determined from data obtained during the remedial action of the landfill. Survey and sampling was performed throughout the remediation action of the landfill. Three samples yielding the highest cesium-137 and cobalt-60 concentrations were processed offsite for the easy-to-detect and hard-to-detect radionuclides. A representative mix was determined from the three samples processed off-site and the 95% upper bound of the surrogate ratios was used to account for the variability and level of uncertainty in the data. This approach is consistent with the MARSSIM and is expected to produce a conservative value for the surrogate ratios as they are based on very high concentrations of activity that are not expected to be present in the landfill based on the remedial action survey data.

The general use of the surrogate relationship is explained by Section 5.4.7.3 of the LTP. This section also provides a formula for performing the calculation for singular radionuclide relationships. The surrogate relationship can also be used for multiple radionuclides using an adaptation of the same relationship. The following equations show the derivation of a simple recurrence formula based on the surrogate relationship described by the LTP.

$$\frac{C_{ETD}}{DCGL_{Surrogate}} = \frac{C_{ETD}}{DCGL_{ETD}} + \frac{C_1}{DCGL_1} + \frac{C_2}{DCGL_2} + \frac{C_3}{DCGL_3} \qquad \textit{Equation 3}$$

or, for simplification

$$\frac{C_E}{D_{Surrogate}} = \frac{C_E}{D_E} + \frac{C_1}{D_1} + \frac{C_2}{D_2} + \frac{C_3}{D_3} \qquad \textit{Equation 4}$$

$$\frac{C_E}{D_{Surrogate}} = \frac{(C_E D_1 D_2 D_3)+(C_1 D_E D_2 D_3)+(C_2 D_E D_1 D_3)+(C_3 D_E D_1 D_2)}{(D_E D_1 D_2 D_3)} \qquad \textit{Equation 5}$$

$$\frac{DCGL_{Surrogate}}{C_E} = \frac{(D_E D_1 D_2 D_3)}{(C_E D_1 D_2 D_3)+(C_1 D_E D_2 D_3)+(C_2 D_E D_1 D_3)+(C_3 D_E D_1 D_2)} \qquad \textit{Equation 6}$$

$$DCGL_{Surrogate} = \frac{(D_E D_1 D_2 D_3)}{(D_1 D_2 D_3)+(\frac{C_1}{C_E} C_1 D_E D_2 D_3)+(\frac{C_2}{C_E} C_2 D_E D_1 D_3)+(\frac{C_3}{C_E} C_3 D_E D_1 D_2)} \qquad \textit{Equation 7}$$

$$DCGL_{Surrogate} = \frac{(D_E D_1 D_2 D_3)}{(D_1 D_2 D_3)+(f_1 D_E D_2 D_3)+(f_2 D_E D_1 D_3)+(f_3 D_E D_1 D_2)} \qquad \textit{Equation 8}$$

where
D_E ≡the DCGL for the easy-to-detect radionuclide
D_1 ≡the DCGL for the first hard-to-detect radionuclide
D_2 ≡the DCGL for the second hard-to-detect radionuclide
D_3 ≡the DCGL for the third hard-to-detect radionuclide
f_1 ≡the activity ratio of the first hard-to-detect radionuclide to the easy-to-detect radionuclide
f_2 ≡the activity ratio of the second hard-to-detect radionuclide to the easy-to-detect radionuclide

f_3 ≡the activity ratio of the third hard-to-detect radionuclide to the easy-to-detect radionuclide

The "Base Case" DCGLs for cesium-137 and cobalt-60 are reduced by 60% to achieve the administrative level of 10 mrem/year TEDE. The reduced DCGLs for cesium-137 is used in conjunction with Equation 6 to establish the surrogate DCGL. Table 4 provides the surrogate DCGL for cesium-137 and cobalt-60 and the Operational DCGL to achieve the unity rule for demonstrating compliance with the release criteria. Note, meeting the administrative level automatically meets the release criteria by design.

Table 4 – Surrogate and administrative DCGLs for Cesium-137 and cobalt-60.

RADIONUCLIDE	DCGL (pCi/g)
Cs-137	2.82E+00
Co-60	1.52E+00
Operational DCGL	1 (unity rule)

Three (3) of the samples collected under this sample plan will be analyzed for all the radionuclides listed in Table 2 as an added measure to verify that the ratios are conservative . The three samples represent 20% of the number of samples that will be used for non-parametric statistical testing. Selection of samples for complete analysis will be randomly selected from the list of sample locations provided further on in this sample plan. All radionuclides listed in Table 2 that are verified to be present in FSS samples will be included in the assessment of data and incorporated into the decision process as necessary.

Basis for Determining the $DCGL_{EMC}$: The Operational DCGL was established for the average residual contamination in the survey unit. The $DCGL_{EMC}$ represents the dose to an individual from residual contamination over a smaller area. The $DCGL_{EMC}$ is defined as the product of the applicable DCGL and a scaling factor known as the area factor. The derived concentration guideline level for the EMC applicable to radionuclide i is:

$$DCGL^{i}_{EMC} = (A_F^{\,i})(DCGL_W^{\,i})$$ *Equation 9*

where A_f ≡area factor
$DCGL_w$ ≡the applicable DCGL

The radionuclides of concern have been determined to be cesium-137 and cobalt-60. The area factors for these radionuclides are a function of the sample density, that is, the number of samples in the survey unit. Station procedures refer to this as the Sample Size Factor which is the area of the survey unit, in square meters, divided by the number of samples. The area of the survey unit is 1860 m^2 and the expected number of samples for non-parametrical statistical samples is fifteen (15). The resulting Sample Size Factor is 124. The area factor for each radionuclide is then determined from Table 5-5 of the LTP by selecting the closest listed area size that is equal to, or greater than, the Sample Size Factor. Table 5 provides applicable DCGLs, area factors and $DCGL_{EMC}$ for cesium-137 and cobalt-60.

Table 5 – $DCGL_{EMC}$ for Cs-137 and Cobalt-60.

	Cesium-137	Cobalt-60
DCGL (pCi/g)	2.82E+00	1.52E+00
Area Factor	2.54	1.3
$DCGL_{EMC}$	7.16E+00	1.98E+00

Basis for Scan Measurements: Scanning is the process by which the operator uses portable radiation detection instruments to detect the presence of radionuclides on a specific surface (e.g., surface soil). A scanning survey is used to identify areas of elevated activity on that surface. This sampling plan augments sampling with scan measurements for elevated levels of radioactivity. Under the LTP, the level of scanning coverage required for a given survey unit is determined by the potential for residual contamination as reflected by its classification. The LTP specifies a required scanning coverage fraction of 100% for outdoor Class 1 areas. The final remedial action survey scan and sample data results indicate a low probability of finding areas of elevated activity. Nevertheless, the historical use of the landfill area to store materials and spoils from construction projects and the relatively small area of the survey unit justify scan coverage representing 100% of the total area.

Basis for Quality Control (QC) Measurements: In addition to the above requirements, 10% of those samples taken for non-parametric statistical testing will be selected for QC evaluation. This evaluation will consist of split samples, that is, homogenized samples from one location that are divided and treated as separate samples. Split sample locations will be determined randomly. Additional sample media will be collected from each location should a third party (e.g., USNRC, CTDEP) request split samples for comparison.

Basis for the Investigation Levels: Investigation levels also serve as a quality control check to determine when a measurement process begins to deviate from expected norms. For example, a measurement that exceeds an investigation level may indicate an improper measurement. However, in general, investigation levels are used to confirm that survey units have been properly classified.

Exceeding an Investigation Level will require additional actions as identified later in this sample plan. The Investigation Levels specific to this survey unit are provided in Table 6.

Table 6 – Investigation Levels (based on Table 5-8 of the LTP). The criteria is based on any measurement meeting or exceeding the $DCGL_{EMC}$.

For samples	For scan measurements
≥7.16 pCi/g for cesium-137 or ≥1.98 pCi/g for cobalt-60 or the unity rule when both are reported above the accepted criteria for detection	>12000 cpm

The basis for the $DCGL_{EMC}$ for samples has been discussed previously in this sample plan. The $DCGL_{EMC}$ for scans is based on Technical Support Document (TSD) BCY-HP-0081, revision 4. Table 1 of this TSD relates instrument response in counts per minute (cpm) to scan MDC. Assuming that the instrument must achieve a scan sensitivity of 7.39 pCi/g for cesium-137 and 1.8 pCi/g for cobalt-60 corresponds to an instrument response of 12000 cpm (12 kcpm). Ambient background in the area currently ranges from 6 kcpm to 9 kcpm.

Elevated Measurement Comparison (EMC) will be performed when a measurement from the survey unit is equal to or exceeds the investigation level. The EMC will be performed for both measurements associated with systematic sampling grid and for locations flagged during scanning. The elevated measurement comparison test (EMC) will be used against the investigation levels to evaluate relatively high measurements. The primary purpose of the EMC is to identify potential failures in the remediation process.

During investigation the true extent of the area of elevated activity will be determined through a combination of scanning and sampling. The actual area of elevated activity will be considered to be bounded by concentration measurements below the applicable DCGL for cesium-137 and cobalt-60. The EMC will use the unity rule to ensure that the total dose is within the release criteria. The unity rule for total dose from radionuclide i is derived from Equation 5-58 of LTP as follows:

$$\frac{\delta}{DCGL_W} + \frac{(\overline{C}_{elevated} - \delta)}{(\text{Area Factor})(DCGL_W)} < 1$$ *Equation 10*

$$\frac{\delta}{DCGL_{op}} + \frac{(\overline{C}_{elevated} - \delta)}{(DCGL_{EMC})} < 1$$ *Equation 11*

$$\frac{\delta^i}{DCGL_{op}^i} + \frac{(\overline{C}_{elevated}^i - \delta^i)}{(DCGL_{EMC}^i)} < 1$$ *Equation 12*

where δ ≡average concentration outside the elevated area
$DCGL_{op}$ ≡the applicable DCGL
$\overline{C}_{elevated}$ ≡average concentration in the elevated area
$DCGL_{EMC}$ ≡the applicable $DCGL_{EMC}$

A separate term will be used in Equation 10 for each elevated area.

Sampling and Analysis Methods to Meet the Data Requirements: The media will consist of surface soil, that is, the soil in the top 15 cm (6 inches) depth. The samples will be collected with new or decontaminated tools to minimize cross-contamination between sampling. Samples will be sent to an approved off-site laboratory. Results exceeding the investigation level will be verified and evaluated as necessary. Several judgmental samples will be taken in the area where remedial action has occurred. These samples will be sent to an approved off-site laboratory. Elevated results will be investigated and evaluated. Elevated results, with regard to the judgmental samples refers to a concentration that differs more than three standard deviations from the mean concentrations used for characterization as described by Table 3.

Samples analyzed off-site at an approved laboratory will be prepared in accordance with approved vendor procedures and analyzed by gamma spectroscopy. Samples processed off-site for HTD radionuclides (e.g., Sr-90, Pu-239/240) will be analyzed using alpha spectroscopy or other radiochemistry methods (e.g., liquid scintillation). Table 6 shows those radionuclides that will always be analyzed (i.e., gamma spectroscopy will always include these radionuclides) and those radionuclides analyzed on an individual basis by other methods when requested.