National Aeronautics and
Space Administration
**John H. Glenn Research Center**
**Lewis Field**
Plum Brook Station
Sandusky, OH 44870

November 12, 2010

Reply to Attn of: QD

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, D.C. 20555

Subject: Technical Basis Document PBRF-TBD-10-001, "Supplemental Radiological Characterization of Plum Brook Section 2", Licenses Nos. TR-3, Docket No. 50-30 and R-93, Docket No, 50-185

This letter submits the report on the final characterization studies of Plum Brook Section 2.

National Aeronautics and Space Administration (NASA) requested an amendment to the operating licenses by letter dated January 9, 2009 (ML090140338). The requested amendment would address the final radiological release criteria for the environmental areas along Plum Brook outside of the Plum Brook Station properties. The amendment request was supported by a supplemental submittal dated March 20, 2009 (ML090900743). This submittal included Technical Basis Documents PBRF-TBD-08-005, "Radiological Characterization of Plum Brook Sediments", Revision 1, and PBRF-TBD-08-006, "Revised Dose Assessment for Plum Brook Sediments", Revision 0.

Following NRC Staff review of the submittals, the NRC staff requested additional information in their letter dated June 11, 2009 (ML091520446). Some of the areas questioned by the staff in their review included inconsistencies in the scope of characterization sampling performed in section 2 of Plum Brook when compared to the extensive sampling completed in other areas. NASA responded to the Request for Additional Information by letter dated October 6, 2009 (ML092870784).

In discussions with the NRC Staff following receipt of NASA responses, NASA committed to perform additional radiological characterization of Plum Brook Section 2 sediments. This commitment was reflected in the NRC Staff Safety Evaluation supporting NRC issuance of Amendment 14 to License TR-3 and Amendment 10 to License R-93 on February 1, 2010 (ML100120679).

This submittal completes NASA's actions on characterization and assessment of residual radioactivity in Plum Brook.

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FSME

Should you have any questions or need additional information, please contact me at NASA Plum Brook Station, 6100 Columbus Avenue, Sandusky, Ohio 44870, or by telephone at (419) 621-3277.

Sincerely,

Keith M. Peecook
NASA Decommissioning Program Manager

Enclosures
1. Technical Basis Document PBRF-TBD-10-001, "Supplemental Radiological Characterization of Plum Brook Section 2", revision 0, dated November 10, 2010

cc:
USNRC/C. J. Glenn (FSME)- CD-ROM Copy
USNRC/J. Webb (FSME)- CD-ROM Copy
USNRC/J. Tapp RIII/DNMS/DB- CD-ROM Copy
ODH/M. J. Rubadue- CD-ROM Copy

# Plum Brook Reactor Facility

# Technical Basis Document

## Supplemental Radiological Characterization of Plum Brook Section 2

**PBRF-TBD-10-001**
**Revision No. 0**

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| Prepared By: | B. Mann | Date: | 11/8/10 |
| Independent Technical Review: | R. Case | Date: | 11/8/10 |
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## 1.0 Summary

A supplemental characterization survey of Plum Brook Section 2 was performed in July and August, 2010. The survey was directed by NASA to develop information requested in "Requests for Additional Information" (RAI) from the US NRC regarding the Plum Brook dose assessment [USNRC 2009]. Over three hundred samples of sediment and soil were collected from Plum Brook Section 2 and analyzed by gamma spectroscopy at the PBRF on-site counting laboratory. Four of the highest activity samples were sent to a qualified vendor laboratory for radiochemical analysis for other possible PBRF radionuclides.

Of the 319 samples analyzed, 207 showed detectable activity for Cs-137 (> MDA) and none showed detectable Co-60 activity. Sample Cs-137 concentrations ranged from 0.10 to 18.2 pCi/g with an average of 0.96 ± 2.3 pCi/g. This is a biased estimate because the samples included 17 samples located by gamma scan surveys designed to identify areas of "elevated" activity. The unbiased estimate of Cs-137 concentration in stream Section 2 is 0.44 ± 0.35 pCi/g.

Principal conclusions are:

- A statistical sampling design was prepared to yield an unbiased estimate of the Section 2 average sediment activity concentration.
- Mean and maximum Cs-137 concentrations in stream Section 2 are less than in Section 1.
- Previous dose assessments using exposure scenarios set in Section 2 are conservative – revised dose calculations using the new survey results obtain doses a factor of two lower than doses calculated using Section 1 characterization results.
- Concentration of Cs-137 in sediments shows a decreasing trend with downstream distance in Section 2.
- Extensive scan surveys were performed to identify areas of elevated activity. Areas of elevated activity are infrequent in Section 2 – only three locations (five samples collected) were identified with Cs-137 concentration above the investigation action level of 7 pCi/g.
- Sediments contaminated with Cs-137 are largely confined within the stream ravine – investigation of flood prone adjacent land areas identified only three localized areas with Cs-137 concentrations above background (only slightly above).
- Other radionuclides of PBRF origin, including Sr-90, were not detected in Section 2 sediment samples.

## 2.0 Introduction

The Plum Brook is one of several surface streams that drain the 6400 acre NASA Plum Brook Station (PBS) in Erie County, Ohio. It originates in farmland south of the facility and terminates in Sandusky Bay on the shore of Lake Erie northeast of the city of Sandusky. Cesium-137, Co-60, and possibly other radionuclides including Sr-90, entered the Plum Brook as a result of Plum Brook Reactor Facility (PBRF) operations from 1963 to 1973. The radionuclides were released in liquid effluents through a monitoring station into a man-made ditch that emptied into the Plum Brook near the northeastern boundary of the PBS.

This report describes the supplemental characterization of the portion of Plum Brook designated as Section 2. Plum Brook Stream Section 2 runs from the US Rt. 2 overpass north to the interior of the Plum Brook Country Club (PBCC). In the terminology of surface stream hydrology, this stream section comprises the lower meander section. It is bounded upstream, on the south by Section 1, the upper meander section and on the north by the upper flood plain, identified as Section 3. The stream course distance of Section 2 is approximately 6200 feet (1.2 mi.).

Section 3.0, provides background information on the decision to perform additional characterization of Plum Brook Section 2. Section 4.0 lists the references cited in the report. A description of Stream Section 2 is provided in Section 5.0 and the survey design and sampling plan is discussed in Section 6.0. The results are presented in Section 7.0.

Appendices provide supporting information. An aerial view map of Plum Brook Section 2 showing the survey transect locations is provided in Appendix A.[1] Appendix B presents the Sampling Plan. Appendix C presents the results of the on-site gamma spectroscopy analysis of the soil and sediment samples collected. An excerpt of the vendor laboratory report containing analytical results of samples selected for radiochemical analysis is provided in Appendix D.

[1] Transect (noun) is a line or strip established to demark an area to be investigated. Many definitions have been published – one which is consistent with the present application is: "In any field (outdoor) study, a transect consists of a line of study, often divided into intervals where observations or samples are collected". www.hwr.arizona.edu/globe/soilwords.html

# 3.0 Background

This section provides background information on stream Section 2 including previous Plum Brook characterization surveys, dose assessments and the NRC request for additional information (RAI). Results of previous Plum Brook characterization surveys are summarized to provide a baseline reference for discussion of Section 2 supplemental characterization results.

## 3.1 Previous Characterization

An extensive campaign was conducted by NASA from 2005 through 2007 to determine the levels and extent of radioactive contaminants in the Plum Brook and environs [NASA 2009]. Samples of soil and sediments were collected from over 900 locations along the four mile stream course from the PBS to Sandusky Bay. It was found that Cs-137 is the predominant man-made radionuclide in the Plum Brook with detectable concentrations measured along the stream course from the PBS and into Sandusky Bay. Cobalt-60 was found to be limited mostly to sediments in portions of the Plum Brook near the PBRF. Detectable concentrations of Cs-137 were measured in sediments deposited in the stream bottom, along the stream banks and in delta deposits in the stream mouth estuary and surrounding wetlands. Detectable concentrations were not found in Plum Brook water.

Objectives evolved for the several characterization surveys conducted between 2005 and 2007. The initial scoping survey, identified as characterization package SVI-04, was designed to determine the extent of downstream transport of PBRF radionuclides in the Plum Brook. From this survey it was concluded that PBRF radionuclides had been deposited throughout the stream downstream of the PBRF and into Sandusky Bay. Subsequent surveys were intended to determine the levels and extent of contaminated sediments in those portions of the Plum Brook without requiring access through private property. This limited collection of samples from Stream Section 2. Detailed surveys were conducted in Stream Section 1 using MARSSIM methods with the intent to determine if the DCGLs for radionuclides in PBRF soil were satisfied. In parallel with this effort, characterization surveys were conducted to determine levels and extent of contaminated sediments in Stream Sections 3 and 4 (upper flood plain, stream mouth-estuary and Sandusky Bay).

After reviewing these results and discussions with the NRC Staff, it was concluded that completion of MARSSIM-based surveys of the entire Plum Brook to demonstrate satisfaction of the 25 mrem/y dose criterion would be expensive and technically difficult. It was proposed by NASA to demonstrate compliance with the 25 mrem/y criterion through dose assessment as discussed below. The data available from the 2005 – 2007 characterization surveys was used to support this effort.

Average concentrations reported in the 2009 characterization report for each stream section were used to develop dose assessment source term models [NASA 2009]. Table 1 shows the estimated average Cs-137 concentration (and standard deviations) for each stream section obtained from the previous characterization surveys. Stream section

average concentrations are estimated from samples selected on a systematic or random basis.

**Table 1, Average Cs-137 Concentrations Measured in Plum Brook Stream Sections**

| Stream Section | Stream Course Distance (mi.) | No. of Locations Sampled [1] | No. of Samples Analyzed [1] | Mean Cs-137 Conc. & Std Dev. (pCi/g) [2] |
|---|---|---|---|---|
| 1 | 1.63 | 621 | 1810 | 1.2 ± 2.8 |
| 2 | 1.20 | 3 | 16 | 0.68 ± 0.69 |
| 3 | 0.45 | 106 | 525 | 0.54 ± 1.33 |
| 4 | 0.65 | 64 | 312 | 0.59 ± 1.63 |

Table 1 Notes:

1. The number of locations sampled and number of samples reported in Table 1 includes only those selected on a random or systematic basis.
2. No Co-60 results are included as the present characterization samples are all < MDA, so no useful comparison with previous characterization survey results can be made.

Source terms for localized areas of elevated activity were also modeled in the Plum Brook dose assessments. These source terms were modeled using the maximum activity concentrations measured in each stream section. Table 2 identifies maximum Cs-137 concentrations measured in each stream section and the average concentration of elevated activity samples. Here, samples with activity concentrations greater than 50% of the Cs-137 DCGL for PBRF soil, (> 7 pCi/g) are included.

**Table 2, Frequency of Samples with Elevated Activity in Plum Brook Stream Sections**

| Stream Section | Maximum Cs-137 Conc. (pCi/g) | Number of Samples with Activity > 0.5 DCGL [1] | Mean Cs-137 Conc. & Std Dev. Of Elevated Activity Samples (pCi/g) |
|---|---|---|---|
| 1 | 72.4 | 253 (0.14) | 15.4 ± 10.3 |
| 2 | 2.8 | None | NA |
| 3 | 14.2 | 6 (0.01) | 10.0 ± 2.7 |
| 4 | 20.6 | 32 (0.10) | 11.2 ± 3.7 |

Table 2 Note:

1. The numbers in parentheses are the fraction of samples showing elevated activity.

## 3.2 Dose Assessment

In 2009, the NASA PBRF Decommissioning Project performed an assessment of radiation exposure to members of the public who could come in contact with contaminated Plum Brook sediments [NASA 2009a]. The purpose of this assessment was to demonstrate that sediment and soil contamination of PBRF origin in the Plum Brook and environs satisfies the same release criteria that apply to the PBRF site (25 mrem/y and ALARA).

Doses to members of the public were calculated for four exposure scenarios using the RESRAD computer code. The scenarios were based on potential exposure conditions in the four stream sections. The settings for two residential scenarios were in the stream meander sections, where all of the stream-side residences are located. The exposure scenario identified as the Brook-side Resident scenario was placed in stream Section 2. In this scenario, a residence was assumed to be constructed on land contaminated with sediments deposited in the vicinity of the stream during a large flood event prior to construction of the home. It is also assumed that the home is situated on an area of contaminated sediment that extends partially beneath the house. The house is assumed to have a 2000 $ft^2$ (186 $m^2$) footprint and the contaminated zone underneath is 45.6 $m^2$ in area. The exposure pathways are direct exposure to a resident inside the house (attenuated by the house-structure), direct exposure to contaminated sediments outside the house (lawn and landscaping maintenance), ingestion of contaminated soil and inhalation of suspended sediment (dust). The resident is assumed to spend 1096 hours per year in the portion of the house located on contaminated sediment and 80 hours a year on the contaminated portion of the outdoor property.

The source term was modeled as:

- The principal source is 186 $m^2$ in area and is comprised of a surface layer 6 in. thick and two subsurface layers each 9 in. thick. This source extended partially underneath the house (46.5 $m^2$).
- A localized elevated area source is modeled as cylindrical three-layer source of one meter radius and is located outside the house. Each layer is 6 in. thick.

In response to an RAI comment from the NRC, a dose assessment was performed for an alternative Brook-side Resident scenario set in Stream Section 2. For the alternative scenario, the principal exposure parameters were modified as follows: The size of the principal zone of contamination that extended beneath the house was increased from 46.5 to 93 $m^2$ and the local elevated area source was moved from outside the house to underneath the house. A new source term component was added to the outdoor area – a garden, from which contaminated vegetables were consumed and direct exposure received for 123 hours/y while tending the garden. A summary of the doses calculated for the exposure scenarios set in stream Section 2 is given in Table 3. Concentrations of Cs-137 and Co-60 assumed for the source term model elements are shown. Calculated doses from the original TBD-08-006, [NASA 2009a] and alternate dose assessment are compared.

**Table 3, Dose Calculation Results for Section 2 Exposure Scenarios**

| Source Term Component | Cs-137 Concentration (pCi/g) | Co-60 Concentration (pCi/g) | Dose (mrem/y) | |
|---|---|---|---|---|
| | | | TBD-08-006 (1) | Alternate Scenario (2) |
| Cont. Zone layer 1 | 9.80E-01 | 1.10E-01 | 3.20E-01 | 5.44E-01 |
| Cont. Zone layer 2 | 1.42E+00 | 1.40E-01 | 7.34E-02 | 1.92E-01 |
| Cont. Zone layer 3 | 1.20E+00 | 1.40E-01 | 2.96E-02 | 4.96E-02 |
| Elev. Local Area layer 1 | 5.78E+01 | 1.60E+00 | 3.57E-01 | 2.30E-01 |
| Elev. Local Area layer 2 | 7.24E+01 | 6.53E-01 | 1.29E-01 | 8.03E-02 |
| Elev. Local Area layer 3 | 2.05E+01 | 2.88E-01 | 1.53E-02 | 8.92E-03 |
| Contaminated Zone in Garden | 1.23E+00 | 1.33E-01 | NA | 2.30E-01 |
| Total Dose (± one standard deviation) => | | | 9.24 ± 4.4 E-01 | 1.34 ± 0.68 E+00 |

Table 3 Notes:

1. Original exposure parameters as reported in TBD-08-006 [NASA 2009a].
2. Scenario exposure parameters suggested by NRC Staff in RAI [USNRC 2009].

## 3.3 NRC Request for Additional Information

Requests from the NRC for additional information (RAI) on the Plum Brook dose assessment included comments that questioned the adequacy of characterization information available from Section 2 to support the dose assessment [USNRC 2009]. Comments that relate to Section 2 characterization are summarized:

- "Section 2 had a significantly lower number of sample results for Cs-137 as compared with sample results for Cs-137 for other Sections" (Comment No. 11).
- "It is unclear how it is known that the concentrations in this section are less than or equal to the concentrations in Section 1 ..... The areas in Section 2 that were not sampled are significant in size and it is possible that areas of elevated concentration could have been missed" (Basis remarks following Comment No. 11).
- "Staff cannot determine the basis for why activity concentrations from Section 1 sample results would be conservative for Section 2" (Comment No.12)

Additional issues raised in the RAI were:

- "More information is needed to confirm that Cs-137 and Co-60 are the only radionuclides of PBRF origin present at levels above background in the Plum Brook" (Comment No. 2).
- Concerns were raised that areas of elevated contamination could occur in land areas adjacent to the Plum Brook due to deposition of sediments during flood events (Comment No. 13, and the Basis remarks following the comment).

In discussions with the NRC Staff following receipt of NASA responses to the 2009 RAI, NASA agreed to perform additional radiological characterization of Section 2 sediments.

## 4.0 References

Gilbert 1987 Richard O. Gilbert, *Statistical Methods for Environmental Pollution Monitoring*, Van Nostrand Reinhold, New York, 1987.

Haag 2007 Haag Environmental Company, Development of Conceptual Model as Basis for Characterization Plan Plum Brook Reactor Facility, Perkins Township, Ohio, Prepared for NASA Plum Brook Decommissioning Program, June 2007.

Haag 2008a Haag Environmental Company, *Characterization Report for Plum Brook Sediment in Floodplain Wetlands*, Prepared for NASA Plum Brook Decommissioning Program, March 2008.

Haag 2008b Haag Environmental Company, *Characterization Report for Plum Brook Sediment in Stream Mouth Wetlands*, Prepared for NASA Plum Brook Decommissioning Program, April 2008

Haag 2008c Haag Environmental Company, Plum Brook Sediments – Presentation for Ohio Dept. of Health, May 2008

LMI 2010 Personal Communication, R. Cantu, Ludlum Measurements, Inc. Sept. 15, 2010.

NASA 2007 NASA Safety and Mission Assurance Directorate, *Final Status Survey Plan for the Plum Brook Reactor Facility*, Revision 1, February 2007.

NASA 2009 NASA Safety and Mission Assurance Directorate Plum Brook Reactor Facility, Technical Basis Document, *Radiological Characterization of Plum Brook Sediments*, PBRF-TBD-08-005, Revision 1, March 2009

NASA 2009a NASA Safety and Mission Assurance Directorate Plum Brook Reactor Facility, Technical Basis Document, *Revised Dose Assessment for Plum Brook Sediments*, PBRF-TBD-08-006, Revision 0, March 2009

NJDEP 2010 New Jersey Department of Environmental Protection, Site Remediation Program *Sampling Plan Design, Sediment Sampling Plan,* http://nj.gov/dep/srp/regs/sediment/02_samp.htm.

ODNR 2006 Ohio Department of Natural Resources and Department of Geology and the Ohio State University, *The Ecology of Old Woman Creek, Ohio: An Estuarine and Watershed Profile,* 2nd. Ed., 2006.

PNNL 2010 Pacific Northwest National Laboratory, Battelle Memorial Institute, *Visual Sample Plan Software*, Version 6.0, 2010.

TBE 2010 Teledyne Brown Engineering, Inc. Work Order # L43319, PBOSG – Plum Brook Waters, November 5, 2010.

USNRC 2003 US Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguards, *Consolidated NMSS Decommissioning Guidance,* NUREG-1757, Final Report, September 2003.

USNRC 2009 US Nuclear Regulatory Commission, Request for Additional Information Related to National Aeronautics and Space Administration Amendment Request to License Nos. TR-3 (Docket No. 50-30) and R-93 (Docket No. 50-185) for Plum Brook Reactor Facility, Sandusky, Ohio, Letter from Chad Glenn, Project Manager, Materials Decommissioning Branch to Keith Peecook, Program Manager, Plum Brook Reactor Decommissioning Program, June 11, 2010

## 5.0 Description of Plum Brook Section 2

The Plum Brook originates in farmland south of the NASA Plum Brook Station and terminates six miles to the north in Sandusky Bay east of the city of Sandusky. An aerial view of the local area with the stream course highlighted is shown in Figure 1.

**Figure 1, Aerial View Showing Plum Brook Stream Course**


### 5.1 Stream Sections

The portion of Plum Brook impacted by radionuclides of PBRF origin lies between the confluence of Plum Brook with Pentolite Ditch and its terminus in Sandusky Bay. It was divided into four sections for characterization purposes, denoted as Sections 1 through 4. Section 1, lies between Pentolite Road, in the northern portion of the PBS, and US Rt. 2.

Section 2 extends from US Rt. 2 to about halfway through the Plum Brook Country Club (PBCC). Section 2 is shown in Figure 2. The figure shows where the stream transitions to flood plain in the vicinity of several ponds located in the northern part of the PBCC. The Flood Plain, identified as Section 3, extends from the PBCC ponds to US Rt. 6

(Cleveland Rd.). The section of the stream from US Rt. 6 to Sandusky Bay, the lower flood plain, also identified as the Plum Brook Estuary, is identified as Section 4.

**Figure 2, Stream Section 2 – Rt. 2 to Plum Brook Country Club**


## 5.2 Sediment Deposition Characteristics

The Plum Brook between Pentolite Ditch and Sandusky Bay is comprised of three hydrologic regimes[2]. From Pentolite Ditch through the lower two-thirds of the PBCC golf course, a stream-course distance of about 3.7 mi., it is described as a meandering stream. The stream channel is carved through dense glacial till composed of clay, sand, unconsolidated gravel and soils. The stream channel lies within steep vegetated banks. The stream escapes the banks only during major floods. From the northern portion of the PBCC to the US Rt. 6 overpass, a stream-course distance of 0.8 mi., the stream environment is classified as floodplain. Here, the stream course tends to be less meandering and the banks much less pronounced than in the meander sections. The stream periodically floods, escaping the banks and the stream width fluctuates accordingly. The stream-mouth estuary extends from US Rt. 6 to the Sandusky Bay shoreline, a distance of about 0.7 mi.

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[2] The description of Plum Brook sediment deposition characteristics is adapted from a series of reports and presentations prepared by Haag Environmental Company for the NASA Plum Brook Decommissioning Program [Haag 2007, Haag 2008a, Haag 2008b, Haag 2008c].

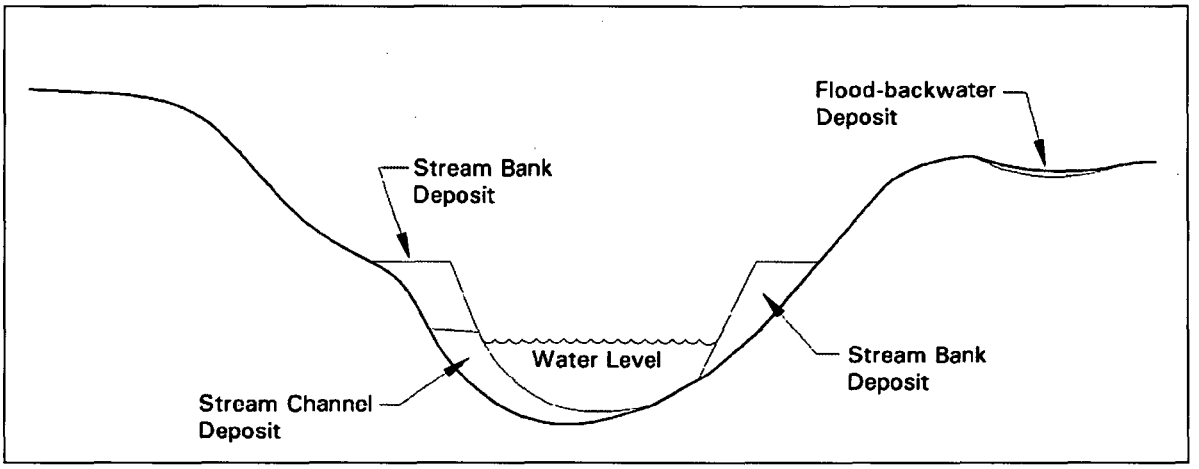
Sediment enters low-lying surface streams as suspended particulate material eroded from soil in the surrounding watershed during storms. This material is carried to the stream in surface runoff. The sediment is transported downstream by flowing water and is continually deposited from and re-suspended in the water column at rates dependent on the water velocity and sediment and water chemistry. Over time, there is net movement of sediment in the downstream direction, with an accumulation of deposited sediments in the Estuary and the Bay.[3] However, at any given time, sediment deposits are found throughout the stream course. The characteristics of sediment deposits are strongly influenced by the stream hydrologic regime.

In streams such as the Plum Brook, three sediment deposition environments are typically associated with meandering sections. Under normal flow conditions, erosion and suspension of material occurs just upstream of bends and deposition takes place on the downstream side as the velocity slows. The second type of deposition occurs during periods of high flow when the water level rises above the meandering channel but is still confined within the stream banks. Erosion and deposition then occurs along stream banks. There is less of a velocity gradient across the stream than in low flow conditions and deposition tends to occur near obstacles such as debris and trees on the stream banks and behind culverts. A third type of deposition occurs under flood conditions. During major flood events, water levels rise above the banks and inundate surrounding land. At points of flow restriction, such as underpass culverts, backwaters are created which may extend well beyond the stream banks. Sediment deposition occurs on the submerged land surface and especially at and near the "shoreline" as the water recedes. This phenomenon is readily observed as a covering of "mud" and silt on lawns and grassy areas which have been flooded. A cross section view of a meandering stream is shown in Figure 3. It illustrates the three types of deposits characteristic of Plum Brook Section 2.

It has been postulated that most of the contaminated sediments in the Plum Brook were moved downstream from Pentolite Ditch during the major flood event of 1969 [Haag 2007, Haag 2008c]. This event caused significant flooding of adjacent land and many flood backwaters were created along the Plum Brook stream meander sections.

[3] Significant quantities of sediment are received and moved downstream each year by streams such as Plum Brook which pass through agricultural land. Using published erosion rates for the nearby Old Woman Creek watershed, it is estimated that between one hundred and two hundred tons of sediment enter the Plum Brook each year [ODNR 2006].

**Figure 3, Deposition Settings in Stream Meander Sections**




From the preceding discussion it is seen that sediment is deposited non-uniformly along Plum Brook stream meander sections. Some sediment will be found nearly everywhere within the stream channel and stream banks, if only in thin layers (< 1 cm. in thickness). Most of the contaminated sediment will reside in discrete deposits of thickness from several cm. up to 10's of cm [NASA 2009].

## *6.0 Survey Design and Sampling Plan*

The survey design and sampling plan is developed to supplement previous radiological sampling surveys of the Plum Brook in which only a limited number of sediment samples were collected in Section 2. This information will strengthen the basis for the source term model used in the Brook-side Resident exposure scenario. It will remove the need to use Stream Section 1 characterization results for the exposure scenario located in Section 2. The sampling plan utilizes published guidance and practical experience from other organizations and from previous characterization surveys of the Plum Brook.[4] It includes collection of samples selected on a probability basis to estimate the mean (average) Section 2 Cs-137 concentration. Gamma scan surveys are used to search for areas of elevated activity in stream banks and areas subjected to overbank flooding during past major flood events.

### 6.1 Data Quality Objectives

Objectives of the Plum Brook Section 2 characterization are to:

- Estimate the average sediment Cs-137 concentration (and uncertainty).
- Identify areas of elevated activity that may be present.

[4] See for example: New Jersey Site Remediation Program, Field Sampling Procedures Manual, Sediment Sampling Plan [NJDEP 2010].

- Determine if Cs-137 is present in flood back-water deposits.
- Determine if other radionuclides of PBRF origin are present in Section 2 sediments.

## 6.2 Number of Samples

The first objective is addressed by collecting sediment samples for analysis by gamma spectroscopy. Determination of the number of samples needed to estimate the mean sediment concentration in Stream Section 2 is based on a confidence interval calculation using the Student's t-distribution. This method is described in Gilbert, [Gilbert 1987] and is implemented in the Visual Sample Plan (VSP) module: *Construct Confidence Interval on Mean* [PNNL 2010]. The formula used to calculate the number of samples is shown in Appendix B.

The number of samples required to estimate a confidence interval width of 1 pCi/g about the mean at a confidence level of 95% is determined. From Table 1, it is seen that the standard deviation of Cs-137 concentration in the Plum Brook stream sections estimated from previous characterization surveys ranges from 0.69 to 2.8. The average standard deviation (weighted by the number of samples analyzed) is 2.4. Using the VSP module, the number of samples was calculated for values of the estimated standard deviation (sigma) ranging from 0.5 to 3.0. The result of these calculations is shown in Figure 1 of Appendix B. From the figure, it is seen that about 100 samples are required for sigma equal to 2.4. Adding 5% for contingencies (inaccessible sample locations, etc) indicates 105 samples.

The sampling plan is implemented by establishing a survey unit in the shape of a narrow rectangle with x dimension corresponding to the Section 2 stream course distance (6320 ft.) and y dimension corresponding to the nominal bank top to bank top cross section distance (approximately 30 ft.). This sampling design covers the stream bed and the two banks, considered to be three strata of approximately equal surface area. They are represented by three parallel strips centered on the stream course. Hence, the 105 samples are allocated equally among the three strata. This is accomplished by selecting 35 sampling transects and collecting three samples at each: one from the stream bed and one from each bank. Sampling locations are placed on a systematic "grid" with randomly selected start location. The VSP software was used to calculate the grid spacing and establish the random start location. Sample locations are established at the x coordinate of each grid node (the y coordinate is not used). [5] The transect coordinates are shown in Table 2 of Appendix B.

[5] The grid patterns created by VSP for the very narrow rectangles used have constant Y coordinates; in effect this places the nodes on a straight line.

## 6.3 Sampling Aided by Gamma Scan Surveys

At each transect, one sampling location was established in the stream bed and one on each bank. Samples were collected at sampling locations to 18 inches depth (or to refusal). Samples were divided into sub-samples (0 to 6, 6 to 12 and 12 to 18 inches) for analysis by gamma spectroscopy.[6] Gamma scans were performed to assist in locating stream bank sample collection points on the transects. Experience has shown that deposits of contaminated sediment in the stream banks are typically found in distinct bands at various elevations above the stream bed.

Gamma scans were performed between transects to identify areas of elevated activity on the stream banks.[7] The survey transects were also extended beyond the stream ravine for gamma scan surveys to search for contaminated sediments deposited beyond the stream banks. Samples of soil/sediment were to be collected at locations where the scan counts indicate elevated activity (> 425 ncpm).

## 6.4 Evaluation of Flood Backwaters

According to a report by Haag Environmental Company (Haag 2007), the entire length of Plum Brook Section 2 has been subjected to overland flooding. Concerns were raised by the NRC, "that, areas of elevated contamination could be created in these areas by flood events" [USNRC 2009]. Whereas the overland scan surveys described in the previous section were performed on the standard transects, it is desired to further investigate land areas adjacent to the Plum Brook focusing on areas subject to flooding.

The sampling plan in Appendix B was supplemented to extend the gamma scan surveys of areas adjacent to the Plum Brook. Locations were selected in Section 2 that are prone to flooding and survey instructions prepared to guide performance of gamma scans on lateral transects extending up to 50 ft. from the stream banks. In this survey, the objective is to determine if Cs-137 activity levels in the surface soil are "different" from background. In order to implement this objective, gamma scan gross count rates are continuously recorded (logged) during the scans for comparison to local area background count rates. Soil samples are collected at locations where technicians observe scan count rates above the local area background.

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[6] Additional strata could be established to describe Cs-137 concentration vs. depth. Sample recovery and other sampling errors diminish the expected utility of this approach. Concentration vs. depth is examined as part of the data evaluation.

[7] Gamma scans are performed with 2 x 2 in. NaI detectors coupled to a Ludlum Model 2350-1 data logging scaler-ratemeter. The instrument is set up to count in a window corresponding to the Cs-137 (Ba-137) 0.66 Mev Gamma. The investigation action level is set at 425 net counts per minute (ncpm). This corresponds to a surface soil concentration of about 7 pCi/g (depending on the background count rate).

### 6.5 Other Radionuclides of PBRF Origin

To determine if other radionuclides of PBRF origin are present, selected samples were sent to a vendor laboratory for radiochemical analysis. Samples from four locations were sent to Teledyne Brown Engineering, Inc. Knoxville, TN for gamma spectroscopy analysis and analysis for Sr-90 and I-129. Samples with the highest Cs-137 concentrations measured by the PBRF on-site counting laboratory were selected. The four samples are identified in Table 4.

**Table 4, Samples Sent to Vendor Laboratory**

| Sample Log # | Sample # | Location | Sample Weight (g) | PBRF Result Cs-137 (pCi/g) |
|---|---|---|---|---|
| PB10-03056 | SR-259-199 | T-1 SM-2 0"-6" | 342.9 | 1.82E+01 |
| PB10-03065 | SR-259-206 | T-5/T-6 SM-1 6"-12" | 332.9 | 1.76E+01 |
| PB10-03057 | SR-259-200 | T-1 SM-2 6"-12" | 362.7 | 1.65E+01 |
| PB10-03059 | SR-259-202 | T-1 SM-3 0"-6" | 343.6 | 7.34E+00 |

## *7.0 Results*

This section presents results of the recent characterization survey of Plum Brook Section 2. Estimates are obtained of the average Cs-137 concentration in Section 2 sediments as a whole and in the stream bed and banks. Behavior of Cs-137 concentration vs. depth and concentration vs. downstream distance are described. The results of scan surveys to identify areas of elevated activity within the stream banks are presented and elevated activity samples are identified. The investigation of flood backwater areas is described and results presented. The effect of these new results on the previous dose assessments is discussed.

### 7.1 Survey Modifications

Several modifications to the survey were made in response to conditions in the field. These were primarily changes in transect location because of obstructions or interferences which prevented their placement as specified in the survey design. The changes are identified in Table 5. In addition to the changes in transect locations identified in Table 5, there were instances where the standard sampling protocol could not be followed, that is, samples collected at three locations on each transect (stream bed, east and west banks). As noted in the table, no scans were performed or samples collected from the stream banks in Transect T-11 because both banks were lined with densely placed landscaping boulders. No survey activities were conducted on Transect 16 because owner permission was not provided. No samples were collected or scans performed on the west bank at Transect T-17 because deep water and vertical bank prevented safe access. These conditions and extensive vegetation and debris on the stream banks limited

access for performance of scan surveys between transects. Overall, 50% of the Section 2 stream bank area was scanned, however.

**Table 5, Field Modifications to Survey Transects**

| Transect | Distance from Rt. 2 Specified in Design (ft.) | Modified Distance from Rt. 2 (ft.) | Explanation |
|---|---|---|---|
| T-10 | 1681 | 1636 | Original location in culvert beneath Galloway Rd overpass – moved 45 ft. upstream. |
| T-11 | 1860 | No change | Banks not scanned or sampled due to densely placed landscaping boulders. |
| T-14 | 2397 | 2437 | Moved 30 ft. downstream to avoid natural gas line. |
| T-16 | 2755 | No change | Not surveyed – owner access not provided. |
| T-17 | 2934 | No Change | West bank not sampled or scanned due to deep water and steep bank. |
| T-33 | 5799 | 5824 | Original location beneath a foot bridge – moved 25 ft. downstream. |

## 7.2 Samples Analyzed

Three hundred and nineteen samples were collected in Plum Brook stream Section 2. These were analyzed by gamma spectroscopy by the PBRF on-site counting laboratory. Thirty five transects were established at specified distances north from the Rt. 2 overpass per the survey design shown in Table 2 of Appendix B. Samples were collected from 33 of the 35 designated transects. Depth samples were collected from the stream bed and from each bank in accordance with survey instructions. The majority of samples, 312 samples, were collected from within the stream banks. These included those collected on the 33 transects plus 17 samples collected as a result of scan survey investigations. Additionally, 7 samples were collected as part of the investigation of flood backwater areas.

## 7.3 Estimated Mean Cs-137 Concentration

A summary of the sample analysis results is presented in Table 6 (individual sample analysis results are provided in Appendix C). A principal objective of the Section 2 supplemental characterization was to provide a more robust estimate of the mean sediment Cs-137 concentration than was previously available. The average Cs-137

concentration estimated from all samples > MDA (203 samples) is approximately 1 pCi/g (0.96 ± 2.32 pCi/g). However this estimate is biased high because 17 of the 19 highest activity samples were collected as the result of scan survey investigations. The overall Section 2 average concentration estimated from the 295 samples that were selected under the statistical sampling design is 0.44 ± 0.35 pCi/g.

All samples were < MDA for Co-60.[8] Stream bed and stream bank sample concentrations are also compared in Table 6. The table shows that average concentration in the stream bed is slightly higher than in the stream banks, but the difference is not significant.

**Table 6, Cs-137 Concentrations in Stream Bed and Banks**

| Stratum | No. of Samples (1) | Max (pCi/g) | Avg. (pCi/g) | St. Dev. (pCi/g) | 95% Confidence Interval (pCi/g) (2) |
|---|---|---|---|---|---|
| All | 312 | 1.82E+01 | 9.58E-01 | 2.32E+00 | 7.0 E-01 to 1.22E+00 |
| Stream Bed | 105 | 1.82E+01 | 1.04E+00 | 2.93E+00 | 4.80 E-01 to 1.60E+00 |
| E Bank | 105 | 1.76E+01 | 1.01E+00 | 2.43E+00 | 5.40 E-01 to 1.47E+00 |
| W Bank | 102 | 6.12E+00 | 8.12E-01 | 1.11E+00 | 5.97 E-01 to 1.03E+00 |

Table 6 Notes:

1. The total number of samples collected is shown. Note that the summary statistics are obtained from sample results that are > MDA. These results are obtained from the samples on the systematic grid transects and the investigational samples.
2. Confidence limits (95%) about the mean are calculated as UCL = Avg. + 1.96 s/√n, and LCL = Avg. – 1.96 s/√n, where s = Std. Dev. And n = number of samples.

## 7.4 Concentration versus Depth

Concentration vs. depth is examined in the tables which follow. Table 7 shows concentration vs. sample depth for all three strata. Table 7 suggests that the highest concentration is found in the 6 to 12 in. layer. However from examination of Tables 8 and 9, it is seen that only the east bank samples show this effect. The stream bed and west bank show a monotonic decrease in concentration with depth.

**Table 7, Cs-137 Concentration vs. Depth**

| Depth | No. of Samples (1) | Max (pCi/g) | Avg. (pCi/g) | St Dev (pCi/g) | 95% Confidence Interval (pCi/g) (2) |
|---|---|---|---|---|---|
| 0 to 6 in | 104 | 1.82E+01 | 9.77E-01 | 2.45E+00 | 5.07 E-01 to 1.45E+00 |
| 6 to 12 in. | 104 | 1.76E+01 | 1.12E+00 | 2.92E+00 | 5.62 E-01 to 1.69E+00 |
| 12 to 18 in | 104 | 6.60E+00 | 7.45E-01 | 1.08E+00 | 5.38 E-01 to 9.52E-01 |

Table 7 Notes:

1. The total number of samples collected is shown. Note that the summary statistics are obtained from sample results that are > MDA.

[8] The average MDA for Cs-137 was 9.7 ± 3.5 E-02 and for Co-60, 1.18 ± 0.22 E-01 pCi/g.

2. Confidence limits (95%) about the mean are calculated as UCL = Avg. + 1.96 s/√n, and LCL = Avg. – 1.96 s/√n, where s = St. Dev. And n = number of samples.

**Table 8, Cs-137 Concentration vs. Depth in Stream Bed**

| Depth | No. of Samples (1) | Max (pCi/g) | Avg. (pCi/g) | St Dev (pCi/g) | 95% Confidence Interval (pCi/g) (2) |
|---|---|---|---|---|---|
| 0 to 6 in. | 35 | 1.82E+01 | 1.26E+00 | 3.65E+00 | 5.59 E-02 to 2.47E+00 |
| 6 to 12 in. | 35 | 1.65E+01 | 1.14E+00 | 3.24E+00 | 6.71 E-02 to 2.22E+00 |
| 12 to 18 in. | 35 | 4.25E+00 | 6.45E-01 | 9.84E-01 | 3.19 E-01 to 9.71E-01 |

Table 8 Notes:

1. The total number of samples collected is shown. Note that the summary statistics are obtained from sample results that are > MDA.
2. Confidence limits (95%) about the mean are calculated as UCL = Avg. + 1.96 s/√n, and LCL = Avg. – 1.96 s/√n, where s = St. Dev. And n = number of samples.

**Table 9, Cs-137 Concentration vs. Depth in Stream Banks**

| Bank/Depth | No. of Samples (1) | Max (pCi/g) | Avg. (pCi/g) | St Dev (pCi/g) | 95% Confidence Interval (pCi/g) (2) |
|---|---|---|---|---|---|
| East 0 to 6 in. | 35 | 7.07E+00 | 7.46E-01 | 1.49E+00 | 2.53 E-01 to 1.24E+00 |
| East 6 to 12 in. | 35 | 1.76E+01 | 1.37E+00 | 3.78E+00 | 1.15 E-01 to 2.62E+00 |
| East 12 to 18 in. | 35 | 6.60E+00 | 9.28E-01 | 1.40E+00 | 4.63 E-01 to 1.39E+00 |
| West 0 to 6 in. | 34 | 6.12E+00 | 8.75E-01 | 1.28E+00 | 4.44 E-01 to 1.31E+00 |
| West 6 to 12 in. | 34 | 5.20E+00 | 8.71E-01 | 1.21E+00 | 4.64 E-01 to 1.28E+00 |
| West 12 to 18 in. | 34 | 2.58E+00 | 6.48E-01 | 6.80E-01 | 4.20 E-01 to 8.77E-01 |

Table 9 Notes:

1. The total number of samples collected is shown. Note that the summary statistics are obtained from sample results that are > MDA.
2. Confidence limits (95%) about the mean are calculated as UCL = Avg. + 1.96 s/√n, and LCL = Avg. – 1.96 s/√n, where s = St. Dev. And n = number of samples.

## 7.5 Frequency Distribution

The differential frequency distribution of 203 samples with detectable Cs-137 activity is shown in Figure 4. It is apparent that this is a highly skewed distribution, with the majority of samples (148) less than 0.5 pCi/g. Only 20 samples are > 2 pCi/g. Ten of these samples are > 4 pCi/g and only 5 are identified as elevated activity (defined here as > 7 pCi/g). The cumulative frequency distribution is shown in Figure 5.

**Figure 4, Differential Frequency Distribution of Cs-137 in Sediment Samples**

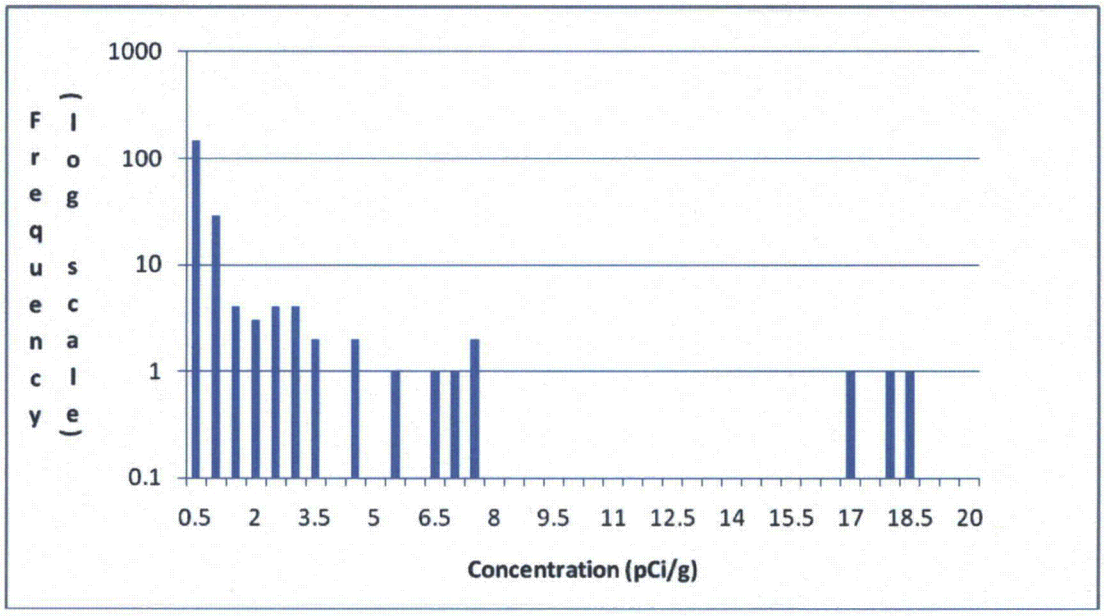
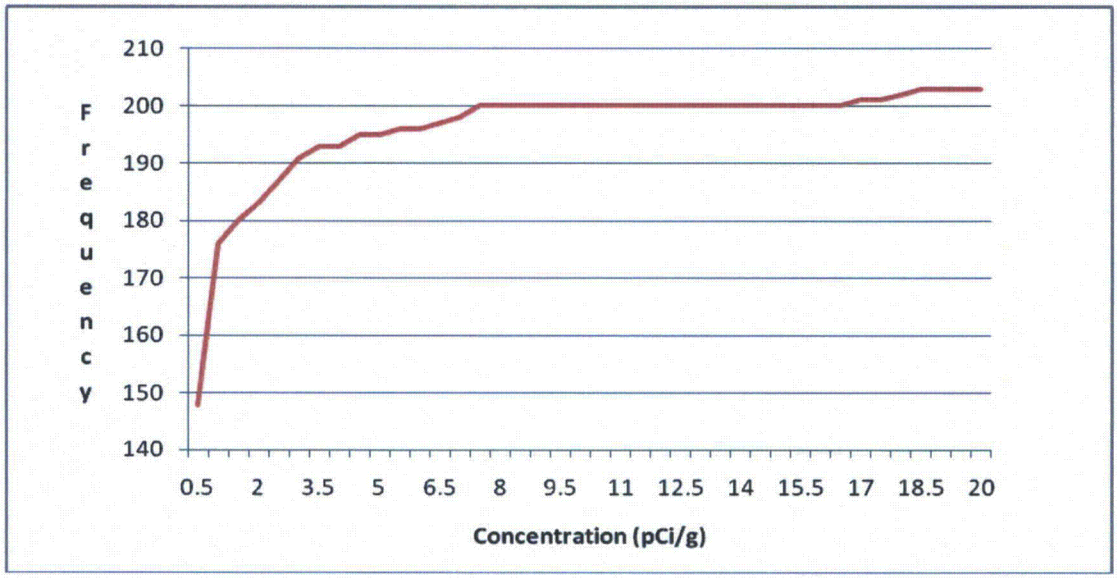



**Figure 5, Cumulative Frequency Distribution – Cs-137 All Samples**



## 7.6 Frequency of Samples with Elevated Activity

The frequency of elevated activity samples from Stream Section 2 is compared to the frequency of elevated activity samples measured in the other stream sections. This is shown in Table 10, an update of Table 2.

**Table 10, Update of Table 2 – Frequency of Samples with Elevated Activity**

| Stream Section | Maximum Cs-137 Conc. (pCi/g) | Number of Samples with Activity > 0.5 DCGL[(1)] | Mean Cs-137 Conc. & Std Dev. Of Elevated Activity Samples (pCi/g) |
|---|---|---|---|
| 1 | 72.4 | 253 (0.14) | 15.4 ± 10.3 |
| 2 [(2)] | 18.2 | 5 (0.02) | 13.4 ± 5.7 |
| 3 | 14.2 | 6 (0.01) | 10.0 ± 2.7 |
| 4 | 20.6 | 32 (0.10) | 11.2 ± 3.7 |

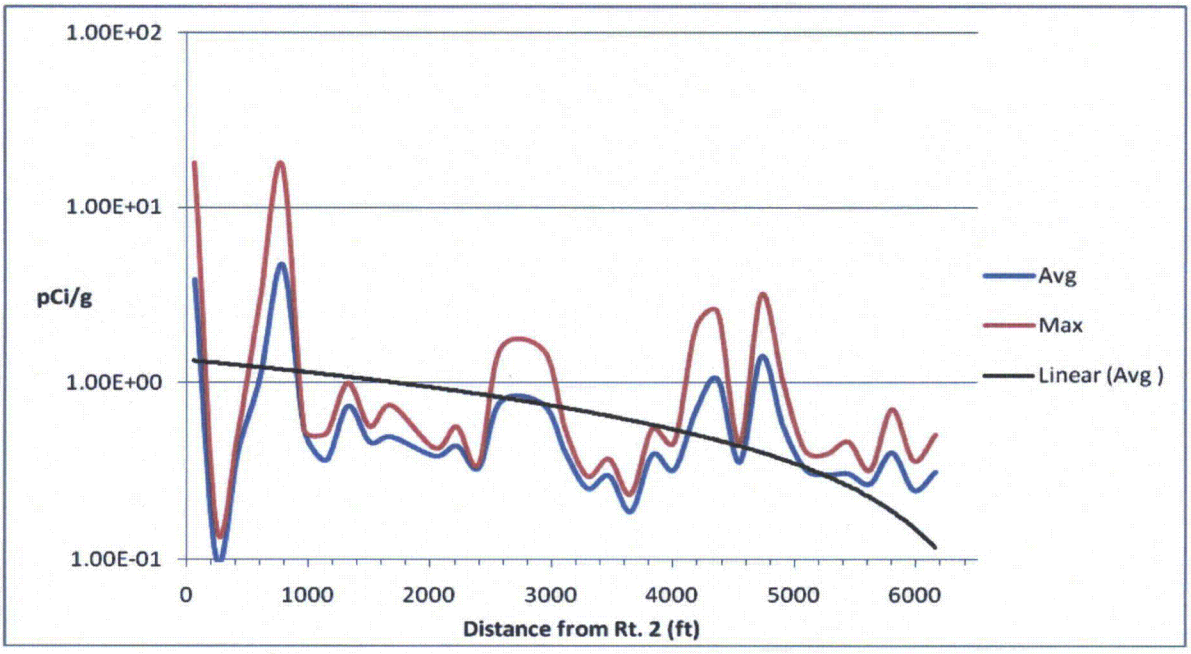
Table 10 Notes:

1. Number in parenthesis is the fraction of samples with activity > 0.5 DCGL.
2. The five samples with activity concentration > 7.0 pCi/g were all investigative samples identified via scan surveys.

## 7.7 Concentration versus Downstream Distance

Concentration vs. downstream distance in Section 2 was evaluated. The results are shown in Figure 5. The average and maximum concentrations of samples collected at each sampling transect are plotted vs. downstream distance (in ft.) from the Rt. 2 over-crossing. The figure shows a clear trend of decreasing concentration with downstream distance. The trend line for average concentration is shown.

**Figure 6, Cs-137 Concentration vs. Downstream Distance**



## 7.8 Scan Survey and Investigative Sample Results

Scan surveys were performed to:

- establish stream bank sampling locations on the transects,
- identify local areas of elevated activity on stream banks between transects and
- search land adjacent to the Plum Brook to identify areas of contaminated sediment deposition.

Scan surveys were performed on accessible portions of transects within the stream banks and on the unobstructed portions of bank sides between the transects. As described in Section 7.1, fifty per cent of the stream banks surface area was covered by scan surveys. Scans of 33 transects were performed within the banks to guide sample collection (except for the west bank of transect T-17 which was inaccessible; no scan or sample collection were performed). Indications of elevated activity were noted, investigative measurements taken and samples collected at six locations. Two of the locations were on transects and four were between transects. Seventeen investigative samples were identified by scan surveys.

Table 11 lists the 17 samples and presents the Cs-137 analysis results. As stated above, most of the samples were located between transects. The highest activity samples are found in the stream bed and on both banks. The Cs-137 activity concentration in these 17 samples ranged from 2.24 to 18.2 pCi/g.

Table 11 also shows the NaI count rates (net cpm from static 60 sec. counts) measured at each location where scan count rates above the action level of 425 ncpm were observed. Static NaI ncpm values above 425 ncpm are associated with sample concentrations of 2.6 pCi/g or greater. It is noted that the static NaI counts are not strongly correlated to sample Cs-137 concentration due to confounding factors such as poor geometry. None-the-less, the data shows that the scan procedure is conservative – it can reliably identify locations with Cs-137 activity at or above the investigation threshold of 7 pCi/g or 50% of the Cs-137 DCGL.

**Table 11, Samples Collected within Stream Banks Identified by Scan Surveys**

| Sample # | Location [1] | Weight (g) | Conc. (pCi/g) [2] | 2σ Error (pCi/g) | Static NaI ncpm [3] |
|---|---|---|---|---|---|
| SR-259-211 [4] | T4/T-5 SM-1 0"-6" | 390.5 | 2.24E+00 | 3.08E-01 | 345 |
| SR-259-258 [5] | T27/T-28 E SM-1 "12-18" | 361.3 | 2.25E+00 | 3.39E-01 | |
| SR-259-210 | T5/T-6 W SM-2 12"-18" | 359.0 | 2.58E+00 | 3.52E-01 | |
| SR-259-256 [5] | T27/T28 E SM-1 "0-6" | 370.7 | 2.95E+00 | 3.60E-01 | 294 |
| SR-259-201 | T1 SM-2 12"-18" | 438.0 | 2.97E+00 | 3.45E-01 | |
| SR-259-212 [4] | T4/T-5 W SM-1 6"-12" | 373.5 | 3.06E+00 | 3.83E-01 | |
| SR-259-257 [5] | T27/T-28 E SM-1 "6-12" | 344.3 | 3.23E+00 | 3.99E-01 | |
| SR-259-204 [6] | T1 SM-3 12"-18" | 338.6 | 4.25E+00 | 4.71E-01 | |
| SR-259-203 [6] | T1 SM-3 6"-12" | 323.9 | 4.38E+00 | 4.83E-01 | |
| SR-259-209 | T5/T-6 W SM-2 6"-12" | 322.1 | 5.20E+00 | 5.30E-01 | |
| SR-259-208 | T5/T-6 W SM-2 0"-6" | 353.4 | 6.12E+00 | 5.42E-01 | 565 |
| SR-259-207 | T5/T-6 E SM-1 12"-18" | 402.9 | 6.60E+00 | 5.54E-01 | |
| SR-259-205 | T5/T-6 E SM-1 0"-6" | 333.4 | 7.07E+00 | 6.08E-01 | 491 |
| SR-259-202 [6] | T1 SM-3 0"-6" | 343.6 | 7.34E+00 | 5.96E-01 | 553 |
| SR-259-200 [7] | T1 SM-2 6"-12" | 362.7 | 1.65E+01 | 9.62E-01 | |
| SR-259-206 | T-5/T-6 E SM-1 6"-12" | 332.9 | 1.76E+01 | 1.04E+00 | |
| SR-259-199 [7] | T1 SM-2 0"-6" | 342.9 | 1.82E+01 | 1.01E+00 | 534 |

Table 11 Notes:

1. Location ID coding of transect number is followed by W for west bank, E for east bank and no suffix for stream bed.
2. The samples are sorted by activity concentration in ascending order.
3. Static NaI counts are listed for comparison to the 0 to 6 in. sample concentrations only.
4. Samples SR-259-211 and SR-259-212 were located 76 ft. downstream of transect T-5.
5. Samples SR-256, SR-257 and SR-258 were located 50 ft. downstream of transect T-27.
6. Samples SR-259-202, SR-259-203 and SR-259-204 were located 68 ft. upstream of transect T-1.
7. Samples SR-259-199 and SR-259-200 were located 9 ft. upstream of transect T-1.

Scan surveys of the land areas adjacent to the stream were conducted on each transect to a distance of 30 ft. beyond the banks (in the absence of obstructions). In none of these scan surveys was a detector response observed above the investigation action level (425 ncpm).

## 7.9 Investigation of Flood Backwater Areas

The scan survey instructions were modified during the course of the field activities to determine if any detectable Cs-137 activity could be found on land areas adjacent to the Plum Brook in Section 2 in areas prone to overbank flooding. The additional scan surveys were performed on ten transects. Four are located within the Plum Brook Country Club golf course (T-29, T-30, T-31 & T-32) and six are located between Rt. 2 and the PBCC (T-2W, west leg only, T-9, T-11, T-22, T-23 & T-24). Gross count rates observed during the scan of each transect were recorded and local background count rates

were measured. Table 12 lists the range and average value of logged gross count rates measured on each transect and the local background count rates.

**Table 12, Summary of Flood Backwater Area Scan Surveys**

| Transect [1] | Number of Scan Counts Logged [2] | Scan Min [3] [4] | Scan Max [3] [4] | Scan Avg. [3] [4] | Local ABCR [3] [5] |
|---|---|---|---|---|---|
| T-2 W | 93 | 96 | 184 | 137.0 | 124.3 |
| T-9 E | 93 | 139 | 238 | 183.5 | 190.7 |
| T-9 W | 93 | 99 | 226 | 176.2 | 165.3 |
| T-11 E | 93 | 141 | 251 | 189.5 | 186.0 |
| T-11 E QC [6] | 94 | 127 | 236 | 174.9 | 186.0 |
| T-11 W | 93 | 125 | 264 | 191.1 | 189.0 |
| T-11 W QC | 93 | 147 | 291 | 206.2 | 216.3 |
| T-22 E | 93 | 157 | 283 | 218.4 | 216.8 |
| T-22 W | 93 | 105 | 199 | 151.7 | 157.3 |
| T-23 E | 93 | 117 | 244 | 172.9 | 158.3 |
| T-23 W | 93 | 131 | 256 | 183.3 | 204.0 |
| T-24 E | 93 | 147 | 265 | 202.8 | 196.3 |
| T-24 W | 93 | 140 | 266 | 198.5 | 210.7 |
| T-29 E | 103 | 141 | 265 | 203.4 | 198.0 |
| T-29 W | 103 | 124 | 232 | 178.8 | 173.0 |
| T-30 E | 103 | 149 | 270 | 199.0 | 179.7 |
| T-30 W | 103 | 110 | 230 | 174.6 | 168.0 |
| T-31 E | 93 | 145 | 289 | 204.7 | 191.0 |
| T-31 W | 93 | 123 | 233 | 182.1 | 162.7 |
| T-32 E | 93 | 128 | 256 | 199.3 | 203.7 |
| T-32 W | 93 | 115 | 257 | 180.0 | 189.3 |

Table 12 Notes:

1. Transect locations shown on map in Appendix A.
2. Scan counts are logged with a LMI-2350-1 scaler-ratemeter coupled to a 2 x 2 in. NaI detector set up to count in an energy window corresponding to the Cs-137 0.66 Mev Gamma energy. The instrument is operated in the recycle count mode to automatically log the count rate on 5 second intervals.
3. Units are counts per minute.
4. The scan minimum, maximum and average count rates are calculated from the logged counts excluding the first three logged counts. This is done because the logged count rates are calculated as weighted running averages of the most recent several counts (the number of counts included in the running average depends on the effective time constant and the count rate) [LMI 2010].
5. ABCR, average background count rates, are obtained in the vicinity of each transect as the average of three 60 second static counts.
6. Background counts not taken for T-11E QC scan. The ABCR for T-11E scan is assigned.

At first glance, Table 12 suggests that all the transects scanned in Section 2 flood backwater areas contain at least one local area with Cs-137 concentration greater than background. This is evidenced by the maximum recorded scan count rate being greater

than the ABCR in all the transects. However when the variability of background is taken into consideration, this conclusion is revisited. If the maximum scan count rates are compared to the combined background from all transect background counts, a different conclusion is reached. The combined background count rate is 184 ± 28 cpm (one standard deviation). Comparing the maximum scan count rate to the combined count rate + 3σ value (approximate 99% confidence level), only three transects have at least one local area above background. These are: T-11W, T-30E and T-31E. If the comparison is made with the combined background count rate + 2σ value (95% confidence level), 10 of 19 transect legs have at least one local area above background. These comparisons do not consider the error in the maximum scan count rate logged values. None-the-less, from the above discussion it is concluded from the logged scan count rate data that at least three transect legs have localized areas which warrant investigation to determine if Cs-137 is present above background concentrations.

To complete this evaluation, empirical results of the scan surveys are presented. Investigations were performed during the scan surveys when technicians observed count rates on the meter display that were above the local background count rate. Table 13 shows that investigations were performed on seven transect legs. All the samples collected as a result of these investigations were analyzed by gamma spectroscopy by the PBRF on-site laboratory (eight samples were analyzed, including one QA split sample).

Table 13 shows that four of eight samples contain detectable Cs-137, with concentrations ranging from 0.20 to 0.71 pCi/g (all were non-detects for Co-60). The average concentration was 0.42 pCi/g. The present characterization survey did not include evaluation of Cs-137 background in a reference area similar to Plum Brook section 2 flood backwater areas. However, it is likely that the sample concentrations from T-9W, T-11W, T-22E and T-22W are above background, if only slightly. It was learned by the technicians that in one of the properties surveyed in this investigation (T-11), dredge spoils from the Plum Brook were distributed on the surrounding landscape. Thus, it is concluded that few areas remain beyond the stream banks where Cs-137 bearing sediments were deposited by flood events (detected in 3 of 19 transect legs investigated and only slightly above background levels).

**Table 13, Samples and Measurements from Flood Backwater Areas**

| Transect | Sample No. (1) | Location (2) | Cs-137 Conc. (pCi/g) (3) | Static Count Rate Measurement | |
|---|---|---|---|---|---|
| | | | | ID | gcpm (4) |
| T-2W | SR-272-6 | 1 ft. west | < MDA (7.3 E-02) | T2W SM5 | 123 ± 11 |
| T-9E | SR-272-7 | 2 ft. east | < MDA (1.4 E-01) | T9ESM6 | 184 ± 14 |
| T-9W | SR-272-8 | 2 ft. west | 7.07 ± 1.90 E-01 | T9W SM7 | 174 ± 13 |
| T-11W | SR-272-1 | 20 ft. west | 4.50 ± 1.32 E-01 | T11WSM1 | 212 ± 15 |
| T-22E | SR-272-2 | 47 ft. east | 3.25 ± 1.23 E-01 | T22ESM2 | 221 ± 15 |
| T-23E | SR-272-3 | 44 ft. east | < MDA (7.7E-02) | T23ESM3 | 195 ± 14 |
| T-23E (5) | SR-272-4 | 44 ft. east | 1.96 ± 0.88 E-01 | T23ESM3 | 195 ± 14 |
| T-24E | SR-272-5 | 30 ft. east | < MDA (8.5 E-02) | T24ESM4 | 236 ± 15 |

Table 13 Notes:

1. All samples are surface soil (0 to 6 in.)

2. Sample locations are recorded as the distance from the stream bank top measured along the transect; for example Sample No. SR-272-6 was collected 1 ft. west of the stream west bank top and Sample No. SR-272-7 was collected 2 ft. east of the east bank top.
3. The Cs-137 concentrations are reported as net activity ± 2-sigma total analytical uncertainty. No other gamma emitters of potential PBRF origin were detected (Co-60, Eu-154). The average MDA for the eight sample counts was 9.06 ± 2.35 E-02 pCi/g (one standard deviation).
4. Static count rates were measured at each sample location. These were 60 sec counts collected with a 2x2 in. NaI detector coupled to an LMI-2350-1 operated in the Cs-137 window mode. The detector was held at contact with the ground surface. Results are reported as gross cpm (gcpm) ± one-sigma counting error, estimated as the square root of the total counts.
5. Sample No. SR-272-3 is a QC split sample.

## 7.10 Other Radionuclides

As described in Section 5.5, four samples were sent to a vendor laboratory, Teledyne Brown Engineering (TBE), for radiochemical analysis. The Request for Analysis requested that the samples be analyzed for Sr-90 and by gamma spectroscopy for Cs-137, Co-60, I-129, Eu-154 and other gamma emitters potentially present in PBRF soil. Sample results from the Teledyne Brown report [TBE 2010] are provided in Appendix D. Table 13 summarizes the results of their analyses and compares Cs-137 sample analysis results with PBRF on-site laboratory results. The Teledyne Brown report does not identify Sr-90 or any other PBRF radionuclides in the Request for Analysis above detection limits. Concentrations of Cs-137 measured by the PBRF laboratory and Teledyne Brown are in good agreement.[9]

**Table 14, Vendor Laboratory Sample Results**

| Sample ID | PBRF | Vendor Laboratory (1) | | |
|---|---|---|---|---|
| | Cs-137 (pCi/g) | Cs-137 (pCi/g) | Co-60 (pCi/g) | Sr-90 (pCi/g) |
| SR-259-199 | 1.82E+01 | 2.14E+01 | ND (3) | ND (3) |
| SR-259-200 | 1.65E+01 | 1.65E+01 | ND (3) | ND (3) |
| SR-259-202 | 7.34E+00 | 7.92E+00 | ND (3) | ND (3) |
| SR-259-206 | 1.76E+01 | 2.07E+01 | ND (3) | ND (3) |

Table 14 Notes:

1. The analyses requested were gamma spectroscopy (specifically Cs-137, Co-60, and Eu-154), Sr-90 and I-129.
2. Co-60 and Sr-90 were reported as "not detected". Also I-129 was reported as not detected.
3. Minimum detectable activity values reported by TBE for Co-60 were from 4.6 E-02 to 1.2 E-01 and for Sr-90 were from 1.2 E-01 to 2.8 E-01 pCi/g.

[9] The initial Cs-137 result reported by TBE for sample No. SR-259-206 showed a significant discrepancy with the PBRF laboratory result. Investigations of both laboratories results were performed – it was determined that the initial TBE result was in error. The PBRF Sample Deviation Report is provided in Appendix D.

## 7.11 Dose Assessment Update

New estimates of radionuclide concentrations in Plum Brook Section 2 obtained from the recent characterization are used to update the dose assessments for exposure scenarios set in Section 2. Results of the original dose assessments identified as TBD-08-006 and the alternate assessment are summarized in Table 3. Table 15 presents doses calculated for the Brook-side Resident exposure scenario using updated source term concentrations. The table also compares the revised and original dose results. The table shows that the new source term values result in significant reduction in the calculated doses. The calculated dose for the original TBD-08-006 scenario is reduced from 9.24 E-01 to 3.99 E-01 mrem/y. For the Alternate scenario, the dose is reduced from 1.34 E+00 to 7.04 E-01 mrem/y.

These results confirm that the original dose assessment for Plum Brook Section 2, which used characterization data from Section 1, was conservative. Use of the recent Section 2 characterization data results in reduction of the calculated dose by about a factor of 2.

**Table 15, Dose Assessment Results using Updated Source Term Concentrations**

| Source Term Component | Updated Cs-137 Conc. (pCi/g) | Dose (mrem/y) | | | |
|---|---|---|---|---|---|
| | | TBD-08-006 Original | TBD-08-006 Revised | Alternate Original | Alternate Revised |
| Cont. Zone layer 1 (1) | 9.80E-01 | 3.20E-01 | 2.17E-01 | 5.44E-01 | 3.69E-01 |
| Cont. Zone layer 2 (2) | 1.12E+00 | 7.34E-02 | 3.57E-02 | 1.92E-01 | 9.88E-02 |
| Cont. Zone layer 3 (3) | 7.50E-01 | 2.96E-02 | 1.13E-02 | 4.96E-02 | 1.88E-02 |
| Elev. Local Area layer 1 (4) | 1.82E+01 | 3.57E-01 | 1.01E-01 | 2.30E-01 | 6.50E-02 |
| Elev. Local Area layer 2 (5) | 1.76E+01 | 1.29E-01 | 3.01E-02 | 8.03E-02 | 1.87E-02 |
| Elev. Local Area layer 3 (6) | 6.60E+00 | 1.53E-02 | 4.59E-03 | 8.92E-03 | 2.67E-03 |
| Contaminated Zone in Garden (7) | 9.46E-01 | NA | NA | 2.30E-01 | 1.31E-01 |
| Total Dose (± one standard deviation) => | | 9.24 ± 4.4 E-01 | 3.99 ± 5.69 E-01 | 1.34 ± 0.68 E+00 | 7.04 ± 10.2 E-01 |

Table 15 Notes:

1. Average concentration of 0 to 6 in. samples (from Table 7).
2. Average concentration of 6 to 12 in. samples (from Table 7).
3. Average concentration of 12 to 18 in. samples (from Table 7).
4. Maximum concentration from 0 to 6 in. samples (from Table 7).
5. Maximum concentration from 6 to 12 in. samples (from Table 7).
6. Maximum concentration from 12 to 18 in. samples (from Table 7).
7. The concentration of Cs-137 in the 9 in single layer garden source is calculated as the thickness-weighted average of the three layer concentrations of the main contaminated zone.

## 7.12 Conclusions

Principal conclusions from the recent supplemental characterization of Plum Brook Section 2 are:

- A statistical sampling design was prepared to yield an unbiased estimate of the mean Section 2 sediment activity concentration within specified tolerance limits.
- Mean and maximum concentrations in Section 2 are less than in Section 1.
- Previous dose assessments using exposure scenarios set in Section 2 are conservative – revised dose calculations using the new survey results obtain doses a factor of two lower than doses calculated using Section 1 characterization results
- Concentration of Cs-137 in sediments shows a decreasing trend with downstream distance in Section 2.
- Extensive scan surveys were performed to identify areas of elevated activity. Areas of elevated activity are infrequent in Section 2 – only three locations (with 5 samples collected) were identified with Cs-137 concentration above the investigation action level of 7 pCi/g.
- Sediments contaminated with Cs-137 are largely confined within the stream ravine – investigation of flood prone adjacent land areas identified only three localized areas with Cs-137 concentrations above background (only slightly above).
- Other radionuclides of PBRF origin, including Sr-90, were not detected in Section 2 sediment samples.

# *8.0 Appendices*

**Appendix A – Plum Brook Section 2 Survey Transect Map**

**Appendix B – Sampling Plan for Characterization of Plum Brook Section 2**

**Appendix C – PBRF Laboratory Sample Analysis Results**

**Appendix D – Vendor Laboratory Report (Excerpt)**

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## Supplemental Radiological Characterization of Plum Brook Section 2

**PBRF-TBD-10-001**
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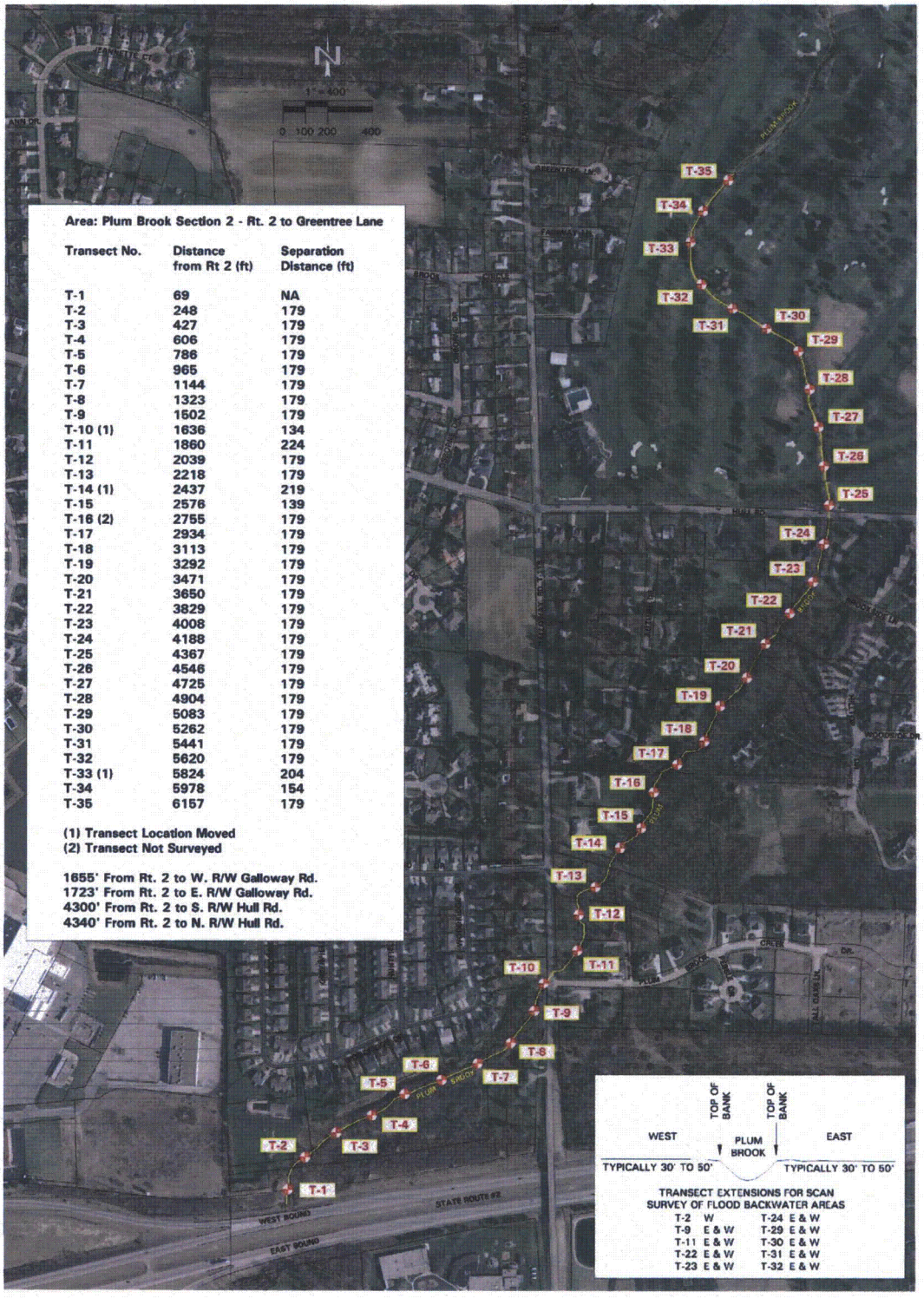
# Appendix A

# Plum Brook Section 2 Survey Transect Map

Plum Brook Section 2 Survey Transect Map




**Area: Plum Brook Section 2 - Rt. 2 to Greentree Lane**

| Transect No. | Distance from Rt 2 (ft) | Separation Distance (ft) |
|---|---|---|
| T-1 | 69 | NA |
| T-2 | 248 | 179 |
| T-3 | 427 | 179 |
| T-4 | 606 | 179 |
| T-5 | 786 | 179 |
| T-6 | 965 | 179 |
| T-7 | 1144 | 179 |
| T-8 | 1323 | 179 |
| T-9 | 1502 | 179 |
| T-10 (1) | 1636 | 134 |
| T-11 | 1860 | 224 |
| T-12 | 2039 | 179 |
| T-13 | 2218 | 179 |
| T-14 (1) | 2437 | 219 |
| T-15 | 2576 | 139 |
| T-16 (2) | 2755 | 179 |
| T-17 | 2934 | 179 |
| T-18 | 3113 | 179 |
| T-19 | 3292 | 179 |
| T-20 | 3471 | 179 |
| T-21 | 3650 | 179 |
| T-22 | 3829 | 179 |
| T-23 | 4008 | 179 |
| T-24 | 4188 | 179 |
| T-25 | 4367 | 179 |
| T-26 | 4546 | 179 |
| T-27 | 4725 | 179 |
| T-28 | 4904 | 179 |
| T-29 | 5083 | 179 |
| T-30 | 5262 | 179 |
| T-31 | 5441 | 179 |
| T-32 | 5620 | 179 |
| T-33 (1) | 5824 | 204 |
| T-34 | 5978 | 154 |
| T-35 | 6157 | 179 |

(1) Transect Location Moved
(2) Transect Not Surveyed

1655' From Rt. 2 to W. R/W Galloway Rd.
1723' From Rt. 2 to E. R/W Galloway Rd.
4300' From Rt. 2 to S. R/W Hull Rd.
4340' From Rt. 2 to N. R/W Hull Rd.

9/13/10
C:\ACAD DRAWINGS\PBRF OVERALL LAYOUT\PLUM BROOK.DWG (SAMPLING TRANSECT COORDINATES)

# Plum Brook Reactor Facility

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# Appendix B

# Sampling Plan for Characterization of Plum Brook Section 2

## Table of Contents



## List of Tables



## List of Figures

## 1.0 Summary

A sampling plan has been developed for radiological characterization of Plum Brook stream Section 2. This section of the stream runs from US Rt. 2 to the Plum Brook Country Club. The sampling plan is developed to supplement previous radiological sampling surveys of the Plum Brook in which only a limited number of sediment samples were collected in Section 2. The number of samples required to estimate the mean Section 2 sediment concentration with specified uncertainty is determined.

The sampling plan utilizes published guidance and practical experience from other organizations and previous characterization of the Plum Brook.[1] The sampling design (number of samples) is based on estimating the mean Cs-137 activity concentration within a specified uncertainty of ± 0.5 pCi/g. Thirty five sampling locations are placed on a systematic "grid" with randomly selected starting location. The grid is centered on the stream channel. At each of the systematic locations, a sampling transect is established. Sampling points are established at three locations on each transect: one in the stream bed and one on each bank side of the stream. Sample collection points on the stream banks are selected with the aid of gamma scans to identify "bands" of sediment deposition. Depth samples are collected at each transect sampling point to 18 inches, or to refusal, and divided into sub-samples (0 to 6, 6 to 12 and 12 to 18 inches) for analysis by gamma spectroscopy.

The transects are extended beyond the stream ravine onto the adjacent land areas. Gamma scan surveys are performed on the transect extensions to identify any areas where sediments were deposited by flood events. Samples of soil/sediment will be collected at locations where the scans indicate elevated activity.

[1] See for example: New Jersey Site Remediation Program, Sampling Plan Design, Sediment Sampling Plan [NJDEP 2010].

## 2.0 Background

Plum Brook Stream Section 2 runs from the US Rt. 2 overpass north to the extension of Greentree Lane in the Plum Brook Country Club (PBCC). In the terminology of surface stream hydrology, this stream section comprises the lower meander section. It is bounded on the south by Section 1, the upper meander section and on the north by the upper flood plain, identified as Section 3. The stream course distance of Section 2 is 6200 feet (1.2 mi.).

In 2009, the NASA PBRF Decommissioning Project performed an assessment of radiation exposure to members of the public who could come in contact with contaminated Plum Brook sediments [NASA 2009]. The purpose of this assessment was to demonstrate that residual contamination of PBRF origin in the Plum Brook and environs satisfies the same dose criteria that apply to the PBRF site (25 mrem/y and ALARA). Requests from the NRC for additional information (RAI) on the Plum Brook dose assessment included comments that questioned the adequacy of the information available from Section 2 to support the dose assessment [USNRC 2009]. In discussions with the NRC Staff following receipt of NASA responses to the 2009 RAI, NASA has agreed to perform additional radiological characterization of Section 2 sediments.

The NRC comments that directly relate to Section 2 characterization are summarized:

- "Section 2 had a significantly lower number of sample results for Cs-137 as compared with sample results for Cs-137 for other Sections" (Comment No. 11).
- "It is unclear how it is known that the concentrations in this section are less than or equal to the concentrations in Section 1 ..... The areas in Section 2 that were not sampled are significant in size and it is possible that areas of elevated concentration could have been missed" (Basis remarks following Comment No. 11).
- "Staff cannot determine the basis for why activity concentrations from Section 1 sample results would be conservative for Section 2" (Comment No.12)

Additional issues raised in the RAI were:

- "More information is needed to confirm that Cs-137 and Co-60 are the only radionuclides of PBRF origin present at levels above background in the Plum Brook" (Comment No. 2).
- Concerns were raised that areas of elevated contamination could occur in land areas adjacent to the Plum Brook due to deposition of sediments during flood events (Comment No. 13, and the Basis remarks following the comment).

A primary objective of additional characterization of Plum Brook Section 2 is to provide information to address the NRC Staff concerns. The sampling design for this characterization is presented following a summary of Plum Brook sampling conducted to date.

## 3.0 Previous Plum Brook Sampling Results

A summary of previous Plum Brook sampling results is provided in Table 1. The data is obtained from PBRF Technical Basis Document TBD-08-005, *Radiological Characterization of Plum Brook Sediments* [NASA 2009a]. The table was prepared to compare Stream Section sampling densities and average Cs-137 concentrations estimated from the available data. As indicated in the NRC RAI and shown in the table, Section 2 is the least-characterized section of the Plum Brook. The Table 1 Notes identify the data sources and explain how average Cs-137 concentrations were obtained. The average Cs-137 concentration is used to calculate doses to individuals exposed to contaminated sediments. The average (mean) concentration and its variability are key parameters for determining the number of samples in supplemental characterization of Section 2.

**Table 1, Plum Brook Sampling Summary**

| Stream Section (1) | No. of Locations Sampled (2) | No. of Samples Analyzed (2) | Stream Course Distance (ft.) | Stream Course Distance (mi.) | Sampling density (Loc./mi.) (3) | Mean Cs-137 Concentration (pCi/g) (4) | Coefficient of Variation (CV) (5) |
|---|---|---|---|---|---|---|---|
| 1 (6) | 621 | 1810 | 8600 | 1.63 | 381 | 1.2 ± 2.8 (7) | 2.3 |
| 2 (8) | 3 | 16 | 6200 | 1.20 | 3 | 0.68 ± 0.69 (9) | 1.0 |
| 3 (10) | 106 | 525 | 2375 | 0.45 | 236 | 0.54 ± 1.33 (11) | 2.5 |
| 4 (12) | 64 | 312 | 3420 | 0.65 | 99 | 0.59 ± 1.63 (13) | 2.8 |

Table 1 Notes:

1. Stream Sections 1 and 2 are described in the text. Section 3 runs from the extension of Greentree Lane in the PBCC to US Rt. 6. Section 4 extends from US Rt. 6 to Sandusky Bay.
2. The number of locations sampled is distinguished from the number of samples as depth samples were collected at most sampling locations.
3. Indicator of sampling density; equal to the No. of Locations Sampled ÷ Stream Course Distance (in mi.).
4. Average concentration ± one standard deviation.
5. Ratio of Standard Deviation to the mean.
6. No. of samples and locations in Section 1 are from TBD-08-005 Table 3 (all SRs except 21, 22 & 95) and includes all samples and locations from Phases 1, 2 and 3.
7. Obtained as the average of Cs-137 concentrations measured in samples collected from all depths in Section 1 from Phase 1 (systematic samples), characterization Packages SR-5, 6, 7, -8 and 19 as reported in TBD-08-005, Table 4.
8. No. of samples and locations in Section 2 are from characterization packages SVI-04 and SR-33, as reported TBD-08-005, Section 5.3.
9. Obtained as the average of Cs-137 concentrations measured in samples collected from all depths in Section 2 (from characterization Packages SVI-04 and SR-33).
10. No. of samples and locations in Section 3 are from SR-41and SR-54, as reported TBD-08-005, Table 10.
11. Obtained as the average of Cs-137 concentrations measured in samples collected from all depths in Section 3 from SR-41 and SR-54.
12. No. of samples and locations in Section 4 are from SR-39, as reported TBD-08-005, Table 12.
13. Obtained as the average of Cs-137 concentrations measured in samples collected from all depths in Section 4 from SR-39.

## 4.0 Sampling Plan

The objectives of the Plum Brook Section 2 characterization are to:

- Estimate the mean sediment Cs-137 concentration (and uncertainty) in Section 2.
- Identify areas of elevated activity that may be present.
- Determine if other radionuclides of PBRF origin are present in Section 2 sediments.

The first objective is addressed by collecting sediment samples for analysis by gamma spectroscopy. To identify areas of elevated activity on stream banks and on nearby land, gamma scan surveys are performed. To determine if other radionuclides of PBRF origin are present, selected samples will be sent to a vendor laboratory for radiochemical analysis.

Determining the number of samples is an estimation problem (as opposed to a hypothesis testing formulation). The number of samples is based on a confidence interval calculation using the Student's t-distribution. This method is described in Gilbert, [Gilbert 1987] and is implemented in the Visual Sample Plan (VSP) module: *Construct Confidence Interval on Mean* [PNNL 2010]. The formula used to calculate the number of samples is:

$$n = \left[ \frac{t_{1-\alpha/2,df} S_{total}}{d} \right]^2$$

Where:

| | |
|---|---|
| $n$ | is the recommended minimum sample size, |
| $S_{total}$ | is the estimated standard deviation due to both sampling and analytical variability, |
| $\alpha$ | is the maximum acceptable probability that the true mean will not lie in the confidence interval (the confidence level is 1-$\alpha$), |
| $d$ | is the half-width of the confidence interval, |
| $t_{1-\alpha/2,df}$ | is the value of the Student's t-distribution with $df=n-1$ degrees of freedom such that the proportion of the distribution less than $t_{1-\alpha/2}$ is 1-$\alpha$/2. |

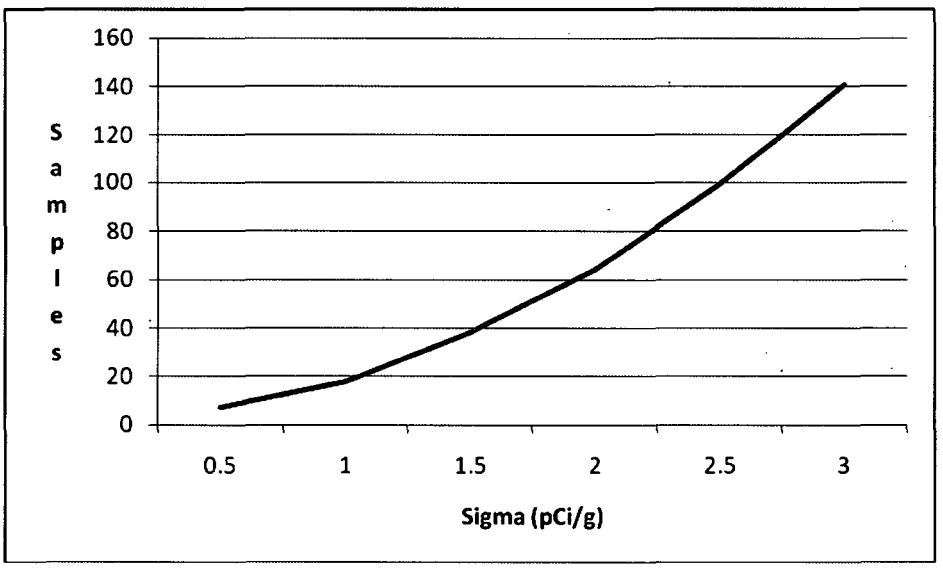
Because $n$ appears on both sides of the equation (on the right side it appears in the degrees of freedom of the t-statistic), the equation must be solved iteratively; VSP does this automatically using the iteration scheme in Gilbert (pg. 32). [2]

To determine the number of samples, the confidence level is set at 95% ($\alpha = 0.05$) and the confidence interval half-width at 0.5 pCi/g. From Table 1, it is seen that the estimated standard deviation of Cs-137 concentration in the Plum Brook stream sections ranges from 0.69 to 2.8. The average standard deviation (weighted by the number of samples analyzed) is 2.4. Using the VSP module, the number of samples was calculated for values of the estimated standard deviation (sigma) ranging from 0.5 to 3.0. The result of these calculations is shown in Figure 1. From the figure, it is seen that about 100

[2] This description of the method for determining the number of samples is adapted from a Visual Sample Plan (VSP) sample design report [PNNL 2010].

samples are required for sigma equal to 2.4. Adding 5% for contingencies (inaccessible sample locations, etc) then, indicates 105 samples.

**Figure 1, Number of Samples vs. Sigma**




## 5.0 Implementation of Sampling Plan

The conceptual site model for the Plum Brook meander sections comprises three sediment deposition environments: the stream bed, stream banks and adjacent land where deposition may have occurred on flood backwater areas [NASA 2009a]. This sampling design covers the stream bed and the two banks, considered to be three strata of approximately equal surface area. They are represented by three parallel strips centered on the stream course. Hence, the 105 samples can be allocated equally among the three strata. This is accomplished by selecting 35 sampling locations and collecting three samples at each: one from the stream bed and one from each bank.

To implement the sampling plan, a survey unit is established in the shape of a narrow rectangle with x dimension corresponding to the Section 2 stream course distance (6320 ft.) and y dimension corresponding to the nominal bank top to bank top cross section distance (approximately 30 ft.). Sampling locations are placed on a systematic "grid" with randomly selected start location. The VSP software was used to calculate the grid spacing and establish the random start location. Sample locations are established at the x coordinate of each grid node (the y coordinate is not used). [3] At each of the 35 systematic locations, a sampling transect is established. Sampling points are established at three locations on each transect: one in the stream bed and one on each bank.

[3] The grid patterns created by VSP for the very narrow rectangles used have constant Y coordinates; in effect this places the nodes on a straight line.

Gamma scans along the transects are used to assist in locating sample collection points and to identify areas of elevated activity on the stream banks. Experience has shown that deposits of contaminated sediment are typically found in thin bands at various elevations above the stream bed. Depth samples are collected at each transect sampling point to 18 inches, or to refusal, and divided into sub-samples (0 to 6, 6 to 12 and 12 to 18 inches) for analysis by gamma spectroscopy. [4]

The sampling transects are extended beyond the stream ravine for performance of gamma scan surveys to identify any areas where contaminated sediments were deposited by flood events. Samples of soil/sediment will be collected at locations where the scan counts indicate elevated activity. Sampling transect coordinates are shown in Table 2. They are given as distance along the stream course (ft.) from the origin where the Plum Brook emerges from the Rt. 2 overpass culvert.

[4] Additional strata could be established to describe Cs-137 concentration vs. depth. Sample recovery and other sampling errors diminish the expected utility of this approach. The sampling design does not attempt to incorporate this degree of stratification. Concentration vs. depth will be examined as part of the data evaluation, however.

**Table 2, Sampling Transect Coordinates**

Area: Plum Brook Section 2 - Rt. 2 to Greentree Lane

| Transect No. | Distance from Rt 2 (ft) | Separation Distance (ft) |
|---|---|---|
| T-1 | 69 | NA |
| T-2 | 248 | 179 |
| T-3 | 427 | 179 |
| T-4 | 606 | 179 |
| T-5 | 786 | 179 |
| T-6 | 965 | 179 |
| T-7 | 1144 | 179 |
| T-8 | 1323 | 179 |
| T-9 | 1502 | 179 |
| T-10 | 1681 | 179 |
| T-11 | 1860 | 179 |
| T-12 | 2039 | 179 |
| T-13 | 2218 | 179 |
| T-14 | 2397 | 179 |
| T-15 | 2576 | 179 |
| T-16 | 2755 | 179 |
| T-17 | 2934 | 179 |
| T-18 | 3113 | 179 |
| T-19 | 3292 | 179 |
| T-20 | 3471 | 179 |
| T-21 | 3650 | 179 |
| T-22 | 3829 | 179 |
| T-23 | 4008 | 179 |
| T-24 | 4188 | 179 |
| T-25 | 4367 | 179 |
| T-26 | 4546 | 179 |
| T-27 | 4725 | 179 |
| T-28 | 4904 | 179 |
| T-29 | 5083 | 179 |
| T-30 | 5262 | 179 |
| T-31 | 5441 | 179 |
| T-32 | 5620 | 179 |
| T-33 | 5799 | 179 |
| T-34 | 5978 | 179 |
| T-35 | 6157 | 179 |

This plan represents a conservative design; it specifies a number of samples that includes a 5 % increase above the calculated minimum number. This is to compensate for sampling errors such as sample recovery problems due to conditions in the Plum Brook ravine. These conditions include:

- Interferences to access to the Plum Brook ravine for collection of samples at designated sampling transect locations. These include steep thickly vegetated banks, mud, rocks dead

trees and stumps, culverts and concrete overpass structures, outfall pipes, human-generated trash and debris.

- Interferences to sample collection at designated sampling locations in the stream bed include exposed bedrock in some locations and deep water pools at others.
- Sample recovery is impacted by the non-homogeneous sampling matrix; sediment is often mixed with gravel, decaying organic material and small debris.

## 6.0 References

Gilbert 1987 Richard O. Gilbert, *Statistical Methods for Environmental Pollution Monitoring*, Van Nostrand Reinhold, New York, 1987.

NASA 2009 NASA Plum Brook Reactor Facility, Technical Basis Document, *Revised Dose Assessment for Plum Brook Sediments*, PBRF-TBD-08-006, March 19, 2009.

NASA 2009a NASA Plum Brook Reactor Facility, Technical Basis Document, *Radiological Characterization of Plum Brook Sediments*, PBRF-TBD-08-005, March 19, 2009.

NJDEP 2010 New Jersey Department of Environmental Protection, Site Remediation Program *Sampling Plan Design, Sediment Sampling Plan,* http://nj.gov/dep/srp/regs/sediment/02_samp.htm.

PNNL 2001 J. R. Davidson, Pacific Northwest National Laboratory, *Verification of the Accuracy of Sample Size Equation Calculations for Visual Sample Plan Version 0.9C*, PNNL-13434, January 2001

PNNL 2010 Pacific Northwest National Laboratory, Battelle Memorial Institute, *Visual Sample Plan Software*, Version 6.0, 2010.

USNRC 2009 US Nuclear Regulatory Commission, *Request for Additional Information Related to National Aeronautics and Space Administration Amendment Request to License Nos. TR-3 (Docket No. 50-30) and R-93 (Docket No. 50-185) for Plum Brook Reactor Facility, Sandusky, Ohio*, Letter from Chad Glenn, Project Manager, Materials Decommissioning Branch to Keith Peecook, Program Manager, Plum Brook Reactor Decommissioning Program, June 11, 2010

**7.0 Attachment – Investigation of Historic Flood Backwater Areas in Plum Brook Section 2**

**DECOMMISSIONING PROJECT OFFICE**
6100 Columbus Avenue, Sandusky, OH 44870
Phone: (419)621-3314 Fax: (419) 621-3318

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**MEMORANDUM**

**09-Aug-2010**

To: Project File

From: Bruce Mann

Subject: Investigation of Historic Flood Backwater Areas in Plum Brook Section 2

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This memo is to supplement SR-259, Plum Brook Section 2 Characterization. The goal of the investigation described below is to determine if sediments contaminated with radionuclides of Plum Brook origin can be detected in areas adjacent to the Plum Brook, outside of the stream banks.

Land areas adjacent to Plum Brook that were inundated by major flood events are called flood backwaters. According to a report by Haag Environmental Company (Haag 2007), the entire length of Plum Brook Section 2 has been subjected to overland flooding. Concerns were raised by the NRC, "that areas of elevated contamination could be created in these areas by flood events".

Scan surveys conducted on 35 transects established in SR-259 did not identify any locations outside the stream banks with Cs-137 gamma counts in excess of the 425 ncpm investigation level. This investigation level corresponds to about 7 pCi/g, or ½ of the Cs-137 DCGL for surface soil published in the PBRF FSS Plan (dependent on the detector background). This supports the conclusion that no areas of elevated activity are present outside the Section 2 stream banks. However, the Plum Brook dose assessment assumed that only low levels of Cs-137 are present in flood backwater areas, with average concentrations on the order of 1 pCi/g.

To determine if "any" Cs-137 deposition can be detected in flood backwater areas in Stream Section 2, perform the following:

1. Identify four to six areas adjacent to the Plum Brook between US Rt 2 and Hull Rd that are likely to have been inundated during past flood events. The most likely candidates are:

    a. Areas located upstream of major restrictions, such as overpass culverts, or
    b. Low-lying areas adjacent to stream locations where the stream ravine is only a few feet deep.
2. Perform a gamma scan with the same detector setup and scan technique as in SR-259. Establish a transect perpendicular to the stream course extending from the stream bank for 50 ft. or to the end of the low-lying area.

3. Measure and record the local area average background count rate in the vicinity of each transect.
4. Record the range of gross cpm values observed during the scan of each transect.
5. If the investigation level indicated in SR-259 is exceeded, perform the actions in the SR-259 instructions.

Candidate locations for the scan surveys are:

1. The vicinity of SR-259 Transect T-2.
2. Between Transect T-9 and the Galloway Rd. overcrossing. See Figure 1.
3. Between Transect T-11 and Plum Brook Creek Drive in the landscaped lot with the bridge. See Figure 2.
4. South of Hull Rd. in the vicinity of Transects T-21 though T-24. See Figure 3. If possible establish two transects in this vicinity.

Figure 1, Back Yard Immediately Upstream of Galloway Rd.

Figure 2, Residence with Landscaped Creek Bank Just Downstream of Galloway Rd

Figure 3, Low-lying Area East of Plum Brook Below Hull Rd.

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# Appendix C

# PBRF Laboratory Sample Analysis Results

## Contents - List of Tables

**Table 1, PBRF Laboratory Results for Stream Section 2 Ravine Samples (Cs-137)**

| Sample # | Location | Weight (g) | Conc. pCi/g | 2σ Error (pCi/g) | MDA (pCi/g) |
|---|---|---|---|---|---|
| SR-259-91 | T1 CNT 0"-6" (SAIC) | 443.7 | 5.87E-01 | 1.47E-01 | |
| SR-259-93 | T1 CNT 12"-18" (SAIC) | 435.9 | 3.17E-01 | 1.09E-01 | |
| SR-259-92 | T1 CNT 6"-12" (SAIC) | 367.3 | 3.49E-01 | 1.22E-01 | |
| SR-259-85 | T1 E 0"-6" (SAIC) | 393.2 | 2.55E-01 | 7.47E-02 | |
| SR-259-89 | T1 E 12"-18" (SAIC) | 365.7 | 2.73E-01 | 8.73E-02 | |
| SR-259-87 | T1 E 6"-12" (SAIC) | 382.7 | 2.51E-01 | 8.06E-02 | |
| SR-259-94 | T1 W 0"-6" (SAIC) | 369.6 | 1.75E+00 | 2.93E-01 | |
| SR-259-96 | T1 W 12"-18" (SAIC) | 402.6 | 4.14E-01 | 1.27E-01 | |
| SR-259-95 | T1 W 6"-12" (SAIC) | 425.2 | 9.52E-01 | 2.07E-01 | |
| SR-259-199 | T1 SM-2 0"-6" | 342.9 | 1.82E+01 | 1.01E+00 | |
| SR-259-201 | T1 SM-2 12"-18" | 438.0 | 2.97E+00 | 3.45E-01 | |
| SR-259-200 | T1 SM-2 6"-12" | 362.7 | 1.65E+01 | 9.62E-01 | |
| SR-259-202 | T1 SM-3 0"-6" | 343.6 | 7.34E+00 | 5.96E-01 | |
| SR-259-204 | T1 SM-3 12"-18" | 338.6 | 4.25E+00 | 4.71E-01 | |
| SR-259-203 | T1 SM-3 6"-12" | 323.9 | 4.38E+00 | 4.83E-01 | |
| SR-259-100 | T2 CNT 0"-6" (SAIC) | 356.0 | <MDA | <MDA | 8.03E-02 |
| SR-259-102 | T2 CNT 12"-18" (SAIC) | 342.6 | <MDA | <MDA | 8.03E-02 |
| SR-259-101 | T2 CNT 6"-12" (SAIC) | 352.2 | <MDA | <MDA | 1.16E-01 |
| SR-259-97 | T2 E 0"-6" (SAIC) | 409.0 | <MDA | <MDA | 1.55E-01 |
| SR-259-99 | T2 E 12"-18" (SAIC) | 372.4 | <MDA | <MDA | 8.05E-02 |
| SR-259-98 | T2 E 6"-12" (SAIC) | 395.6 | <MDA | <MDA | 9.64E-02 |
| SR-259-103 | T2 W 0"-6" (SAIC) | 322.1 | <MDA | <MDA | 8.88E-02 |
| SR-259-105 | T2 W 12"-18" (SAIC) | 320.1 | <MDA | <MDA | 1.20E-01 |
| SR-259-104 | T2 W 6"-12" (SAIC) | 346.6 | <MDA | <MDA | 8.65E-02 |
| SR-259-113-T3W. | T3 6"-12" | 331.1 | <MDA | <MDA | 9.05E-02 |
| SR-259-110-T3 | T3 CNT 6"-12" | 407.4 | 2.38E-01 | 9.55E-02 | |
| SR-259-109-T3 | T3 CNT. 0"- 6" | 401.4 | 4.66E-01 | 1.38E-01 | |
| SR-259-111-T3 | T3 CNT. 12"-18" | 423.7 | <MDA | <MDA | 1.31E-01 |
| SR-259-106-T3 | T3 E. 0"- 6" | 378.1 | <MDA | <MDA | 1.00E-01 |
| SR-259-115-T4 E. | T3 E. 0"-6" | 323.4 | 5.37E-01 | 1.72E-01 | |
| SR-259-108-T3 | T3 E. 12"- 18" | 392.8 | <MDA | <MDA | 7.63E-02 |
| SR-259-107-T3 | T3 E. 6"- 12" | 373.4 | <MDA | <MDA | 8.03E-02 |
| SR-259-112-T3 | T3 W. 0"-6" | 437.0 | <MDA | <MDA | 6.30E-02 |
| SR-259-114-T3W | T3 W. 12"-18" | 396.2 | <MDA | <MDA | 1.01E-01 |
| SR-259-122-T4 | T4 CNT 6"-12" | 446.0 | 4.65E-01 | 1.31E-01 | |
| SR-259-123-T4 | T4 CNT 12"-18" | 412.1 | 3.25E-01 | 1.24E-01 | |
| SR-259-121-T4 | T4 CNT. 0"-6" | 428.6 | 3.92E-01 | 1.38E-01 | |
| SR-259-119-T4 | T4 E 12"-18" | 356.2 | 6.85E-01 | 1.78E-01 | |
| SR-259-117-T4 E. | T4 E. 6"-12" | 411.9 | 4.90E-01 | 1.37E-01 | |

**Table 1, PBRF Laboratory Results for Stream Section 2 Ravine Samples (Cs-137)**

| Sample # | Location | Weight (g) | Conc. pCi/g | 2σ Error (pCi/g) | MDA (pCi/g) |
|---|---|---|---|---|---|
| SR-259-124-T4 | T4 W. 0"-6" | 370.3 | <MDA | <MDA | 1.02E-01 |
| SR-259-125-T4 | T4 W. 6"-12" | 384.7 | <MDA | <MDA | 7.79E-02 |
| SR-259-126-T4 | T4 W. 12"-18" | 389.9 | <MDA | <MDA | 7.33E-02 |
| SR-259-211 | T4/T-5 SM-1 0"-6" | 390.5 | 2.24E+00 | 3.08E-01 | |
| SR-259-213 | T4/T-5 SM-1 12"-18" | 368.5 | 1.06E+00 | 2.14E-01 | |
| SR-259-212 | T4/T-5 SM-1 6"-12" | 373.5 | 3.06E+00 | 3.83E-01 | |
| SR-259-130-T5 | T5 C. 0"-6" | 455.6 | <MDA | <MDA | 1.01E-01 |
| SR-259-132-T5 | T5 C. 12"-18" | 390.4 | <MDA | <MDA | 1.31E-01 |
| SR-259-131-T5 | T5 C. 6"-12" | 400.0 | 3.35E-01 | 1.17E-01 | |
| SR-259-127-T5 | T5 E. 0"-6" | 348.5 | <MDA | <MDA | 8.60E-02 |
| SR-259-129-T5 | T5 E. 12"-18" | 349.8 | <MDA | <MDA | 8.57E-02 |
| SR-259-128-T5 | T5 E. 6"-12" | 352.9 | <MDA | <MDA | 8.10E-02 |
| SR-259-133-T5 | T5 W. 0"-6" | 354.6 | 5.50E-01 | 1.60E-01 | |
| SR-259-135-T5 | T5 W. 12"-18" | 346.3 | 4.58E-01 | 1.47E-01 | |
| SR-259-134-T5 | T5 W. 6"-12" | 360.3 | 7.97E-01 | 1.87E-01 | |
| SR-259-205 | T5/T-6 SM-1 0"-6" | 333.4 | 7.07E+00 | 6.08E-01 | |
| SR-259-207 | T5/T-6 SM-1 12"-18" | 402.9 | 6.60E+00 | 5.54E-01 | |
| SR-259-206 | T-5/T-6 SM-1 6"-12" | 332.9 | 1.76E+01 | 1.04E+00 | |
| SR-259-208 | T5/T-6 SM-2 0"-6" | 353.4 | 6.12E+00 | 5.42E-01 | |
| SR-259-210 | T5/T-6 SM-2 12"-18" | 359.0 | 2.58E+00 | 3.52E-01 | |
| SR-259-209 | T5/T-6 SM-2 6"-12" | 322.1 | 5.20E+00 | 5.30E-01 | |
| SR-259-142-T6 | T6 C. 0"-6" | 401.3 | 5.37E-01 | 1.64E-01 | |
| SR-259-144-T6 | T6 C. 12"-18" | 417.5 | <MDA | <MDA | 1.63E-01 |
| SR-259-143-T6 | T6 C. 6"-12" | 393.1 | 5.43E-01 | 1.47E-01 | |
| SR-259-136-T6 | T6 E. 0"-6" | 356.3 | <MDA | <MDA | 1.24E-01 |
| SR-259-140-T6 | T6 E.12"-18" | 342.3 | <MDA | <MDA | 4.18E-02 |
| SR-259-138-T6 | T6 E.6"-12" | 405.4 | <MDA | <MDA | 9.65E-02 |
| SR-259-145-T6 | T6 W. 0"-6" | 344.2 | <MDA | <MDA | 8.31E-02 |
| SR-259-147-T6 | T6 W. 12"-18" | 388.0 | <MDA | <MDA | 7.37E-02 |
| SR-259-146-T6 | T6 W. 6"-12" | 348.9 | <MDA | <MDA | 1.57E-01 |
| SR-259-151-T7 | T7 C. 0"-6" | 422.3 | <MDA | <MDA | 1.03E-01 |
| SR-259-153-T7 | T7 C. 12"-18" | 405.7 | 2.49E-01 | 9.78E-02 | |
| SR-259-152-T7 | T7 C. 6"-12" | 388.0 | <MDA | <MDA | 1.06E-01 |
| SR-259-148-T7 | T7 E. 0"-6" | 354.5 | <MDA | <MDA | 8.45E-02 |
| SR-259-150-T7 | T7 E. 12"-18" | 365.5 | 4.34E-01 | 1.39E-01 | |
| SR-259-149-T7 | T7 E. 6"-12" | 316.6 | 5.15E-01 | 1.59E-01 | |
| SR-259-154-T7 | T7 W. 0"-6" | 312.9 | 2.40E-01 | 7.93E-02 | |
| SR-259-164 | T8 C. 6"-12" | 331.7 | <MDA | <MDA | 8.29E-02 |
| SR-259-163 | T8 C. 0"-6" | 392.9 | <MDA | <MDA | 7.28E-02 |
| SR-259-165 | T8 C. 12"-18" | 383.9 | <MDA | <MDA | 7.45E-02 |
| SR-259-157 | T8 E 0"-6" | 340.2 | <MDA | <MDA | 9.24E-02 |
| SR-259-159 | T8 E 6"-12" | 320.3 | <MDA | <MDA | 1.15E-01 |
| SR-259-161 | T8 E. 12"-18" | 313.2 | <MDA | <MDA | 9.13E-02 |
| SR-259-166 | T8 W. 0"-6" | 314.4 | 9.97E-01 | 2.19E-01 | |
| SR-259-168 | T8 W. 12"-18" | 341.8 | 2.86E-01 | 9.03E-02 | |
| SR-259-156-T7 | T8 W. 12"-18" | 329.3 | <MDA | <MDA | 9.10E-02 |

**Table 1, PBRF Laboratory Results for Stream Section 2 Ravine Samples (Cs-137)**

| Sample # | Location | Weight (g) | Conc. pCi/g | 2σ Error (pCi/g) | MDA (pCi/g) |
|---|---|---|---|---|---|
| SR-259-155-T7 | T8 W. 6"-12" | 311.2 | <MDA | <MDA | 9.19E-02 |
| SR-259-167 | T8 W. 6"-12" | 333.8 | 9.32E-01 | 2.23E-01 | |
| SR-259-172 | T9 C. 0"-6" | 389.3 | 4.60E-01 | 1.33E-01 | |
| SR-259-174 | T9 C. 12"-18" | 388.6 | <MDA | <MDA | 7.71E-02 |
| SR-259-173 | T9 C. 6"-12" | 450.1 | 3.69E-01 | 1.22E-01 | |
| SR-259-169 | T9 E. 0"-6" | 389.2 | <MDA | <MDA | 7.70E-02 |
| SR-259-171 | T9 E. 12"-18" | 314.7 | <MDA | <MDA | 6.67E-02 |
| SR-259-170 | T9 E. 6"-12" | 351.0 | <MDA | <MDA | 8.15E-02 |
| SR-259-175 | T9 W. 0"-6" | 331.0 | 4.29E-01 | 1.39E-01 | |
| SR-259-177 | T9 W. 12"-18" | 323.6 | 4.74E-01 | 1.67E-01 | |
| SR-259-176 | T9 W. 6"-12" | 314.2 | 5.69E-01 | 1.22E-01 | |
| SR-259-178 | T10 E. 0"-6" | 393.5 | 3.25E-01 | 1.14E-01 | |
| SR-259-182 | T10 E. 12"-18" | 331.5 | 7.49E-01 | 1.88E-01 | |
| SR-259-180 | T10 E. 6"-12" | 361.7 | 5.58E-01 | 1.55E-01 | |
| SR-259-184 | T10-C 0"-6" | 400.0 | 6.56E-01 | 1.82E-01 | |
| SR-259-186 | T10-C 12"-18" | 337.0 | 4.72E-01 | 1.48E-01 | |
| SR-259-185 | T10-C 6"-12" | 381.2 | 5.33E-01 | 1.52E-01 | |
| SR-259-187 | T10-W 0"-6" | 379.2 | <MDA | <MDA | 7.90E-02 |
| SR-259-189 | T10-W 12"-18" | 336.2 | 3.63E-01 | 1.33E-01 | |
| SR-259-188 | T10-W 6"-12" | 402.7 | 2.89E-01 | 1.06E-01 | |
| SR-259-79 | T12 CNT 0"-6" (SAIC) | 360.9 | <MDA | <MDA | 7.62E-02 |
| SR-259-81 | T12 CNT 12"-18" (SAIC) | 348.4 | <MDA | <MDA | 8.21E-02 |
| SR-259-80 | T12 CNT 6"-12" (SAIC) | 335.3 | <MDA | <MDA | 8.94E-02 |
| SR-259-76 | T12 E 0"-6" (SAIC) | 378.6 | 2.99E-01 | 1.25E-01 | |
| SR-259-78 | T12 E 12"-18" (SAIC) | 436.1 | 4.27E-01 | 1.24E-01 | |
| SR-259-77 | T12 E 6"-12" (SAIC) | 419.7 | 4.17E-01 | 1.28E-01 | |
| SR-259-82 | T12 W 0"-6" (SAIC) | 386.9 | <MDA | <MDA | 7.11E-02 |
| SR-259-84 | T12 W 12"-18" (SAIC) | 397.7 | <MDA | <MDA | 7.19E-02 |
| SR-259-83 | T12 W 6"-12" (SAIC) | 372.4 | <MDA | <MDA | 8.05E-02 |
| SR-259-193 | T13 C 0"-6" | 385.6 | 3.12E-01 | 1.12E-01 | |
| SR-259-195 | T13 C 12"-18" | 381.1 | <MDA | <MDA | 7.50E-02 |
| SR-259-194 | T13 C 6"-12" | 378.6 | <MDA | <MDA | 7.92E-02 |
| SR-259-190 | T13 E 0"-6" | 349.2 | 3.96E-01 | 1.36E-01 | |
| SR-259-192 | T13 E 12"-18" | 352.2 | 5.66E-01 | 1.62E-01 | |
| SR-259-191 | T13 E 6"-12" | 391.6 | 4.74E-01 | 1.14E-01 | |
| SR-259-196 | T13 W 0"-6" | 379.6 | <MDA | <MDA | 9.97E-02 |
| SR-259-198 | T13 W 12"-18" | 391.3 | <MDA | <MDA | 7.31E-02 |
| SR-259-197 | T13 W 6"-12" | 377.1 | <MDA | <MDA | 7.59E-02 |
| SR-259-262 | T14 C "0-6" | 454.7 | <MDA | <MDA | 6.59E-02 |
| SR-259-264 | T14 C "12-18" | 429.1 | <MDA | <MDA | 6.41E-02 |
| SR-259-263 | T14 C "6-12" | 409.5 | <MDA | <MDA | 6.99E-02 |
| SR-259-259 | T14 E "0-6" | 409.5 | <MDA | <MDA | 7.32E-02 |
| SR-259-261 | T14 E "12-18" | 434.5 | <MDA | <MDA | 6.33E-02 |
| SR-259-260 | T14 E "6-12" | 388.7 | <MDA | <MDA | 7.36E-02 |

**Table 1, PBRF Laboratory Results for Stream Section 2 Ravine Samples (Cs-137)**

| Sample # | Location | Weight (g) | Conc. pCi/g | 2σ Error (pCi/g) | MDA (pCi/g) |
|---|---|---|---|---|---|
| SR-259-265 | T14 W "0-6" | 401.5 | 3.04E-01 | 1.11E-01 | |
| SR-259-267 | T14 W "12-18" | 449.1 | 3.41E-01 | 1.07E-01 | |
| SR-259-266 | T14 W "6-12" | 459.3 | 3.30E-01 | 1.06E-01 | |
| SR-259-274 | T15 C "0-6" | 439.2 | <MDA | <MDA | 8.61E-02 |
| SR-259-276 | T15 C "12-18" | 426.9 | <MDA | <MDA | 7.02E-02 |
| SR-259-275 | T15 C "6-12" | 423.0 | <MDA | <MDA | 6.76E-02 |
| SR-259-268 | T15 E "0-6" | 324.4 | 3.39E-01 | 1.31E-01 | |
| SR-259-272 | T15 E "12-18" | 312.7 | 1.56E+00 | 2.82E-01 | |
| SR-259-270 | T15 E "6-12" | 341.9 | 4.44E-01 | 1.01E-01 | |
| SR-259-277 | T15 W "0-6" | 403.9 | <MDA | <MDA | 7.08E-02 |
| SR-259-279 | T15 W "12-18" | 406.8 | <MDA | <MDA | 7.03E-02 |
| SR-259-278 | T15 W "6-12" | 400.0 | <MDA | <MDA | 7.49E-02 |
| SR-259-73 | T17 CNT 0"-6" (SAIC) | 441.7 | 3.04E-01 | 1.02E-01 | |
| SR-259-75 | T17 CNT 12"-18" (SAIC) | 423.5 | 2.98E-01 | 1.07E-01 | |
| SR-259-74 | T17 CNT 6"-12" (SAIC) | 410.1 | 4.19E-01 | 1.24E-01 | |
| SR-259-70 | T17 E 0"-6" (SAIC) | 330.1 | 7.47E-01 | 1.85E-01 | |
| SR-259-72 | T17 E 12"-18" (SAIC) | 319.4 | 1.53E+00 | 2.22E-01 | |
| SR-259-71 | T17 E 6"-12" (SAIC) | 317.2 | 1.19E+00 | 2.39E-01 | |
| SR-259-64 | T18 CNT 0"-6" (SAIC) | 409.0 | 3.56E-01 | 1.14E-01 | |
| SR-259-66 | T18 CNT 12"-18" (SAIC) | 387.9 | 3.72E-01 | 1.32E-01 | |
| SR-259-65 | T18 CNT 6"-12" (SAIC) | 374.6 | 5.43E-01 | 1.54E-01 | |
| SR-259-61 | T18 E 0"-6" (SAIC) | 386.1 | 3.79E-01 | 1.27E-01 | |
| SR-259-63 | T18 E 12"-18" (SAIC) | 412.0 | 3.55E-01 | 1.19E-01 | |
| SR-259-62 | T18 E 6"-12" (SAIC) | 378.7 | 4.54E-01 | 1.34E-01 | |
| SR-259-67 | T18 W 0"-6" (SAIC) | 355.5 | 4.02E-01 | 1.56E-01 | |
| SR-259-69 | T18 W 12"-18" (SAIC) | 324.4 | 3.51E-01 | 9.43E-02 | |
| SR-259-68 | T18 W 6"-12" (SAIC) | 343.0 | 3.59E-01 | 1.25E-01 | |
| SR-259-55 | T19 CNT 0"-6" (SAIC) | 431.6 | 1.90E-01 | 8.13E-02 | |
| SR-259-57 | T19 CNT 12"-18" (SAIC) | 415.2 | 2.52E-01 | 9.54E-02 | |
| SR-259-56 | T19 CNT 6"-12" (SAIC) | 430.7 | 2.94E-01 | 1.23E-01 | |
| SR-259-52 | T19 E 0"-6" (SAIC) | 380.0 | <MDA | <MDA | 9.01E-02 |
| SR-259-54 | T19 E 12"-18" (SAIC) | 362.7 | <MDA | <MDA | 8.27E-02 |
| SR-259-53 | T19 E 6"-12" (SAIC) | 378.7 | <MDA | <MDA | 7.27E-02 |
| SR-259-58 | T19 W 0"-6" (SAIC) | 339.5 | 2.64E-01 | 1.08E-01 | |
| SR-259-60 | T19 W 12"-18" (SAIC) | 327.7 | <MDA | <MDA | 8.40E-02 |
| SR-259-59 | T19 W 6"-12" (SAIC) | 329.5 | <MDA | <MDA | 1.62E-01 |
| SR-259-46 | T20 CNT 0"-6" (SAIC) | 453.5 | 2.69E-01 | 9.85E-02 | |
| SR-259-48 | T20 CNT 12"-18" (SAIC) | 403.8 | 3.02E-01 | 1.11E-01 | |
| SR-259-47 | T20 CNT 6"-12" | 421.6 | 1.95E-01 | 8.32E-02 | |

**Table 1, PBRF Laboratory Results for Stream Section 2 Ravine Samples (Cs-137)**

| Sample # | Location | Weight (g) | Conc. pCi/g | 2σ Error (pCi/g) | MDA (pCi/g) |
|---|---|---|---|---|---|
| | (SAIC) | | | | |
| SR-259-43 | T20 E 0"-6" (SAIC) | 373.8 | <MDA | <MDA | 7.36E-02 |
| SR-259-45 | T20 E 12"-18" (SAIC) | 416.6 | <MDA | <MDA | 6.61E-02 |
| SR-259-44 | T20 E 6"-12" (SAIC) | 387.0 | <MDA | <MDA | 8.50E-02 |
| SR-259-49 | T20 W 0"-6" (SAIC) | 323.2 | 3.70E-01 | 1.31E-01 | |
| SR-259-51 | T20 W 12"-18" (SAIC) | 388.5 | 2.69E-01 | 1.02E-01 | |
| SR-259-50 | T20 W 6"-12" (SAIC) | 356.7 | 3.65E-01 | 1.29E-01 | |
| SR-259-37 | T21 CNT 0"-6" (SAIC) | 412.1 | 1.65E-01 | 7.20E-02 | |
| SR-259-39 | T21 CNT 12"-18" (SAIC) | 408.7 | 1.92E-01 | 7.44E-02 | |
| SR-259-38 | T21 CNT 6"-12" (SAIC) | 443.5 | 2.27E-01 | 8.94E-02 | |
| SR-259-31 | T21 E 0"-6" (SAIC) | 351.4 | 2.34E-01 | 7.00E-02 | |
| SR-259-35 | T21 E 12"-18" (SAIC) | 351.1 | 1.99E-01 | 7.00E-02 | |
| SR-259-33 | T21 E 6"-12" (SAIC) | 341.4 | 1.64E-01 | 5.18E-02 | |
| SR-259-40 | T21 W 0"-6" (SAIC) | 330.8 | 2.11E-01 | 9.97E-02 | |
| SR-259-42 | T21 W 12"-18" (SAIC) | 369.9 | <MDA | <MDA | 7.73E-02 |
| SR-259-41 | T21 W 6"-12" (SAIC) | 400.8 | 9.58E-02 | 4.80E-02 | |
| SR-259-25 | T22 CNT 0"-6" (SAIC) | 387.8 | 3.50E-01 | 1.19E-01 | |
| SR-259-27 | T22 CNT 12"-18" (SAIC) | 424.6 | 4.66E-01 | 1.31E-01 | |
| SR-259-26 | T22 CNT 6"-12" (SAIC) | 402.6 | 5.56E-01 | 1.51E-01 | |
| SR-259-22 | T22 E 0"-6" (SAIC) | 414.6 | <MDA | <MDA | 2.09E-01 |
| SR-259-24 | T22 E 12"-18" (SAIC) | 355.2 | 4.92E-01 | 1.51E-01 | |
| SR-259-23 | T22 E 6"-12" (SAIC) | 368.8 | 1.89E-01 | 8.94E-02 | |
| SR-259-28 | T22 W 0"-6" (SAIC) | 364.2 | 3.91E-01 | 1.33E-01 | |
| SR-259-30 | T22 W 12"-18" (SAIC) | 361.0 | <MDA | <MDA | 1.29E-01 |
| SR-259-29 | T22 W 6"-12" (SAIC) | 357.7 | 2.84E-01 | 1.32E-01 | |
| SR-259-16 | T23 CNT 0"-6" (SAIC) | 444.2 | 2.66E-01 | 9.88E-02 | |
| SR-259-18 | T23 CNT 12"-18" (SAIC) | 366.0 | 2.80E-01 | 1.34E-01 | |
| SR-259-17 | T23 CNT 6"-12" (SAIC) | 444.4 | 2.75E-01 | 7.87E-02 | |
| SR-259-10 | T23 E 0"-6" (SAIC) | 438.4 | 2.57E-01 | 8.04E-02 | |
| SR-259-14 | T23 E 12"-18" (SAIC) | 412.3 | 4.23E-01 | 1.27E-01 | |
| SR-259-12 | T23 E 6"-12" (SAIC) | 462.1 | 3.24E-01 | 8.79E-02 | |
| SR-259-19 | T23 W 0"-6" (SAIC) | 370.9 | 4.60E-01 | 1.39E-01 | |
| SR-259-21 | T23 W 12"-18" (SAIC) | 328.9 | <MDA | <MDA | 1.10E-01 |
| SR-259-20 | T23 W 6"-12" (SAIC) | 330.4 | 2.71E-01 | 1.16E-01 | |
| SR-259-4 | T24 CNT 0"-6" (SAIC) | 449.0 | 2.20E-01 | 9.37E-02 | |
| SR-259-6 | T24 CNT 12"-18" (SAIC) | 392.6 | 2.17E-01 | 9.29E-02 | |
| SR-259-5 | T24 CNT 6"-12" (SAIC) | 463.3 | 3.72E-01 | 1.27E-01 | |
| SR-259-1 | T24 E 0"-6" (SAIC) | 349.2 | <MDA | <MDA | 8.58E-02 |

**Table 1, PBRF Laboratory Results for Stream Section 2 Ravine Samples (Cs-137)**

| Sample # | Location | Weight (g) | Conc. pCi/g | 2σ Error (pCi/g) | MDA (pCi/g) |
|---|---|---|---|---|---|
| SR-259-3 | T24 E 12"-18" (SAIC) | 376.5 | <MDA | <MDA | 1.06E-01 |
| SR-259-2 | T24 E 6"-12" (SAIC) | 328.0 | 2.11E-01 | 8.81E-02 | |
| SR-259-7 | T24 W 0"-6" (SAIC) | 372.6 | 6.77E-01 | 1.73E-01 | |
| SR-259-9 | T24 W 12"-18" (SAIC) | 381.4 | 2.10E+00 | 3.04E-01 | |
| SR-259-8 | T24 W 6"-12" (SAIC) | 345.4 | 1.11E+00 | 2.26E-01 | |
| SR-259-217 | T25 C "0-6" | 427.0 | 2.86E-01 | 1.05E-01 | |
| SR-259-219 | T25 C "12-18" | 405.8 | 5.24E-01 | 1.40E-01 | |
| SR-259-218 | T25 C "6-12" | 418.4 | 2.97E-01 | 1.05E-01 | |
| SR-259-214 | T25 E "0-6" | 328.6 | 3.22E-01 | 1.27E-01 | |
| SR-259-216 | T25 E "12-18" | 319.9 | <MDA | <MDA | 8.60E-02 |
| SR-259-215 | T25 E "6-12" | 370.7 | <MDA | <MDA | 7.72E-02 |
| SR-259-220 | T25 W "0-6" | 385.0 | 2.55E+00 | 3.35E-01 | |
| SR-259-224 | T25 W "12-18" | 319.9 | 8.88E-01 | 1.74E-01 | |
| SR-259-222 | T25 W "6-12" | 354.1 | 2.43E+00 | 3.26E-01 | |
| SR-259-229 | T26 C "0-6" | 322.3 | 3.03E-01 | 1.24E-01 | |
| SR-259-231 | T26 C "12-18" | 437.2 | 4.56E-01 | 1.31E-01 | |
| SR-259-230 | T26 C "6-12" | 370.2 | 3.91E-01 | 1.55E-01 | |
| SR-259-226 | T26 E "0-6" | 360.8 | 2.71E-01 | 1.11E-01 | |
| SR-259-228 | T26 E "12-18" | 381.4 | 3.73E-01 | 1.46E-01 | |
| SR-259-227 | T26 E "6-12" | 342.0 | 3.21E-01 | 1.24E-01 | |
| SR-259-232 | T26 W "0-6" | 330.1 | 3.88E-01 | 1.35E-01 | |
| SR-259-234 | T26 W "12-18" | 343.9 | 2.60E-01 | 1.08E-01 | |
| SR-259-233 | T26 W "6-12" | 323.7 | 4.02E-01 | 1.43E-01 | |
| SR-259-238 | T27 C "0-6" | 371.1 | 3.56E-01 | 1.22E-01 | |
| SR-259-240 | T27 C "12-18" | 418.8 | <MDA | <MDA | 8.36E-02 |
| SR-259-239 | T27 C "6-12" | 360.7 | <MDA | <MDA | 1.36E-01 |
| SR-259-235 | T27 E "0-6" | 380.9 | 2.46E-01 | 1.03E-01 | |
| SR-259-237 | T27 E "12-18" | 370.6 | <MDA | <MDA | 8.09E-02 |
| SR-259-236 | T27 E "6-12" | 339.8 | <MDA | <MDA | 1.37E-01 |
| SR-259-241 | T27 W "0-6" | 317.5 | 4.87E-01 | 1.58E-01 | |
| SR-259-243 | T27 W "12-18" | 321.4 | <MDA | <MDA | 1.28E-01 |
| SR-259-242 | T-27 W "6-12" | 363.3 | 3.42E-01 | 1.21E-01 | |
| SR-259-256 | T27/T28 SM-1 "0-6" | 370.7 | 2.95E+00 | 3.60E-01 | |
| SR-259-258 | T27/T-28 SM-1 "12-18" | 361.3 | 2.25E+00 | 3.39E-01 | |
| SR-259-257 | T27/T-28 SM-1 "6-12" | 344.3 | 3.23E+00 | 3.99E-01 | |
| SR-259-250 | T28 C "0-6" | 425.9 | 2.69E-01 | 1.13E-01 | |
| SR-259-252 | T28 C "12-18" | 400.9 | 3.68E-01 | 1.20E-01 | |
| SR-259-251 | T28 C "6-12" | 432.5 | 3.29E-01 | 1.12E-01 | |
| SR-259-246 | T28 E "6-12" | 328.4 | 8.51E-01 | 2.02E-01 | |
| SR-259-244 | T28 E "0-6" | 389.7 | 5.68E-01 | 1.51E-01 | |
| SR-259-248 | T28 E "12-18" | 325.9 | 1.01E+00 | 2.21E-01 | |
| SR-259-253 | T28 W "0-6" | 349.6 | <MDA | <MDA | 1.78E-01 |
| SR-259-255 | T28 W "12-18" | 386.3 | <MDA | <MDA | 7.76E-02 |
| SR-259-254 | T28 W "6-12" | 371.8 | <MDA | <MDA | 7.69E-02 |
| SR-259-286 | T29 C 0-6 | 416.5 | 3.05E-01 | 1.05E-01 | |
| SR-259-288 | T29 C 12-18 | 371.6 | 2.71E-01 | 1.07E-01 | |

**Table 1, PBRF Laboratory Results for Stream Section 2 Ravine Samples (Cs-137)**

| Sample # | Location | Weight (g) | Conc. pCi/g | 2σ Error (pCi/g) | MDA (pCi/g) |
|---|---|---|---|---|---|
| SR-259-287 | T29 C 6-12 | 378.7 | 3.65E-01 | 1.26E-01 | |
| SR-259-280 | T29 E 0-6 | 341.1 | 2.85E-01 | 1.12E-01 | |
| SR-259-284 | T29 E 12-18 | 363.1 | 3.36E-01 | 1.23E-01 | |
| SR-259-282 | T29 E 6-12 | 364.4 | <MDA | <MDA | 1.19E-01 |
| SR-259-289 | T29 W 0-6 | 320.6 | 3.61E-01 | 1.30E-01 | |
| SR-259-291 | T29 W 12-18 | 328.0 | 4.14E-01 | 1.40E-01 | |
| SR-259-290 | T29 W 6-12 | 333.6 | 2.44E-01 | 1.09E-01 | |
| SR-259-295 | T30 C 0-6 | 405.2 | 3.41E-01 | 1.12E-01 | |
| SR-259-297 | T30 C 12-18 | 411.0 | 3.40E-01 | 1.14E-01 | |
| SR-259-296 | T30 C 6-12 | 386.4 | 2.11E-01 | 9.43E-02 | |
| SR-259-292 | T30 E 0-6 | 347.4 | 3.12E-01 | 1.16E-01 | |
| SR-259-294 | T30 E 12-18 | 355.3 | 3.93E-01 | 1.31E-01 | |
| SR-259-293 | T30 E 6-12 | 330.8 | 2.95E-01 | 1.21E-01 | |
| SR-259-298 | T30 W 0-6 | 362.6 | 2.68E-01 | 1.05E-01 | |
| SR-259-300 | T30 W 12-18 | 381.1 | <MDA | <MDA | 1.20E-01 |
| SR-259-299 | T30 W 6-12 | 384.8 | 2.33E-01 | 9.93E-02 | |
| SR-259-307 | T31 C 0-6 | 433.7 | 2.07E-01 | 8.45E-02 | |
| SR-259-309 | T31 C 12-18 | 408.0 | 3.04E-01 | 1.08E-01 | |
| SR-259-308 | T31 C 6-12 | 452.5 | 2.97E-01 | 1.04E-01 | |
| SR-259-301 | T31 E 0-6 | 317.0 | 3.53E-01 | 1.29E-01 | |
| SR-259-305 | T31 E 12-18 | 385.8 | <MDA | <MDA | 9.70E-02 |
| SR-259-303 | T31 E 6-12 | 392.9 | 1.88E-01 | 8.62E-02 | |
| SR-259-310 | T31 W 0-6 | 329.2 | 4.65E-01 | 1.78E-01 | |
| SR-259-312 | T31 W 12-18 | 318.8 | <MDA | <MDA | 8.97E-02 |
| SR-259-311 | T31 W 6-12 | 351.4 | <MDA | <MDA | 1.14E-01 |
| SR-259-316 | T32 C 0-6 | 328.2 | <MDA | <MDA | 1.28E-01 |
| SR-259-318 | T32 C 12-18 | 367.9 | <MDA | <MDA | 1.01E-01 |
| SR-259-317 | T32 C 6-12 | 380.9 | 1.71E-01 | 8.55E-02 | |
| SR-259-313 | T32 E 0-6 | 333.1 | 2.80E-01 | 1.12E-01 | |
| SR-259-315 | T32 E 12-18 | 340.0 | <MDA | <MDA | 2.69E-01 |
| SR-259-314 | T32 E 6-12 | 347.1 | <MDA | <MDA | 2.52E-01 |
| SR-259-319 | T32 W 0-6 | 348.3 | 2.75E-01 | 1.24E-01 | |
| SR-259-321 | T32 W 12-18 | 332.2 | 2.80E-01 | 1.15E-01 | |
| SR-259-320 | T32 W 6-12 | 318.8 | 3.19E-01 | 1.28E-01 | |
| SR-259-328 | T33 C 0-6 | 428.3 | 4.85E-01 | 1.46E-01 | |
| SR-259-330 | T33 C 12-18 | 419.1 | 6.39E-01 | 1.55E-01 | |
| SR-259-329 | T33 C 6-12 | 405.4 | 7.12E-01 | 1.70E-01 | |
| SR-259-322 | T33 E 0-6 | 346.9 | 2.47E-01 | 1.03E-01 | |
| SR-259-326 | T33 E 12-18 | 403.0 | 2.61E-01 | 1.16E-01 | |
| SR-259-324 | T33 E 6-12 | 403.4 | 3.37E-01 | 1.14E-01 | |
| SR-259-331 | T33 W 0-6 | 351.0 | 2.87E-01 | 1.11E-01 | |
| SR-259-333 | T33 W 12-18 | 353.0 | 2.20E-01 | 9.85E-02 | |
| SR-259-332 | T33 W 6-12 | 373.7 | <MDA | <MDA | 1.10E-01 |
| SR-259-337 | T34 C 0-6 | 423.1 | 2.38E-01 | 9.19E-02 | |
| SR-259-339 | T34 C 12-18 | 441.9 | <MDA | <MDA | 8.63E-02 |
| SR-259-338 | T34 C 6-12 | 437.0 | <MDA | <MDA | 6.86E-02 |

**Table 1, PBRF Laboratory Results for Stream Section 2 Ravine Samples (Cs-137)**

| Sample # | Location | Weight (g) | Conc. pCi/g | 2σ Error (pCi/g) | MDA (pCi/g) |
|---|---|---|---|---|---|
| SR-259-334 | T34 E 0-6 | 353.2 | 1.80E-01 | 8.73E-02 | |
| SR-259-336 | T34 E 12-18 | 360.1 | 2.48E-01 | 1.04E-01 | |
| SR-259-335 | T34 E 6-12 | 373.4 | 1.96E-01 | 9.25E-02 | |
| SR-259-340 | T34 W 0-6 | 316.6 | <MDA | <MDA | 1.13E-01 |
| SR-259-342 | T34 W 12-18 | 340.4 | <MDA | <MDA | 8.40E-02 |
| SR-259-341 | T34 W 6-12 | 316.2 | 3.60E-01 | 1.36E-01 | |
| SR-259-349 | T35 C 0-6 | 432.3 | 2.68E-01 | 9.64E-02 | |
| SR-259-351 | T35 C 12-18 | 463.7 | 3.43E-01 | 1.08E-01 | |
| SR-259-350 | T35 C 6-12 | 414.8 | 2.55E-01 | 1.00E-01 | |
| SR-259-343 | T35 E 0-6 | 367.2 | 2.95E-01 | 1.10E-01 | |
| SR-259-347 | T35 E 12-18 | 346.7 | 3.17E-01 | 1.22E-01 | |
| SR-259-345 | T35 E 6-12 | 348.2 | <MDA | <MDA | 1.46E-01 |
| SR-259-352 | T35 W 0-6 | 329.3 | 5.10E-01 | 1.53E-01 | |
| SR-259-354 | T35 W 12-18 | 339.5 | 2.63E-01 | 1.10E-01 | |
| SR-259-353 | T35 W 6-12 | 327.6 | 2.23E-01 | 1.05E-01 | |
| Number | | 312 | 203 | 203 | 109 |
| Max | | 463.7 | 1.82E+01 | 1.04E+00 | 2.69E-01 |
| Avg | | 375.0 | 9.58E-01 | 1.65E-01 | 9.66E-02 |
| SD | | 38.53 | 2.32E+00 | 1.40E-01 | 3.52E-02 |

**Table 2, PBRF Laboratory Results for Flood Backwater Investigation Samples (Cs-137)**

| Sample # | Location | Weight (g) | Conc. pCi/g | 2σ Error (pCi/g) | MDA (pCi/g) |
|---|---|---|---|---|---|
| SR-272-1 | T-11 W. SM-1 0"-6" | 390.0 | 4.50E-01 | 1.32E-01 | 7.05E-02 |
| SR-272-2 | T-22 E. SM-2 0"-6" | 350.3 | 3.25E-01 | 1.23E-01 | 8.55E-02 |
| SR-272-3 | T-23 E. SM-3 0"-6" | 373.7 | <MDA | <MDA | 7.65E-02 |
| SR-272-4 | T-23E QC SM-3 0"-6" | 380.9 | 1.96E-01 | 8.78E-02 | 7.22E-02 |
| SR-272-5 | T-24 E. SM-4 0"-6" | 351.5 | <MDA | <MDA | 8.53E-02 |
| SR-272-6 | T-2 E. SM-5 0"-6" | 389.1 | <MDA | <MDA | 7.35E-02 |
| SR-272-7 | T-9 E. SM-6 0"-6" | 367.3 | <MDA | <MDA | 1.37E-01 |
| SR-272-8 | T-9 W. SM-7 0"-6" | 321.9 | 7.07E-01 | 1.90E-01 | 9.31E-02 |

**Table 3, PBRF Laboratory Results for all Section 2 QC Samples (Cs-137)**

| Sample # | Location | Weight (g) | Conc. pCi/g | 2σ Error (pCi/g) | MDA (pCi/g) |
|---|---|---|---|---|---|
| SR-259-86 | T1 E QC 0"-6" (SAIC) | 391 | 2.00E-01 | 7.10E-02 | |
| SR-259-88 | T1 E QC 6"-12" (SAIC) | 395.1 | 1.47E-01 | 5.86E-02 | |
| SR-259-90 | T1 E QC 12"-18" (SAIC) | 370.3 | 9.33E-02 | 4.58E-02 | |
| SR-259-116-T4 | E QC. 0"-6" | 346.2 | 7.05E-01 | 1.83E-01 | |
| SR-259-118-T4 | E. QC 6"-12" | 375.1 | 6.97E-01 | 1.68E-01 | |
| SR-259-120-T4 | 120 T4 E. QC 12"-18" | 403.1 | 6.93E-01 | 1.64E-01 | |
| SR-259-137-T6 | E. 0"-6" QC | 360.7 | <MDA | <MDA | 1.11E-01 |
| SR-259-139-T6 | E. 6"-12" QC | 393.2 | <MDA | <MDA | 5.75E-02 |
| SR-259-141-T6 | E.12"-18" QC | 351.3 | 2.26E-01 | 7.10E-02 | |
| SR-259-158 | T8 E QC 0"-6" | 338.4 | <MDA | <MDA | 1.07E-01 |
| SR-259-160 | T8 E QC 6"-12" | 322.2 | <MDA | <MDA | 8.54E-02 |
| SR-259-162 | T8 E QC 12"-18" | 382.1 | <MDA | <MDA | 0.090857 |
| SR-259-179 | T10 E. QC 0"-6" | 421.8 | <MDA | <MDA | 6.78E-02 |
| SR-259-181 | T10 E. QC 6"-12" | 337.1 | 7.37E-01 | 1.85E-01 | |
| SR-259-183 | T10 E. QC 12"-18" | 332.6 | 3.95E-01 | 1.60E-01 | |
| SR-259-269 | T-15 E QC "0-6" | 386.7 | 4.52E-01 | 1.35E-01 | |
| SR-259-271 | T-15 E QC "6-12" | 433.9 | 2.73E-01 | 8.42E-02 | |
| SR-259-272 | T-15 E "12-18" | 312.7 | 1.54E+00 | 2.74E-01 | |
| SR-259-273 | T-15 E QC "12-18" | 368.6 | 1.39E+00 | 2.55E-01 | |
| SR-259-15 | T 23 E 12"-18" QC SAIC) | 445.1 | 2.85E-01 | 5.69E-02 | |
| SR-259-32 | T 21 E 0"-6" QC (SAIC) | 332.9 | 2.05E-01 | 7.93E-02 | |
| SR-259-34 | T 21 E 6"-12" QC (SAIC) | 343.9 | 2.09E-01 | 6.89E-02 | |
| SR-259-36 | T 21 E 12"-18" QC SAIC) | 355.1 | 1.73E-01 | 6.23E-02 | |
| SR-259-11 | T 23 E 0"-6" QC (SAIC) | 439.9 | 3.14E-01 | 1.08E-01 | |
| SR-259-13 | T 23 E 6"-12" QC (SAIC) | 441.9 | 4.34E-01 | 8.48E-02 | |
| SR-259-221 | T-25 W QC "0-6" | 344.2 | 2.23E+00 | 3.23E-01 | |
| SR-259-223 | T-25 W QC "6-12" | 385.4 | 2.39E+00 | 3.23E-01 | |
| SR-259-225 | T-25 W QC "12-18" | 349.8 | 9.29E-01 | 2.01E-01 | |
| SR-259-245 | T28 E QC "0-6" | 346.5 | 5.30E-01 | 1.42E-01 | |
| SR-259-245 | T28 E QC "0-6" | 346.5 | 4.98E-01 | 1.31E-01 | |
| SR-259-247 | T28 E QC "6-12" | 316.7 | 8.33E-01 | 2.03E-01 | |
| SR-259-249 | T28 E QC "12-18" | 353.2 | 8.29E-01 | 1.97E-01 | |
| SR-259-281 | T-29 E QC 0-6 | 340.7 | 2.98E-01 | 1.20E-01 | |
| SR-259-283 | T-29 E QC 6-12 | 367.2 | 2.64E-01 | 1.04E-01 | |
| SR-259-285 | T-29 E QC 12-18 | 395.4 | 2.85E-01 | 1.06E-01 | |
| SR-259-302 | T-31 E QC 0-6 | 360.2 | 3.05E-01 | 1.18E-01 | |
| SR-259-304 | T-31 E QC 6-12 | 405.1 | <MDA | <MDA | 7.14E-02 |
| SR-259-306 | T-31 E QC 12-18 | 397.7 | 2.63E-01 | 1.02E-01 | |
| SR-259-325 | T-33 E QC 6-12 | 400.7 | 3.46E-01 | 1.29E-01 | |
| SR-259-327 | T-33 E QC 12-18 | 388.8 | 2.44E-01 | 1.15E-01 | |
| SR-259-344 | T-35 E QC 0-6 | 349.2 | 2.91E-01 | 1.17E-01 | |
| SR-259-346 | T-35 E QC 6-12 | 372.2 | 2.21E-01 | 1.08E-01 | |
| SR-259-348 | T-35 E QC 12-18 | 360.5 | 2.14E-01 | 7.86E-02 | |
| SR-272-4 | T-23E QC SM-3 0"-6" | 380.9 | 1.96E-01 | 8.78E-02 | 7.22E-02 |

**Table 3, PBRF Laboratory Results for all Section 2 QC Samples (Cs-137)**

| Sample # | Location | Weight (g) | Conc. pCi/g | 2σ Error (pCi/g) | MDA (pCi/g) |
|---|---|---|---|---|---|
| Number | | 44 | 37 | 37 | 7 |
| Max | | 445.1 | 2.39E+00 | 3.23E-01 | 1.11E-01 |
| Avg | | 371.4 | 5.50E-01 | 1.36E-01 | 8.43E-02 |
| SD | | 33.74 | 5.38E-01 | 7.10E-02 | 2.00E-02 |

# Plum Brook Reactor Facility

# Technical Basis Document

## Supplemental Radiological Characterization of Plum Brook Section 2

**PBRF-TBD-10-001**

**Revision No. 0**

# Appendix D

# Vendor Laboratory Report
## (Excerpt – Sample Results)

## CONTENTS

TELEDYNE
BROWN ENGINEERING, INC.
A Teledyne Technologies Company
2508 Quality Lane
Knoxville, TN 37931-3133
865-690-6819

# Work Order #: L43319

# PBOSG - Plum Brook waters

# November 5, 2010

REVISED
11-4-10

# Table of Contents

REVISED
Nov. 4, 2010

TELEDYNE
BROWN ENGINEERING, INC.
A Teledyne Technologies Company
2508 Quality Lane
Knoxville, TN 37931-3133

Kim Kostzer
Empirical Laboratories
621 Mainstream Drive
Suite 270
Nashville TN 37228

# Case Narrative - L43319
## PL001-3EREG-08

11/04/2010 14:11

## Sample Receipt

The following samples were received on August 17, 2010 in good condition, unless otherwise noted.

*Cross Reference Table*

| Client ID | Laboratory ID | Station ID(if applicable) |
|---|---|---|
| SR-259-199 | L43319-1 | |
| SR-259-200 | L43319-2 | |
| SR-259-202 | L43319-3 | |
| SR-259-206 | L43319-4 | |

## Sample Analysis

Instruments used for all analyses were in calibration.
Standard solutions used in analyses were National Institute of Standards and Technology (NIST) traceable.

*Analytical Method Cross Reference Table*

| Radiological Parameter | TBE Knoxville Method | Reference Method |
|---|---|---|
| Gamma Spectrometry | TBE-2007 | EPA 901.1 |
| I-129 | TBE-2012 | SM7500-I C |
| SR-90 | TBE-2019 | EPA 905.0 |

REVISED
Nov. 4, 2010

TELEDYNE
BROWN ENGINEERING, INC.
A Teledyne Technologies Company
2508 Quality Lane
Knoxville, TN 37931-3133

# Case Narrative - L43319
## PL001-3EREG-08

11/04/2010 14:11

## Special Considerations

The duplicate failed on the original Sr-90 Work Group. All Sr-90 samples were rerun. All QC results for the rerun work group were acceptable.

Revision 1:
I-129 was not scheduled at receipt. The I-129 was listed under the gamma nuclides, but it cannot be reported from a gamma scan. After the problem was discovered, the client was notified and the I-129 analysis was scheduled.

Revision 2:
The gamma scan for sample L43319-4 was processed with an incorrect efficiency file. The data has been reprocessed and the report is being reissued.

## Gamma Spectroscopy

### Quality Control

Quality control samples were analyzed as WG10412.

Duplicate Sample

Duplicates were analyzed for the following samples. All duplicate results were within acceptance limits, unless otherwise noted.

| Client ID | Laboratory ID | QC Sample # | |
|---|---|---|---|
| SR-259-199 | L43319-1 | WG10412-1 | BI-214-F |

## I-129

### Quality Control

Quality control samples were analyzed as WG10632.

Method Blank

All blanks were within acceptance limits, unless otherwise noted.

Laboratory Control Sample

All laboratory control samples were within acceptance limits, unless otherwise noted.

Laboratory Control Sample Duplicate

All laboratory control samples duplicate results were within acceptance limits, unless otherwise noted.

REVISED
Nov. 4, 2010

TELEDYNE
BROWN ENGINEERING, INC.
A Teledyne Technologies Company
2508 Quality Lane
Knoxville, TN 37931-3133

# Case Narrative - L43319
## PL001-3EREG-08
11/04/2010 14:11

## SR-90

### Quality Control

Quality control samples were analyzed as WG10448,WG10529.

Method Blank
All blanks were within acceptance limits, unless otherwise noted.

Laboratory Control Sample
All laboratory control samples were within acceptance limits, unless otherwise noted.

Duplicate Sample
Duplicates were analyzed for the following samples. All duplicate results were within acceptance limits, unless otherwise noted.

| Client ID | Laboratory ID | QC Sample # |
|---|---|---|
| EAST WALL, TURBINE 882 | L43178-1R1 | WG10529-3 |

## Certification

This is to certify that Teledyne Brown Engineering - Environmental Services, located at 2508 Quality Lane, Knoxville, Tennessee, 37931, has analyzed, tested and documented samples as specified in the applicable purchase order.

This also certifies that requirements of applicable codes, standards and specifications have been fully met and that any quality assurance documentation which verified conformance to the purchase order is on file and may be examined upon request.

I hereby certify that the above statements are true and correct.

Keith Jeter
Operations Manager

# ANALYTICAL RESULTS

# Report of Analysis

11/05/10 08:06

## L43319

Empirical Laboratories

PL001-3EREG-08

TELEDYNE BROWN ENGINEERING, INC.
A Teledyne Technologies Company

**REVISED**
**Nov. 4, 2010**

Kim Kostzer

Sample ID: SR-259-199 | Collect Start: 07/20/2010 07:15 | Matrix: Soil | (S)
Station: | Collect Stop: | Volume:
Description: | Receive Date: 08/17/2010 | % Moisture: 1.45
LIMS Number: L43319-1

| Radionuclide | SOP# | Activity Conc | Uncertainty 2 Sigma | MDC | Units | Run # | Aliquot Volume | Aliquot Units | Reference Date | Count Date | Count Time | Count Units | Flag Values | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I-129 | 2012 | -1.82E-02 | 1.71E-01 | 2.76E-01 | pCi/g Dry | | 10.0092 | g dry | 07/20/10 07:15 | 10/11/10 | 1200 | Sec | U | | No |
| SR-90 | 2018 | 9.13E-02 | 1.35E-01 | 2.15E-01 | pCi/g Dry | R1 | 7.0417 | g dry | 07/20/10 07:15 | 09/29/10 | 15 | M | U | | |
| AG-108M | 2007 | -2.02E-02 | 9.20E-02 | 1.48E-01 | pCi/g Dry | | 329.68 | g dry | 07/20/10 07:15 | 09/03/10 | 3600 | Sec | U | | No |
| K-40 | 2007 | 1.69E+01 | 1.88E+00 | 6.61E-01 | pCi/g Dry | | 329.68 | g dry | 07/20/10 07:15 | 09/03/10 | 3600 | Sec | + | | Yes |
| CO-60 | 2007 | 1.20E-01 | 6.80E-02 | 8.19E-02 | pCi/g Dry | | 329.68 | g dry | 07/20/10 07:15 | 09/03/10 | 3600 | Sec | + | | Yes |
| NB-94 | 2007 | 2.70E-02 | 4.49E-02 | 7.99E-02 | pCi/g Dry | | 329.68 | g dry | 07/20/10 07:15 | 09/03/10 | 3600 | Sec | U | | No |
| CS-137 | 2007 | 2.14E+01 | 5.03E-01 | 1.20E-01 | pCi/g Dry | | 329.68 | g dry | 07/20/10 07:15 | 09/03/10 | 3600 | Sec | + | | Yes |
| EU-152 | 2007 | 2.05E-01 | 2.52E-01 | 4.27E-01 | pCi/g Dry | | 329.68 | g dry | 07/20/10 07:15 | 09/03/10 | 3600 | Sec | U | | No |
| EU-154 | 2007 | -4.11E-02 | 1.55E-01 | 2.43E-01 | pCi/g Dry | | 329.68 | g dry | 07/20/10 07:15 | 09/03/10 | 3600 | Sec | U | | No |
| TL-208 | 2007 | 8.44E-01 | 4.46E-01 | 3.33E-01 | pCi/g Dry | | 329.68 | g dry | 07/20/10 07:15 | 09/03/10 | 3600 | Sec | + | | Yes |
| PB-212 | 2007 | 8.57E-01 | 1.71E-01 | 2.17E-01 | pCi/g Dry | | 329.68 | g dry | 07/20/10 07:15 | 09/03/10 | 3600 | Sec | + | | Yes |
| BI-214 | 2007 | 2.29E+00 | 2.81E-01 | 2.10E-01 | pCi/g Dry | | 329.68 | g dry | 07/20/10 07:15 | 09/03/10 | 3600 | Sec | + | | Yes |
| PB-214 | 2007 | 2.09E+00 | 2.91E-01 | 2.97E-01 | pCi/g Dry | | 329.68 | g dry | 07/20/10 07:15 | 09/03/10 | 3600 | Sec | + | | Yes |
| RA-226 | 2007 | 4.41E+00 | 2.85E+00 | 2.67E+00 | pCi/g Dry | | 329.68 | g dry | 07/20/10 07:15 | 09/03/10 | 3600 | Sec | + | | Yes |
| AC-228 | 2007 | 9.11E-01 | 3.50E-01 | 3.23E-01 | pCi/g Dry | | 329.68 | g dry | 07/20/10 07:15 | 09/03/10 | 3600 | Sec | + | | Yes |
| RA-228 | 2007 | 8.54E-01 | 4.24E-01 | 5.50E-01 | pCi/g Dry | | 329.68 | g dry | 07/20/10 07:15 | 09/03/10 | 3600 | Sec | + | | Yes |
| TH-228 | 2007 | 8.57E-01 | 1.71E-01 | 2.17E-01 | pCi/g Dry | | 329.68 | g dry | 07/20/10 07:15 | 09/03/10 | 3600 | Sec | + | | Yes |
| TH-232 | 2007 | 8.98E-01 | 3.44E-01 | 3.18E-01 | pCi/g Dry | | 329.68 | g dry | 07/20/10 07:15 | 09/03/10 | 3600 | Sec | + | | Yes |
| U-235 | 2007 | -3.77E-01 | 4.58E-01 | 7.50E-01 | pCi/g Dry | | 329.68 | g dry | 07/20/10 07:15 | 09/03/10 | 3600 | Sec | U | | No |

Flag Values
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U* = Compound/Analyte not detected. Peak not identified, but forced activity concentration exceeds MDC and 3 sigma
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H = High recovery

**Bolded text indicates reportable value.**

No = Peak not identified in gamma spectrum
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MDC - Minimum Detectable Concentration

# Report of Analysis

11/05/10 08:06

## L43319

Empirical Laboratories

PL001-3EREG-08

TELEDYNE BROWN ENGINEERING, INC.
A Teledyne Technologies Company

**REVISED**
**Nov. 4, 2010**

Kim Kostzer

Sample ID: SR-259-200 | Collect Start: 07/20/2010 07:25 | Matrix: Soil | (S)
Station: | Collect Stop: | Volume:
Description: | Receive Date: 08/17/2010 | % Moisture: 1.24
LIMS Number: L43319-2

| Radionuclide | SOP# | Activity Conc | Uncertainty 2 Sigma | MDC | Units | Run # | Aliquot Volume | Aliquot Units | Reference Date | Count Date | Count Time | Count Units | Flag Values | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I-129 | 2012 | -2.02E-02 | 1.57E-01 | **2.52E-01** | pCi/g Dry | | 10.0212 | g dry | 07/20/10 07:25 | 10/11/10 | 1200 | Sec | U | | No |
| SR-90 | 2018 | .00E+00 | 1.36E-01 | **2.77E-01** | pCi/g Dry | R1 | 7.0158 | g dry | 07/20/10 07:25 | 09/29/10 | 15 | M | U | | |
| AG-108M | 2007 | -2.83E-02 | 7.78E-02 | **1.22E-01** | pCi/g Dry | | 330.6 | g dry | 07/20/10 07:25 | 09/03/10 | 3600 | Sec | U | | No |
| K-40 | 2007 | **1.67E+01** | 1.70E+00 | 5.68E-01 | pCi/g Dry | | 330.6 | g dry | 07/20/10 07:25 | 09/03/10 | 3600 | Sec | + | | Yes |
| CO-60 | 2007 | -6.28E-02 | 5.64E-02 | **1.20E-01** | pCi/g Dry | | 330.6 | g dry | 07/20/10 07:25 | 09/03/10 | 3600 | Sec | U | | No |
| NB-94 | 2007 | -1.44E-02 | 3.59E-02 | **5.52E-02** | pCi/g Dry | | 330.6 | g dry | 07/20/10 07:25 | 09/03/10 | 3600 | Sec | U | | No |
| CS-137 | 2007 | **1.65E+01** | 4.14E-01 | 7.94E-02 | pCi/g Dry | | 330.6 | g dry | 07/20/10 07:25 | 09/03/10 | 3600 | Sec | + | | Yes |
| EU-152 | 2007 | -1.74E-01 | 2.13E-01 | **3.24E-01** | pCi/g Dry | | 330.6 | g dry | 07/20/10 07:25 | 09/03/10 | 3600 | Sec | U | | No |
| EU-154 | 2007 | -4.17E-02 | 1.04E-01 | **1.60E-01** | pCi/g Dry | | 330.6 | g dry | 07/20/10 07:25 | 09/03/10 | 3600 | Sec | U | | No |
| TL-208 | 2007 | **9.76E-01** | 2.73E-01 | 2.41E-01 | pCi/g Dry | | 330.6 | g dry | 07/20/10 07:25 | 09/03/10 | 3600 | Sec | + | | Yes |
| PB-212 | 2007 | **8.16E-01** | 1.54E-01 | 1.92E-01 | pCi/g Dry | | 330.6 | g dry | 07/20/10 07:25 | 09/03/10 | 3600 | Sec | + | | Yes |
| BI-214 | 2007 | **2.39E+00** | 2.67E-01 | 1.56E-01 | pCi/g Dry | | 330.6 | g dry | 07/20/10 07:25 | 09/03/10 | 3600 | Sec | + | | Yes |
| PB-214 | 2007 | **1.96E+00** | 2.41E-01 | 2.41E-01 | pCi/g Dry | | 330.6 | g dry | 07/20/10 07:25 | 09/03/10 | 3600 | Sec | + | | Yes |
| RA-226 | 2007 | **3.96E+00** | 2.34E+00 | 2.28E+00 | pCi/g Dry | | 330.6 | g dry | 07/20/10 07:25 | 09/03/10 | 3600 | Sec | + | | Yes |
| AC-228 | 2007 | **7.36E-01** | 2.98E-01 | 1.47E-01 | pCi/g Dry | | 330.6 | g dry | 07/20/10 07:25 | 09/03/10 | 3600 | Sec | + | | Yes |
| RA-228 | 2007 | **6.50E-01** | 4.31E-01 | 4.31E-01 | pCi/g Dry | | 330.6 | g dry | 07/20/10 07:25 | 09/03/10 | 3600 | Sec | + | | Yes |
| TH-228 | 2007 | **8.16E-01** | 1.53E-01 | 1.92E-01 | pCi/g Dry | | 330.6 | g dry | 07/20/10 07:25 | 09/03/10 | 3600 | Sec | + | | Yes |
| TH-232 | 2007 | **7.25E-01** | 2.94E-01 | 1.45E-01 | pCi/g Dry | | 330.6 | g dry | 07/20/10 07:25 | 09/03/10 | 3600 | Sec | + | | Yes |
| U-235 | 2007 | 2.72E-01 | 4.08E-01 | **6.97E-01** | pCi/g Dry | | 330.6 | g dry | 07/20/10 07:25 | 09/03/10 | 3600 | Sec | U | | No |

Flag Values
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MDC - Minimum Detectable Concentration

# Report of Analysis

11/05/10 08:06

## L43319

Empirical Laboratories

PL001-3EREG-08

TELEDYNE BROWN ENGINEERING, INC.
A Teledyne Technologies Company

**REVISED**
**Nov. 4, 2010**

Kim Kostzer

Sample ID: SR-259-202 | Collect Start: 07/20/2010 08:00 | Matrix: Soil | (S)
Station: | Collect Stop: | Volume:
Description: | Receive Date: 08/17/2010 | % Moisture: 1.56
LIMS Number: L43319-3

| Radionuclide | SOP# | Activity Conc | Uncertainty 2 Sigma | MDC | Units | Run # | Aliquot Volume | Aliquot Units | Reference Date | Count Date | Count Time | Count Units | Flag Values | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I-129 | 2012 | -5.10E-02 | 1.80E-01 | **2.83E-01** | pCi/g Dry | | 10.0147 | g dry | 07/20/10 08:00 | 10/11/10 | 1200 | Sec | U | | No |
| SR-90 | 2018 | 3.68E-02 | 1.36E-01 | **2.57E-01** | pCi/g Dry | R1 | 7.1502 | g dry | 07/20/10 08:00 | 09/29/10 | 15 | M | U | | |
| AG-108M | 2007 | 3.77E-02 | 7.16E-02 | **1.19E-01** | pCi/g Dry | | 306.23 | g dry | 07/20/10 08:00 | 09/03/10 | 3600 | Sec | U | | No |
| K-40 | 2007 | **1.82E+01** | 1.83E+00 | 8.15E-01 | pCi/g Dry | | 306.23 | g dry | 07/20/10 08:00 | 09/03/10 | 3600 | Sec | + | | Yes |
| CO-60 | 2007 | 1.05E-01 | 7.06E-02 | **8.75E-02** | pCi/g Dry | | 306.23 | g dry | 07/20/10 08:00 | 09/03/10 | 3600 | Sec | U | | Yes |
| NB-94 | 2007 | 1.31E-02 | 5.15E-02 | **8.79E-02** | pCi/g Dry | | 306.23 | g dry | 07/20/10 08:00 | 09/03/10 | 3600 | Sec | U | | No |
| CS-137 | 2007 | **7.92E+00** | 3.02E-01 | 1.24E-01 | pCi/g Dry | | 306.23 | g dry | 07/20/10 08:00 | 09/03/10 | 3600 | Sec | + | | Yes |
| EU-152 | 2007 | -1.60E-01 | 2.54E-01 | **3.52E-01** | pCi/g Dry | | 306.23 | g dry | 07/20/10 08:00 | 09/03/10 | 3600 | Sec | U | | No |
| EU-154 | 2007 | -7.74E-02 | 1.73E-01 | **2.62E-01** | pCi/g Dry | | 306.23 | g dry | 07/20/10 08:00 | 09/03/10 | 3600 | Sec | U | | No |
| TL-208 | 2007 | **6.96E-01** | 3.45E-01 | 3.32E-01 | pCi/g Dry | | 306.23 | g dry | 07/20/10 08:00 | 09/03/10 | 3600 | Sec | + | | Yes |
| PB-212 | 2007 | **9.18E-01** | 1.69E-01 | 2.12E-01 | pCi/g Dry | | 306.23 | g dry | 07/20/10 08:00 | 09/03/10 | 3600 | Sec | + | | Yes |
| BI-214 | 2007 | **3.94E+00** | 3.10E-01 | 2.03E-01 | pCi/g Dry | | 306.23 | g dry | 07/20/10 08:00 | 09/03/10 | 3600 | Sec | + | | Yes |
| PB-214 | 2007 | **3.04E+00** | 2.81E-01 | 2.46E-01 | pCi/g Dry | | 306.23 | g dry | 07/20/10 08:00 | 09/03/10 | 3600 | Sec | + | | Yes |
| AC-228 | 2007 | **7.99E-01** | 3.67E-01 | 3.30E-01 | pCi/g Dry | | 306.23 | g dry | 07/20/10 08:00 | 09/03/10 | 3600 | Sec | + | | Yes |
| TH-228 | 2007 | **9.18E-01** | 1.69E-01 | 2.12E-01 | pCi/g Dry | | 306.23 | g dry | 07/20/10 08:00 | 09/03/10 | 3600 | Sec | + | | Yes |
| TH-232 | 2007 | **7.87E-01** | 3.61E-01 | 3.26E-01 | pCi/g Dry | | 306.23 | g dry | 07/20/10 08:00 | 09/03/10 | 3600 | Sec | + | | Yes |
| U-235 | 2007 | -1.15E-02 | 5.70E-01 | **9.05E-01** | pCi/g Dry | | 306.23 | g dry | 07/20/10 08:00 | 09/03/10 | 3600 | Sec | U | | No |

Flag Values
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MDC - Minimum Detectable Concentration

# Report of Analysis

11/05/10 08:06

## L43319

Empirical Laboratories

PL001-3EREG-08

TELEDYNE BROWN ENGINEERING, INC.
A Teledyne Technologies Company

**REVISED**
**Nov. 4, 2010**

Kim Kostzer

Sample ID: SR-259-206 | Collect Start: 07/20/2010 08:30 | Matrix: Soil | (S)
Station: | Collect Stop: | Volume:
Description: | Receive Date: 08/17/2010 | % Moisture: 1.07
LIMS Number: L43319-4

| Radionuclide | SOP# | Activity Conc | Uncertainty 2 Sigma | MDC | Units | Run # | Aliquot Volume | Aliquot Units | Reference Date | Count Date | Count Time | Count Units | Flag Values | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I-129 | 2012 | -1.35E-01 | 1.71E-01 | **2.43E-01** | pCi/g Dry | | 10.0036 | g dry | 07/20/10 08:30 | 10/11/10 | 1200 | Sec | U | | No |
| SR-90 | 2018 | 1.34E-01 | 1.58E-01 | **2.37E-01** | pCi/g Dry | R1 | 7.0726 | g dry | 07/20/10 08:30 | 09/29/10 | 15 | M | U | | |
| AG-108M | 2007 | -1.72E-02 | 1.01E-01 | **1.67E-01** | pCi/g Dry | R1 | 290.9 | g Dry | 07/20/10 08:30 | 09/03/10 | 3600 | Sec | U | | No |
| K-40 | 2007 | **1.64E+01** | 2.00E+00 | 6.38E-01 | pCi/g Dry | R1 | 290.9 | g Dry | 07/20/10 08:30 | 09/03/10 | 3600 | Sec | + | | Yes |
| CO-60 | 2007 | 1.62E-01 | 7.13E-02 | **1.47E-01** | pCi/g Dry | R1 | 290.9 | g Dry | 07/20/10 08:30 | 09/03/10 | 3600 | Sec | U* | | No |
| NB-94 | 2007 | -1.76E-02 | 4.80E-02 | **7.41E-02** | pCi/g Dry | R1 | 290.9 | g Dry | 07/20/10 08:30 | 09/03/10 | 3600 | Sec | U | | No |
| CS-137 | 2007 | **2.07E+01** | 5.13E-01 | 1.24E-01 | pCi/g Dry | R1 | 290.9 | g Dry | 07/20/10 08:30 | 09/03/10 | 3600 | Sec | + | | Yes |
| EU-152 | 2007 | 5.35E-02 | 2.71E-01 | **4.48E-01** | pCi/g Dry | R1 | 290.9 | g Dry | 07/20/10 08:30 | 09/03/10 | 3600 | Sec | U | | No |
| EU-154 | 2007 | -8.53E-02 | 1.73E-01 | **2.59E-01** | pCi/g Dry | R1 | 290.9 | g Dry | 07/20/10 08:30 | 09/03/10 | 3600 | Sec | U | | No |
| TL-208 | 2007 | **6.56E-01** | 4.32E-01 | 3.80E-01 | pCi/g Dry | R1 | 290.9 | g Dry | 07/20/10 08:30 | 09/03/10 | 3600 | Sec | + | | Yes |
| PB-212 | 2007 | **7.82E-01** | 1.73E-01 | 2.19E-01 | pCi/g Dry | R1 | 290.9 | g Dry | 07/20/10 08:30 | 09/03/10 | 3600 | Sec | + | | Yes |
| BI-214 | 2007 | **1.70E+00** | 2.80E-01 | 2.44E-01 | pCi/g Dry | R1 | 290.9 | g Dry | 07/20/10 08:30 | 09/03/10 | 3600 | Sec | + | | Yes |
| PB-214 | 2007 | **1.54E+00** | 3.14E-01 | 3.19E-01 | pCi/g Dry | R1 | 290.9 | g Dry | 07/20/10 08:30 | 09/03/10 | 3600 | Sec | + | | Yes |
| RA-224 | 2007 | **5.05E+00** | 2.45E+00 | 2.49E+00 | pCi/g Dry | R1 | 290.9 | g Dry | 07/20/10 08:30 | 09/03/10 | 3600 | Sec | + | | Yes |
| AC-228 | 2007 | **9.29E-01** | 3.76E-01 | 3.16E-01 | pCi/g Dry | R1 | 290.9 | g Dry | 07/20/10 08:30 | 09/03/10 | 3600 | Sec | + | | Yes |
| TH-228 | 2007 | **7.82E-01** | 1.73E-01 | 2.19E-01 | pCi/g Dry | R1 | 290.9 | g Dry | 07/20/10 08:30 | 09/03/10 | 3600 | Sec | + | | Yes |
| TH-232 | 2007 | **9.16E-01** | 3.70E-01 | 3.11E-01 | pCi/g Dry | R1 | 290.9 | g Dry | 07/20/10 08:30 | 09/03/10 | 3600 | Sec | + | | Yes |
| U-235 | 2007 | -2.86E-02 | 4.89E-01 | **8.11E-01** | pCi/g Dry | R1 | 290.9 | g Dry | 07/20/10 08:30 | 09/03/10 | 3600 | Sec | U | | No |

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