CHARACTERIZATION REPORT FOR SEDIMENT IN GROUNDWATER WELLS NEAR THE PLUM BROOK REACTOR FACILITY PERKINS TOWNSHIP, OHIO

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INTRODUCTION

This report documents an investigation of the potential distribution of a radioactive isotope of the element cesium, known as ^{137}Cs, or Cs-137, in groundwater (GW) near the Plum Brook Reactor Facility (PBRF) in Sandusky, Ohio. This investigation was conducted to determine whether Cs-137 attributable to a decommissioned reactor facility could be detected above the levels attributable to other sources, such as past atmospheric atomic bomb testing.

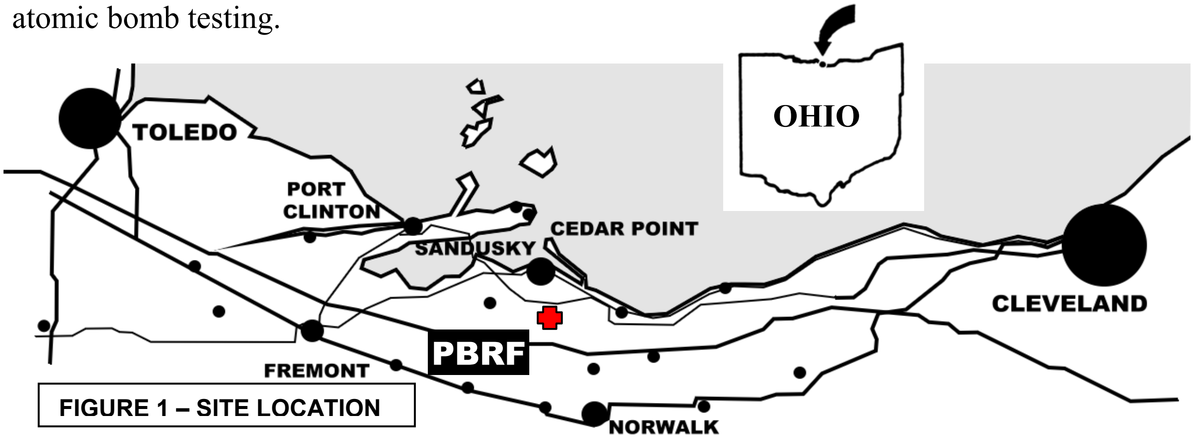


FIGURE 1 – SITE LOCATION

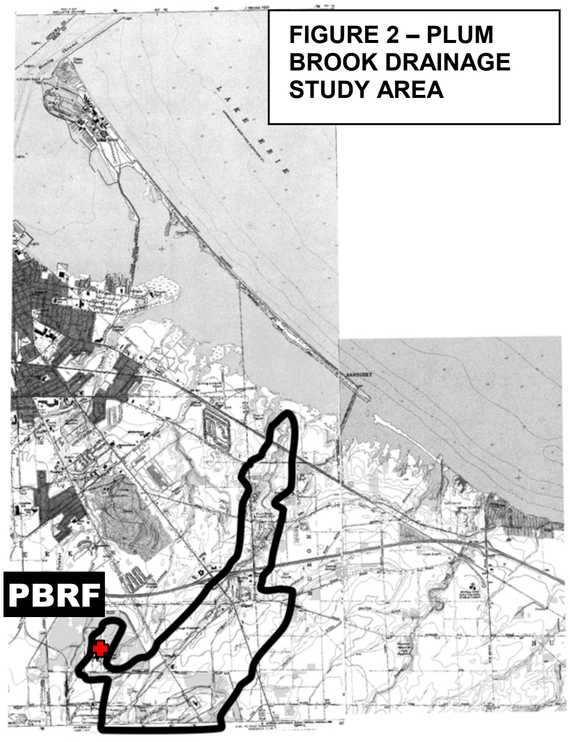


FIGURE 2 – PLUM BROOK DRAINAGE STUDY AREA

The PBRF was built by the National Aeronautics and Space Administration (NASA), on property referred to as NASA's Plum Brook Station. The relative locations of the PBRF and the groundwater wells that were sampled are illustrated in Figures 1, 2, 3, 4 and 5.

PLUM BROOK FACILITY BACKGROUND

Prior to acquisition by NASA, the Plum Brook Station was known as the Plum Brook Ordnance Works (PBOW). The PBOW was a World War II-era facility that made explosives for the war effort, including TNT and Pentolite. Operation of the PBOW ceased in 1945. Using a portion of the former site of the PBOW's Pentolite manufacturing facility, north of Pentolite Road, NASA began construction of a nuclear research facility in 1958. At this site, which NASA called the PBRF, NASA constructed two nuclear reactors, a 60 MW test reactor and a 100 KW research reactor. The reactors at the PBRF operated between 1961 and 1973.

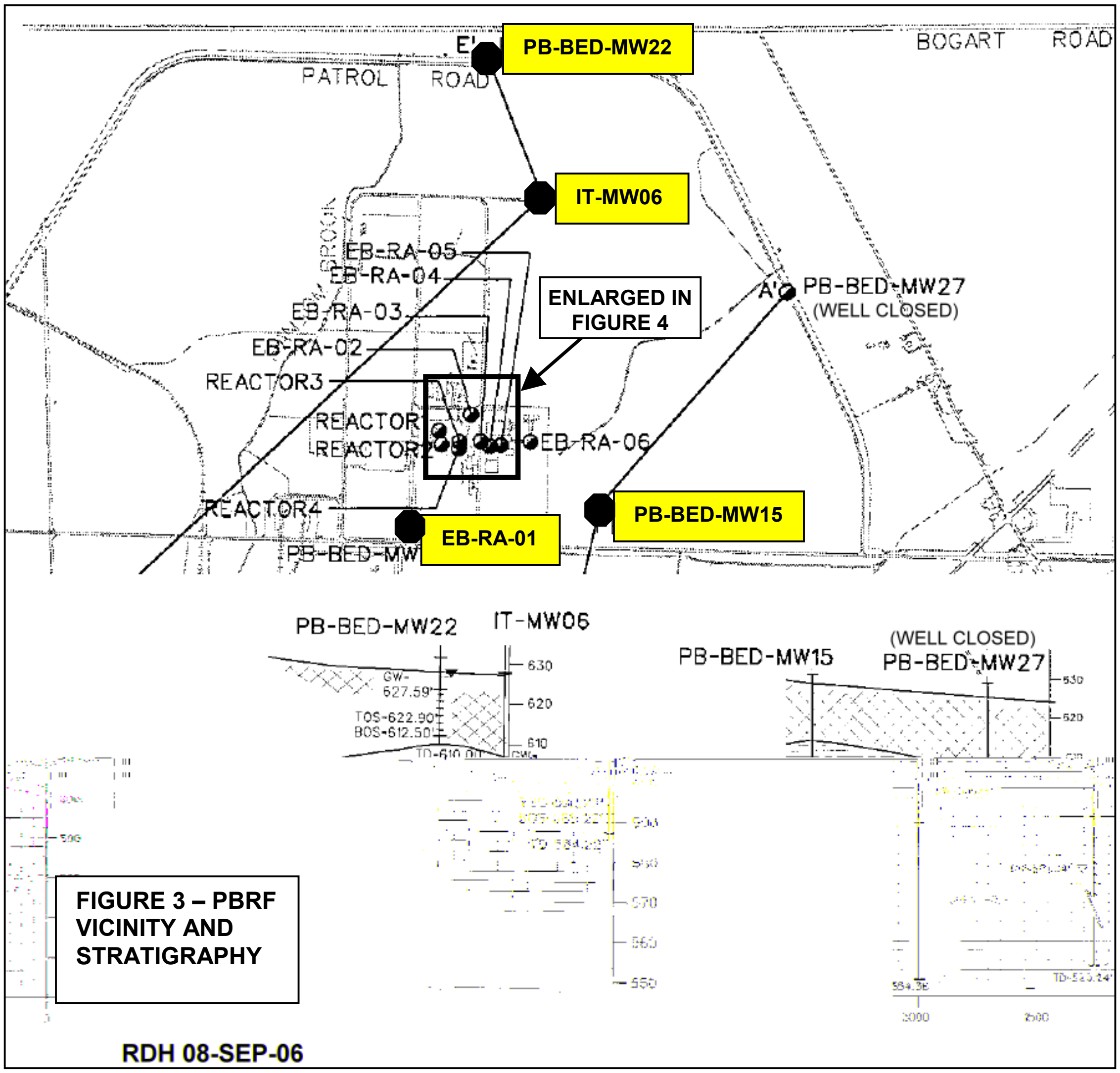


FIGURE 3 – PBRF VICINITY AND STRATIGRAPHY

● **WELL ID** Wells Sampled in First Round

Water was an essential element for nuclear reactor operations. Raw water from Lake Erie was pumped to the site at roughly 400-800 gallons per minute to support plant operations. Most raw water was softened through precipitation, sand filtering and chlorination to become process water. As needed, process water was de-ionized for the following uses: as the coolant for the nuclear reactors and experiment equipment; in the quadrants and canals for shielding when transferring radioactive materials; and in the analytical laboratories. The de-ionized water used for reactor and experiment cooling became radioactively contaminated due to exposure in the reactor, and that in the quadrants and canals due to mixing with radioactive sources (reactor water, experiment hardware, irradiated fuel, etc.).

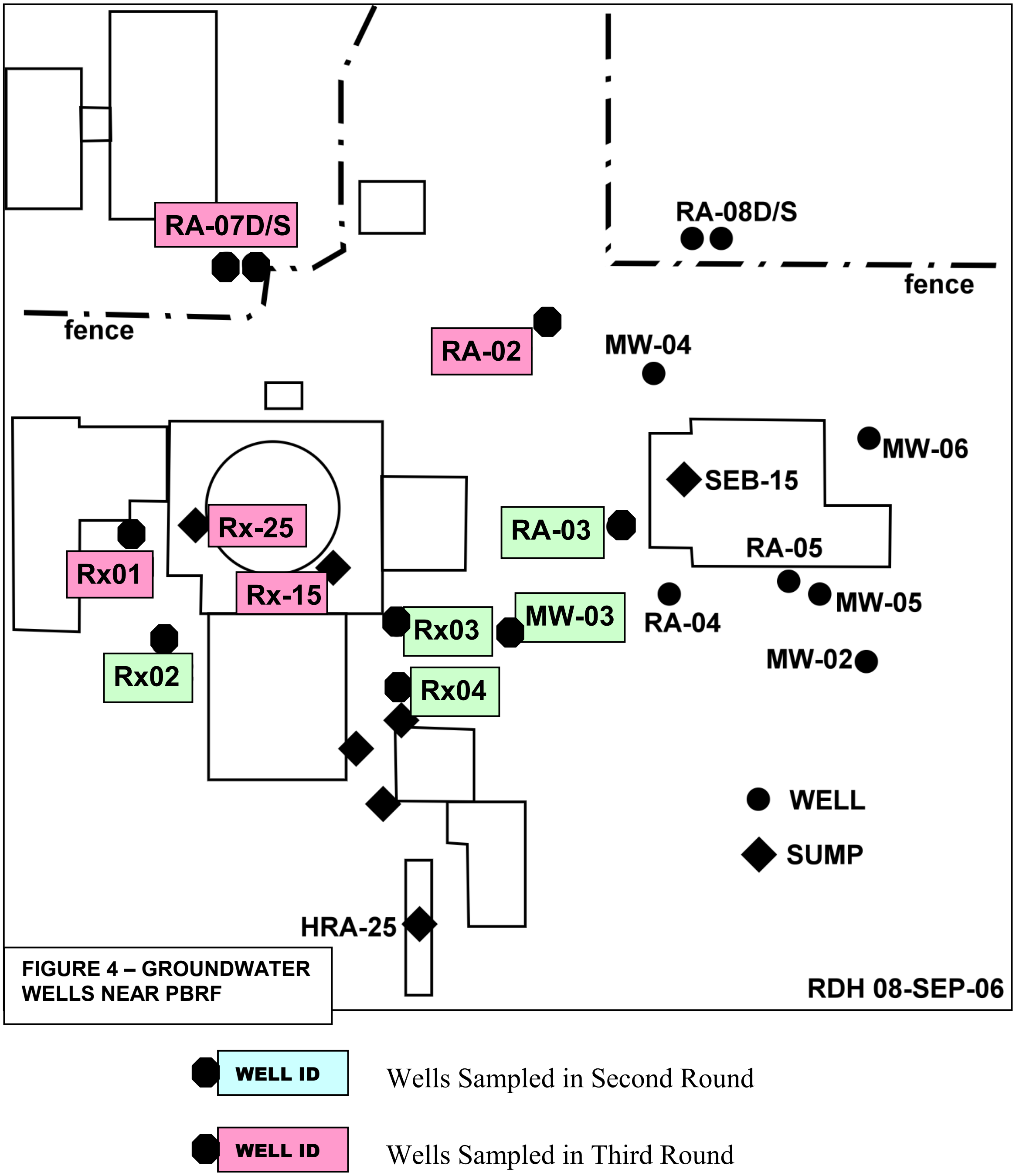


FIGURE 4 – GROUNDWATER WELLS NEAR PBRF

Wells Sampled in Second Round

Wells Sampled in Third Round

Radioactively contaminated water was normally recycled for reuse on-site or stored for decay or batch release processing in areas such as the Hot and Cold Retention Areas (HRAs, CRAs) or the Emergency Retention Basin (ERB). Prior to release to the environment, stored waters were sampled and analyzed for chemical and radioisotope contaminants, and then, as appropriate, (1) treated by filtering, demineralization or evaporation to reduce the contamination levels or (2) diluted with uncontaminated water (raw or process water) for off-site release within existing Federal regulatory limits.

Water used in operation of the reactor was discharged off-site after analysis and/or continuous monitoring for radioactivity levels to ensure compliance with Federal regulatory requirements. PBRF utilized a water effluent monitoring system (WEMS) at the site boundary that continuously monitored radioactivity levels and volumes of surface and wastewater leaving the site. If radioactivity levels exceeded pre-set safety limits, the WEMS would shut associated gates that stopped any further releases from the site.

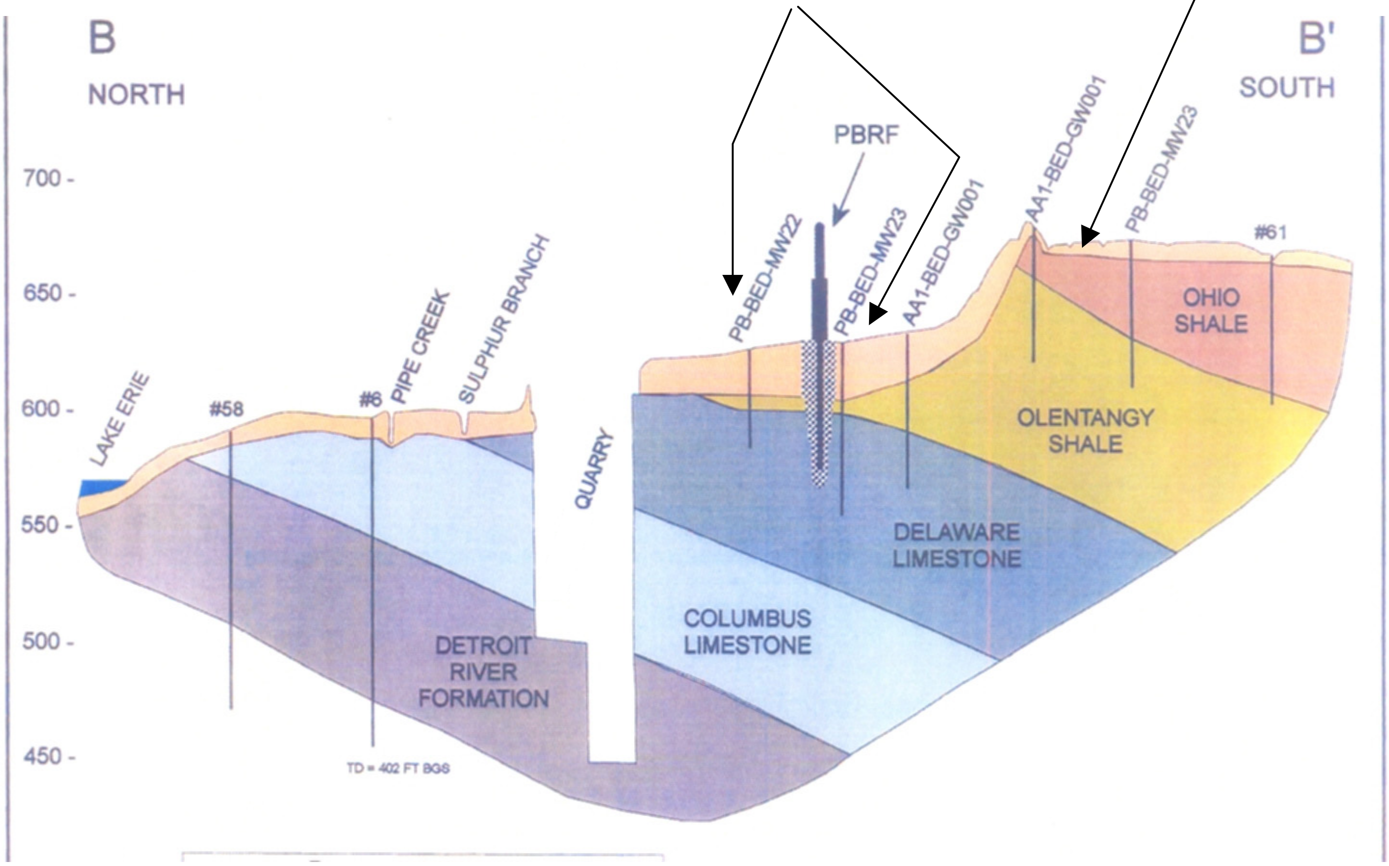
PBRF effluent water was released from the site directly into Pentolite Ditch, which runs along the south side of Pentolite Road. PBRF effluents mixed with drainage from the remains of the contaminated PBOW pond called the Pentolite Road Red Water Pond (PRRWP). This pond was south of Pentolite Ditch, just downstream from the reactor facility's WEMS. This former pond had once contained the acidic wash water from the TNT manufacturing process, known as red water. While the pond no longer exists, soil and groundwater in the area remain contaminated, and some leaching of red water into Pentolite Ditch has been known to occur.

Decommissioning of the PBRF was in progress at the time of this writing. During the decommissioning process, it was discovered that Cs-137 was detectable in the sediments of Plum Brook, at the southern end of the part of the stream's drainage basin shown on the map in Figure 2.

Based upon its initial testing results from the sediments of Plum Brook, NASA judged that it would be important to understand the stream and groundwater hydrology governing the distribution and deposition of Cs-137. NASA therefore commissioned a review of hydrogeologic data, and preparation of a characterization plan.

The characterization plan was based upon the results of the hydrogeologic review, as well as the results of scoping surveys that had been conducted previously for NASA. Those scoping surveys were conducted in meandering-stream sediments near the PBRF. The meandering-stream sediment testing results revealed scattered small areas of elevated Cs-137 activity, as opposed to a uniform distribution of Cs-137 activity over a broad area. Upon further evaluation, it was determined that the distribution of Cs-137 activity in the meandering-stream sediments was lognormal, which is typical for such settings.

The purpose of the study documented in this report was to assess the distribution of Cs-137 activity in sediments trapped at the bottom of groundwater wells near the PBRF.



Range of GW Sediment Sampling Locations Near PBRF

Background GW Sediment Sampling Locations

FIGURE 5 – RELATIVE LOCATION OF BACKGROUND WELLS

CHARACTERIZATION PLAN OBJECTIVES

Sampling and analysis to determine the lateral and vertical character and extent of Cs-137 contamination had the following objectives:

1. Verify mechanisms of Cs-137 transport
2. Provide approximate accounting for all Cs-137 known to be released
3. Identify Cs-137 deposits still in transit
4. Locate final resting places of Cs-137 no longer in transit

Sampling and analysis to support possible future remediation, if warranted, added the following objective to the Characterization Plan:

5. Describe Cs-137 deposit characteristics that affect removal

The requirements to support objectives 1-4 are governed by standard principles of surface hydrology, geomorphology, and groundwater hydrology. For sediment in groundwater, relevant concepts are documented in USEPA's "RCRA Ground Water Monitoring: Draft Technical Guidance", November 1992, as accessed on the Internet on April 23, 2007, at:

http://www.epa.gov/correctiveaction/resource/guidance/sitechar/gwmonitr/rcra_gw.pdf

The requirements to support objective 5, for groundwater, can be guided by experience gained in groundwater remediation in the Superfund program.

DATA QUALITY OBJECTIVES

Data quality objectives (DQOs) are developed to ensure that measurement data will be suitable for decision-making. The DQO development process requires one to identify a scientific "problem" to solve, to formulate a decision regarding that problem, and to specify a rule for making that decision.

The decision is normally framed as a hypothesis, which will be accepted or rejected. The decision rule often contains a statistical test, and is often stated as follows: "We will reject the hypothesis if the statistical test is greater than [a value]."

The problem statements, decisions, and decision rules for this plan are provided below. From these we can develop quantitative measures of the data quality needed to make the decision.

PROBLEM STATEMENTS

This sampling program was premised upon the assumption that Cs-137 was dissolved in water in the reactor's primary cooling system. During each of 152 cycles of reactor operation, spanning a decade, water from this system was discharged into Pentolite Ditch, after treatment and careful monitoring to maintain contaminant levels below regulatory limits. Based upon data showing compliance with those regulatory limits, it was estimated by former NASA employee Jack Crooks that Cs-137 producing a total of only 5 millicuries (5×10^{-3} curies), or 5,000,000,000 picoCuries ($5{,}000{,}000{,}000 \times 10^{-12}$ curies) of radioactivity was discharged into Pentolite Ditch, over the ten years of the reactor's operation. Due to the natural radioactive decay of Cs-137, which has a half-life of 30 years, it was estimated that less than 2,500,000,000 picoCuries (pCi) of Cs-137 activity remained to be found in the year 2006, when this study was conducted.

This sampling program was also premised upon the assumption that all of the Cs-137 dissolved in that cooling water was quickly and irreversibly adsorbed by clay minerals in fine sediment. Most of that fine sediment was expected to have been originally located in the bottom of Pentolite Ditch and Plum Brook. Some of that fine sediment may have been originally located in the PBRF drainage systems. Some of that fine sediment may have been originally located in bedrock fractures.

Finally, this sampling program was premised upon the assumption that, wherever the contaminated fine sediment was transported since the reactor began operating in 1963, the Cs-137 was also transported.

Problem Statement for Extent – Clay minerals are created by the weathering of rock. Clays are carried by water, and are deposited in known patterns in different depositional environments. To define the extent of Cs-137 contamination, our goal was to identify clays over which PBRF cooling water passed, between 1963 and 1973. Once those clays were identified, our goal was to determine where they had traveled since 1973.

Problem Statement for Remediation – If remediation should be needed, the goal would be to remove as much Cs-137 as possible, with the smallest effort possible. It was considered that this would likely translate into a goal of removing contaminated clay, without removing other types of soil, which were expected to be relatively uncontaminated.

DECISIONS

For each of seven identified depositional environments, including the groundwater environment addressed by this report, the decisions to be made were as follows:

Decision Regarding Extent – Is Cs-137 absent, permanently present, or present and in transit? Does the sum of Cs-137 activity in the seven depositional environments account for the total Cs-137 activity discharged in PBRF cooling water?

Decision Related to Remediation – If present at levels of concern, can clay carrying Cs-137 be easily removed, without removing anything else?

INPUTS TO THE DECISIONS

Inputs to Decision Regarding Extent – The extent decision was to be based upon the following factors, to be determined for each depositional environment:

1. Amount of Cs-137 activity per gram of sediment

2. Size of sediment areas contaminated by Cs-137

3. Mobility of the contaminated sediment

Inputs to Decisions Regarding Remediation – Remediation decisions, if any should be needed, were to be based upon the following factors, to be determined for each depositional environment:

1. Ease of reaching the contaminated sediment with remediation equipment

2. Ease of removing only the contaminated sediment

3. Ease of separating contaminated clay from other materials

STUDY BOUNDARIES

Study Boundaries for Vertical and Lateral Extent - To define the sediment depositional environments, the limits of the study area were determined to be (1) the surface drainage basin of Plum Brook, downstream of the PBRF, and (2) the groundwater basin in which the PBRF is located. These basins are illustrated in Figure 6 on the following page.

For the determination of sediment movement within those basins, the hydrogeologic study identified the following 7 depositional environments to be evaluated for fine sediment carrying Cs-137:

1. Meandering streams
2. Stream backwaters
3. Ponds
4. Floodplain wetlands
5. Stream mouth wetlands
6. Bay behind barrier island
7. Rock fractures bearing groundwater

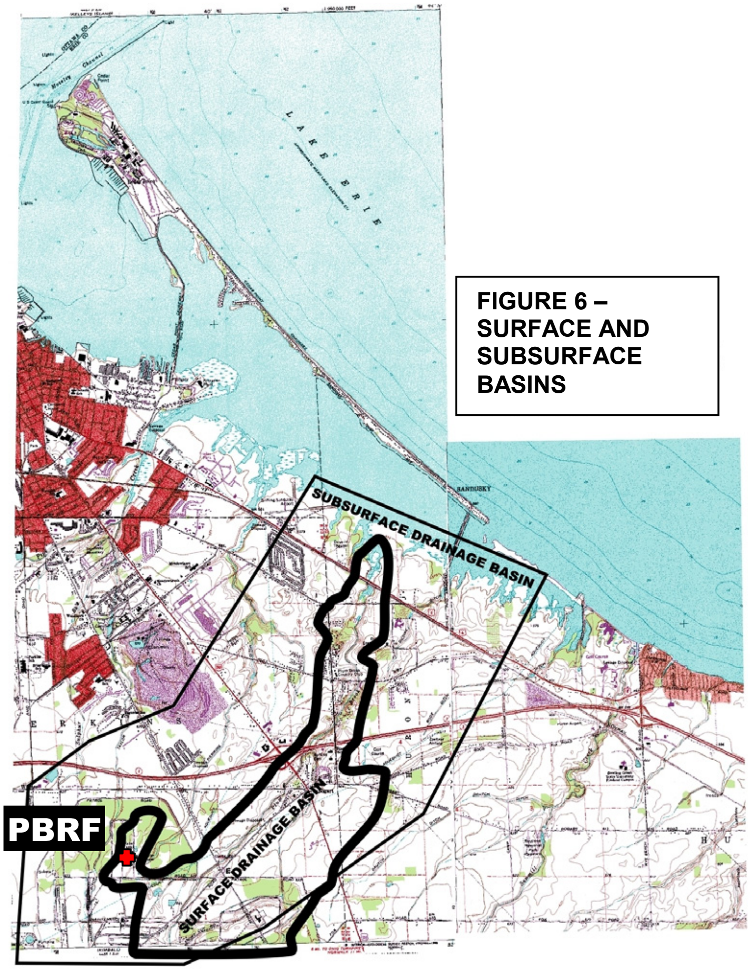


FIGURE 6 – SURFACE AND SUBSURFACE BASINS

Study Boundaries for Remediation – Definition of remedial work areas, if any, was to be governed by residential character, distribution pattern of Cs-137, and equipment accessibility.

DECISION RULES

Decision Rules for Vertical and Lateral Extent - were to be based upon amount of Cs-137 activity released versus amount found, and professional judgment that the limits of all reasonable depositional environments had been adequately explored. The latter is documented in a separate report, entitled “Development of Conceptual Model as Basis for Characterization Plan,” also referred to during its development as the “Concept Report.”

Decision Rules for Remediation – were to be determined after the need for remediation, if any, was ascertained.

LIMITS ON DECISION ERRORS

When Cs-137 from the PBRF reached the offsite environment, it was expected that it would be distributed lognormally. This was evaluated in a "Minimum Number of Samples" task.

This means that variations of Cs-137 activity were considered significant when they varied by an order of magnitude. Thus, it was appropriate to consider masses "adequately balanced" when the amount of Cs-137 activity accounted for was within one order of magnitude of the amount estimated to have been released.

Many significant hydrogeologic patterns show variations that are best evaluated from an order-of-magnitude perspective. For example, soil grainsizes are typically graphed on a logarithmic scale. Differences in permeabilities are also considered significant only when they differ by orders of magnitude.

For the dimensions of the depositional environments, a linear scale was appropriate. However, it was important to bear in mind that meaningful vertical geologic measurements span inches, while meaningful lateral geologic measurements span feet or miles. To identify a sediment layer that might represent a decade of Cs-137 deposition, it was judged that core samples should span an interval of no more than 3 inches. However, to adequately locate a sampling point in map view, a measurement needed to be reproducible only to within 10 feet.

DATA QUALITY INDICATORS

Data quality indicators (DQIs) are the mostly-quantitative parameters used to determine whether measurements are achieving the quality needed to support the decision. DQI values for this work are given below. DQIs related to lognormally distributed phenomena should be applied after the data are transformed. DQIs related to normally distributed phenomena should be applied to the original, untransformed, data. Variations attributable to sampling and testing are expected to be normally distributed. Variations attributable to the movement of Cs-137 by natural processes are expected to be lognormally distributed.

Precision – is also called repeatability. To assess repeatability in the onsite laboratory, the PBRF uses an approach described in NRC Inspection Manual 84750. That approach allows a greater margin for error when the statistical uncertainty underlying a result is large compared with the result itself. However, in this assessment, it was important to be able to compare the precisions achieved with other hydrogeologic investigations. For hydrogeologic/extent purposes, successive field measurements of the same area or sample are traditionally expected to yield results within 20% of one another, as measured by the relative percent difference (RPD).

RPD is defined here as follows:

$$\text{RPD} = (\text{duplicate 1} - \text{duplicate 2}) / \text{average}(\text{duplicate 1, duplicate 2})$$

However, when a phenomenon follows a lognormal distribution, RPD values less than 20% are not consistently achievable. Historical RPD values related to metals in sediment often exceed 50% to 100% of one another. For Cs-137 distribution, therefore, RPD should be measured after the test results have been transformed, as follows:

$$\text{RPD} = [\log(\text{dup1}) - \log(\text{dup2})] / \text{average}[\log(\text{dup1}), \log(\text{dup2})]$$

For this work, quantitative test results for all duplicate samples were expected to achieve RPDs less than 20%, after log-transformation.

In some cases, repeatability must be considered acceptable if presence or absence of the contaminant is the same in the original and duplicate samples. This was the rule applied here to assess the repeatability of laboratory screening analyses, which were performed on unprocessed 3-inch samples still in their sample tubes. This rule was also applied to testing results marked “Qualitative Analysis Only”. This was also the applicable rule for results that fell below the project’s practical quantitation limit (PQL), as discussed below.

In the course of a “Minimum Number of Samples” task, which reviewed the statistical distribution of test results obtained from Plum Brook stream meander areas near the PBRF, it was concluded that the PQL for the combined sampling/testing measurement system in use on the PBRF Decommissioning Project was 3 pCi/g. Below this level, it might be possible to say that Cs-137 was detected or not detected, but it was not possible to define a repeatable value for the activity detected.

Accuracy – is the degree to which measurements approach the “true” value. The accuracy of laboratory measurements is often evaluated by measurement of a known standard injected into a laboratory “blank”. The resulting sample is called a Laboratory Control Sample (LCS), or a blank “spike.” A LCS is typically analyzed along with each batch of samples. The ratio of the laboratory-measured value to the known value, for a standard that was added to a blank sample, is called the “spike recovery.” For decision-making purposes without special evaluation, we expected contract laboratories to achieve spike recoveries between 80% and 120%.

In the PBRF onsite laboratory analysis of Cs-137 activity, samples were not grouped in batches, so there were no batch LCS spike results. According to PBRF procedure RP-021, a comparable measure of system accuracy was provided by means of daily quality control (QC) checks, in which Cs-137 sources traceable to the National Institute for Standards and Technology (NIST) were measured. The results obtained were plotted on control charts. Investigation was undertaken if the results exceeded the warning limits, and corrective action was taken if the results exceeded the control limits. The warning limits were set at 2 standard deviations above or below the known activity, and the control limits were set at 3 standard deviations above or below the known activity. When the system was calibrated, it was expected that the test results would be within ±10% of the known activity.

A qualified data reviewer, Rod Case, also characterized accuracy of the PBRF onsite laboratory results. Based upon the reviewer's assessment, Cs-137 values reported above the minimum detectable activity (MDA) were marked either "Yes" or "No" on the PBRF onsite laboratory reports. If a result was marked "Yes," but the volume of the sample was less than the standard geometry for which the system was calibrated, then the PBRF onsite laboratory report was marked "Qualitative Analysis Only." For those cases, with undersized samples, it was expected that the reported activity was likely higher than the true activity.

In the course of the "Minimum Number of Samples" task, which reviewed the statistical distribution of test results obtained from Plum Brook stream meander areas near the PBRF, it was noted that Cs-137 measurements in the natural environment surrounding the PBRF needed to be transformed to log(measurement) before they could be evaluated for statistical distribution, trends, and patterns. After transformation, the results conformed to the normal distribution. This means that the accuracy, or proximity to a "true" value, can only be assessed on an order-of-magnitude basis.

Representativeness – is often a non-quantitative DQI. A sample is considered representative of a condition if it is taken from the right place, at the right time. A representative sample must recover all of the parts of the medium being characterized. A representative sample must not contain contaminants from other samples.

To achieve representativeness in contaminant measurements, the contaminant's creation, fate, and transport must be understood and specified. That information is provided here in the section entitled "Expected Characteristics of the Groundwater Sediment Depositional Environment."

To achieve representativeness, samples must have little or no cross-contamination. Adverse effects of cross-contamination may be reduced by making efforts to sample areas expected to be least contaminated first, finishing a sampling run with areas expected to be most contaminated. This was achieved for the groundwater sediment samples by carrying out sampling in 3 rounds, as illustrated in Figures 3 and 4.

The degree of sample cross-contamination is normally measured by obtaining clean, or "blank" samples following sampler decontamination. Testing results for blank samples should show no detection of the contamination found in field samples.

Completeness – means having enough verified measurements to support a decision. "Verified" results are those that satisfy the other DQIs. Most hydrogeologic phenomena can be approximated by planar surfaces, or by logarithmic time-sequences. Since at least 3 points are required to define a plane or a curve, we employed the fundamental rule that 3 valid measurements distributed either in space or in time, are the minimum number to support a hydrogeologic/extent decision.

Comparability – is achieved by using standard procedures for obtaining measurements. The well-sampling field procedures that were employed are attached to this plan as Appendix A. The laboratory procedures that were employed are PBRF's RP-021 and EPA Method 901.1 Modified.

EXPECTED CHARACTERISTICS OF THE GROUNDWATER SEDIMENT DEPOSITIONAL ENVIRONMENT

The following section describes the expected characteristics of the groundwater sediment depositional environment, one of 7 identified depositional environments. These characteristics were used to guide the field scientists in obtaining representative samples.

PRIOR GROUNDWATER INVESTIGATIONS

Many years of groundwater investigations had been conducted for closure of the Plum Brook Ordnance Works. This work gradually led to an understanding that the principal groundwater aquifer of concern was in the fractured limestone of the Delaware formation, illustrated by Figures 7 and 8, which were adapted from a report by the U.S. Army Corps of Engineers (USACE). Figure 7 was adapted to suggest that Plum Brook might intersect the Delaware aquifer, which was a hypothesis to be evaluated.

Some unconfirmed studies suggested that fractures in this aquifer might have been enlarged by solution, particularly between the PBRF and Wagner Quarry to the North. A preliminary map of potential solution features, prepared by the Ohio Department of Natural Resources (ODNR), is shown in Figure 9.

Groundwater flow in fractures and solution cavities could be fairly rapid and turbulent; thus it could have the ability to transport fine sediment bearing Cs-137. It was expected that pumping to maintain Wagner Quarry operations would dominate the direction of groundwater flow in the fractured-limestone aquifer, as illustrated in Figure 10.

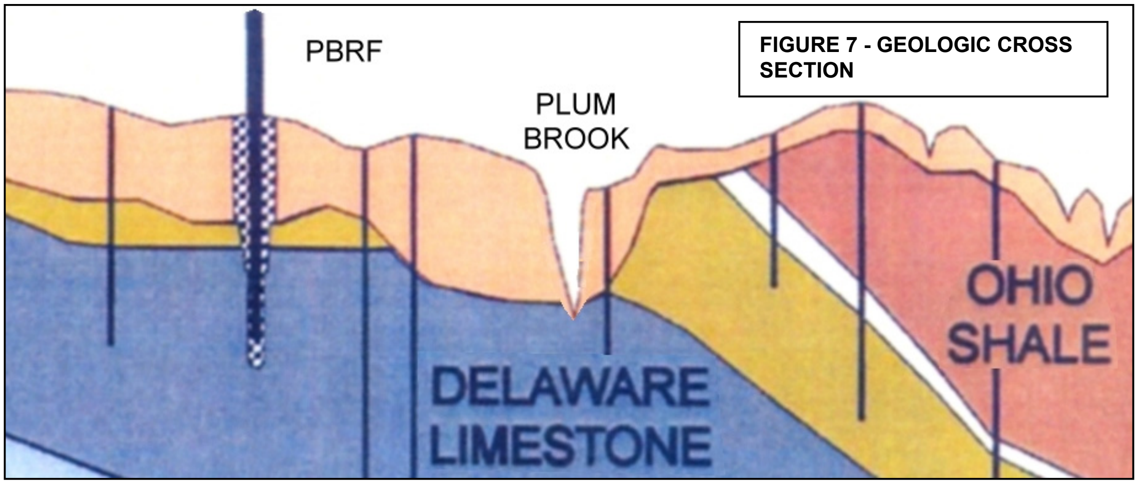


FIGURE 7 - GEOLOGIC CROSS SECTION

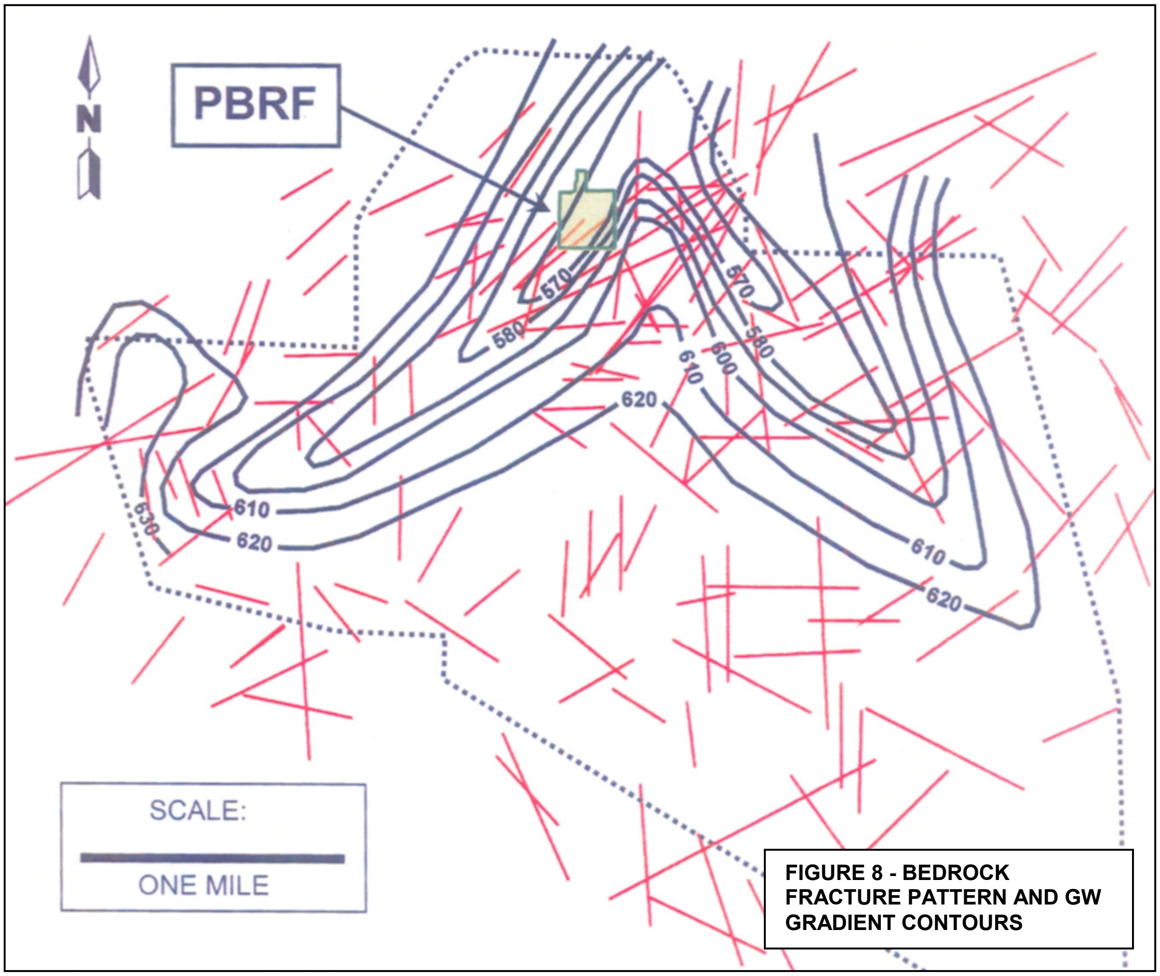
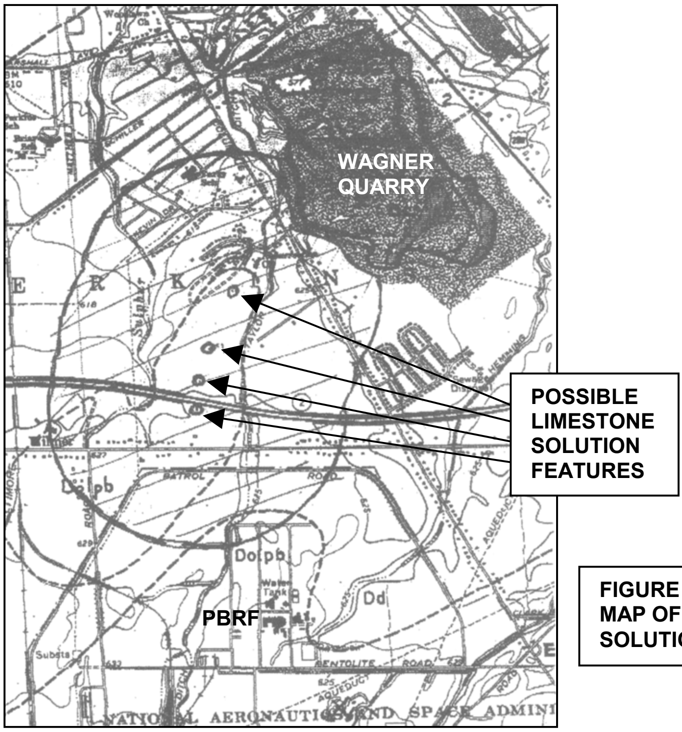


FIGURE 8 - BEDROCK FRACTURE PATTERN AND GW GRADIENT CONTOURS



POSSIBLE LIMESTONE SOLUTION FEATURES

FIGURE 9 - ODNR PRELIMINARY MAP OF POSSIBLE LIMESTONE SOLUTION FEATURES

Particular fractures carrying groundwater are very difficult to locate and follow, causing well drilling to be very costly and ineffective in tracing contaminants in bedrock fracture aquifer systems. Dye-tracer studies are often attempted to delineate fracture flow patterns, but they are also often ineffective. For this reason, the initial evaluations of this depositional environment focused upon sediment collected in existing wells onsite, on the assumption that Cs-137 would have accumulated in the sediment at the bottom of such wells.

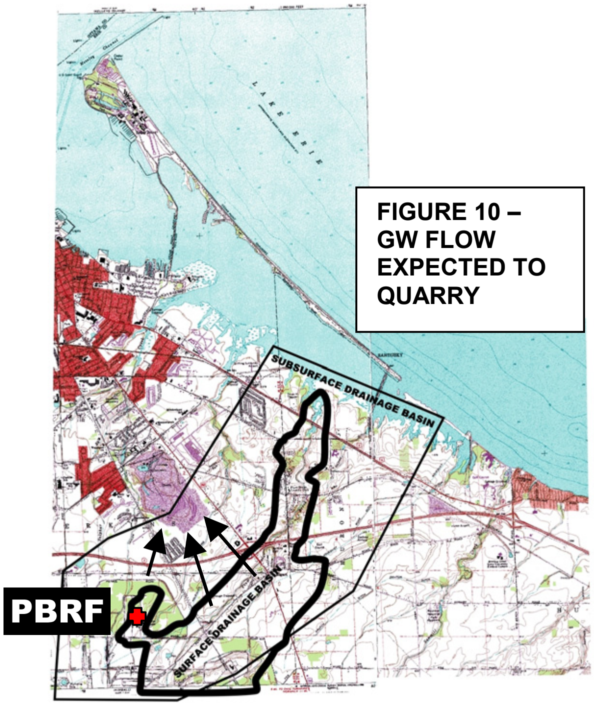


FIGURE 10 – GW FLOW EXPECTED TO QUARRY

It was expected that a continuous core of fine sediment from the bottom of such wells might contain a layer, or a gradation, of fine sediment bearing Cs-137. Patterns being sought included the following possibilities:

1. No Cs-137 is detected in the accumulated sediments
2. Cs-137 occurs in a narrow band within the accumulated sediments
3. Cs-137 is found to increase upward or downward
4. Cs-137 is uniformly distributed throughout the accumulated sediments

Figure 11 illustrates the originally expected means of sediment accumulation in groundwater wells.

Upon further evaluation of the wells nearest the PBRF, it was observed that there was a second possibility; that contaminated surface sediment might have entered the wells from the ground surface. Figure 12 illustrates this potential mode of sediment accumulation in groundwater wells.

STEPWISE APPROACH

The groundwater-sampling program to define the extent of Cs-137 began by testing the reasonableness of this hypothesis: Clay carrying Cs-137 could move through fractures and could accumulate in wells. This hypothesis was first tested where the condition was most likely to have occurred: in wells near to, and downgradient from, the PBRF.

If sediment in the onsite wells was found to contain detectable Cs-137, then the program could be taken further. “Further” could include assessment of possible background levels of Cs-137 in PBOW wells that were located far upgradient from the PBRF. “Further” could include evaluations of wells near stretches of Plum Brook where sediment might have entered the fractured bedrock. "Further" could also include an evaluation of downgradient sediment deposition features. Subsequent investigations, if warranted, could attempt to trace water-bearing fracture patterns between the PBRF and Wagner Quarry, possibly by geophysical methods.

If such investigations were to be conducted, two scenarios would be considered: (1) in a "PBRF-as-continuing-source" scenario, the highest activities would be expected near the PBRF, with values declining downgradient from the facility, and (2) in a "PBRF-as-remnant" scenario, activities downgradient from the PBRF would be expected to be higher than those near the facility.

On the other hand, if testing of sediment in the wells very near the PBRF revealed no activity at levels of interest, then further testing might not be called for.

In this study, after sediment in the onsite wells was found to contain detectable Cs-137, the following steps were taken:

1. An assessment was made of possible background levels of Cs-137 in PBOW wells that were located far upgradient from the PBRF.

2. An assessment was made of groundwater well contamination by the introduction of surface materials.

NASA's evaluation of the radiological condition of the site, and assessment of the data, is an ongoing process. Additional assessments will be made as necessary to demonstrate compliance with NRC license termination requirements.

NATURAL HYDROCARBONS EXEPCTED

Based upon prior PBOW investigations, it was anticipated that some naturally occurring petroleum hydrocarbons and hydrogen sulfide would be encountered in some of the wells. This was confirmed when Karen Hite of the Plum Brook Operations Support Group (PBOSG) noted that the lid of well PB-BED-MW22 typically popped into the air when the well was opened, under the pressure of natural gas in that well.

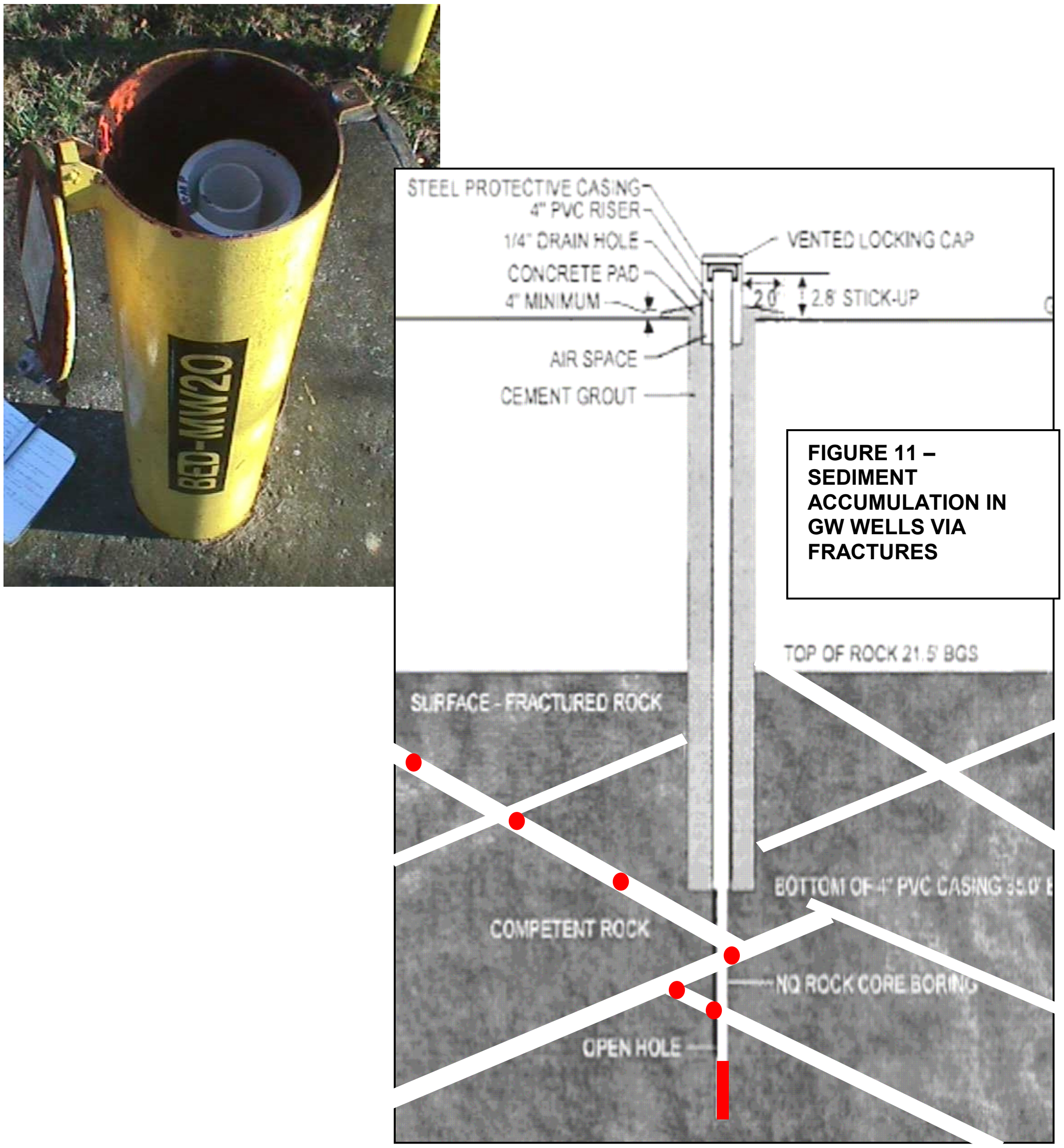
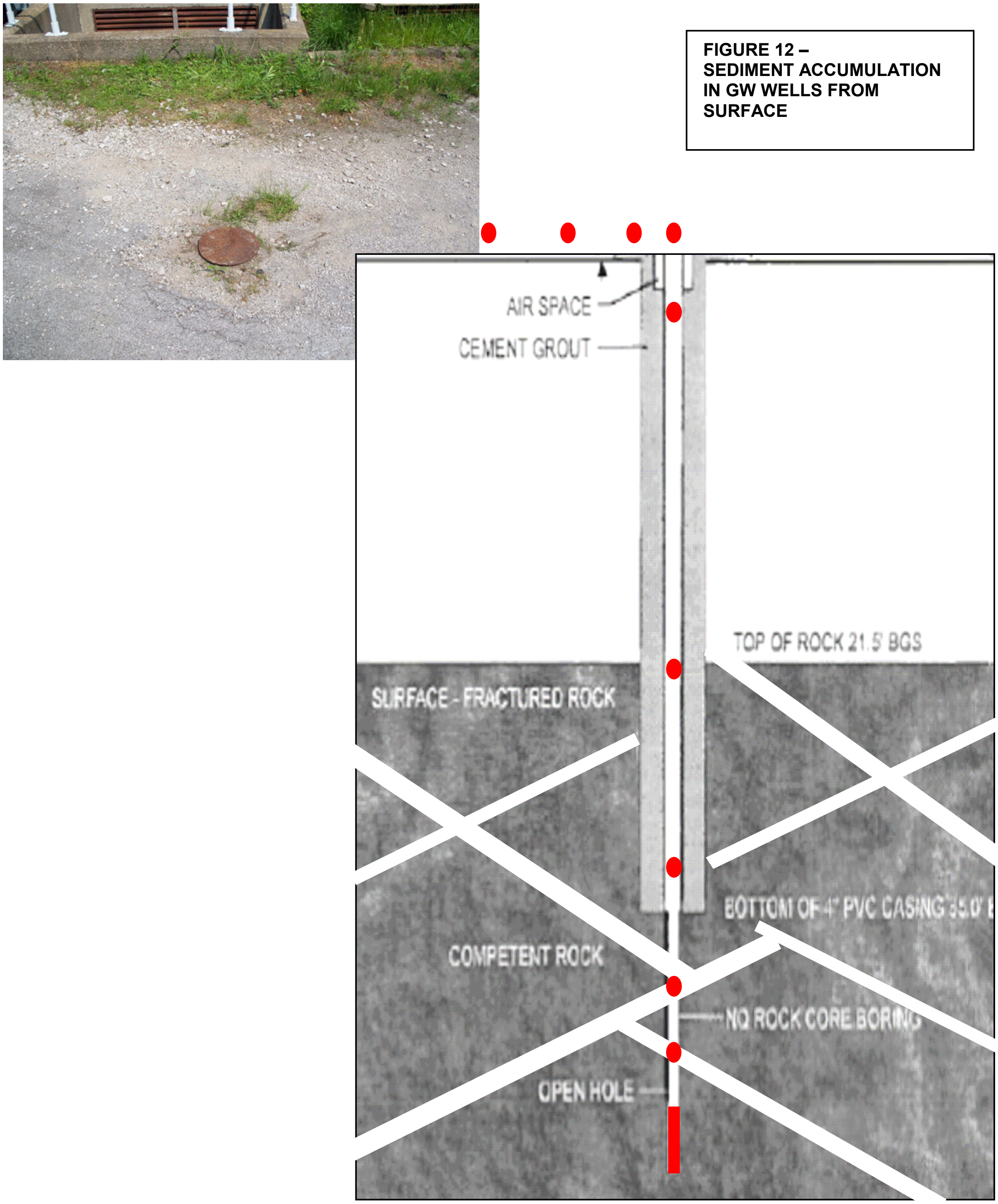


FIGURE 11 – SEDIMENT ACCUMULATION IN GW WELLS VIA FRACTURES

FIGURE 12 – SEDIMENT ACCUMULATION IN GW WELLS FROM SURFACE



METHODS

Based upon the HaagEnviro Characterization Plan for the groundwater depositional environment, NASA's contractor, MOTA, prepared Survey Request (SR) number 35 to cover this work. The NASA Radiation Safety Officer (RSO), Bill Stoner, approved SR 35.

In the field, a HaagEnviro scientist directed locations, sampled, logged, screened samples for organics, and made field judgments regarding the character of the depositional environment and the need for more or fewer samples. A MOTA Operations Technician assisted in sampling, sampler transport, preparation, and decontamination. A MOTA Radiation Protection (RP) Technician scanned samples for radioactivity, and maintained sample custody according to PBRF decommissioning procedures.

Samples were field-screened, laboratory-screened, and analyzed quantitatively. Data reduction was focused mainly upon determining whether any Cs-137 was detectable in the sediments removed from the bottoms of the wells.

DEVELOPMENT OF SAMPLING GRID

Geologist Phil Weimer reviewed the logs of wells in the PBRF vicinity, and selected candidates for sampling. The candidate list was reviewed by Hydrogeologist Bob Haag, who made the final selections, and organized the wells to be sampled into 3 initial rounds, as follows:

Round 1: Wells of interest most distant from the PBRF

Round 2: Wells of interest very near to the PBRF, but upgradient or across-gradient

Round 3: Wells of interest inside and/or immediately downgradient from the PBRF

One well, BED-MW-23, was dropped from the list due to the presence of floating hydrocarbons on the water surface. The wells finally selected are illustrated on Figures 3 and 4.

A fourth round of sampling, intended to provide background results, was based on a similar review of existing well logs. The relative location of the wells selected for the background evaluation is shown on Figure 5.

Some additional sampling was conducted by personnel working separately from HaagEnviro. This was sampling of surficial sediment near wells in which it was considered likely that surface sediment had entered the wells. This work was directed by the RSO.

SAMPLING METHODS

Before sampling, each well-head was monitored for explosive vapors using a Gastech model GT 402 meter for measuring lower explosive limit (LEL), oxygen (O_2), hydrogen sulfide (H_2S), and carbon monoxide (CO). When explosive vapor readings exceeding 20% of LEL were obtained, the well was ventilated until the LEL readings fell below 20%. An attempt was made to accelerate venting by inserting a tube supplying compressed air, but the improvement did not warrant the effort. Subsequently, such wells were simply left open for several days, until acceptable readings were obtained.

Sampling involved careful insertion of the inner tube of Geoprobe's dual-tube sampling system into the sediment at the bottom of each well. The sediment-filled tube was carefully withdrawn; the tube was cut into 3-inch segments, which were capped.

If no sediment was recovered in the tube sampler, then the water and sediment at the bottom of the well were mixed by lowering and raising rods at the bottom of the hole, and a slurry sample was then obtained with a bailer.

Documentation of the surface sampling methods employed near selected wells was not provided, but all work subject to the RSO's oversight is performed in accordance with PBRF Procedure CS-04.

SAMPLE FIELD-SCREENING AND CHAIN-OF-CUSTODY DOCUMENTATION

Upon extraction from the well, the sampling devices were screened by the RP technician for radioactivity, and by the environmental scientist for organic compounds. The RP technician employed a NASA-provided Ludlum model 2350 meter with a model 4410 probe, and a gamma-spectrum window set to focus on Cs-137 activity. The scientist employed a NASA-provided Mini-RAE 2000 photoionization detector (PID), with a 10.6 eV lamp. The PID was calibrated, and the Ludlum meter was source-checked, by MOTA personnel at the PBRF site at the beginning of each field day. After scanning, the plastic sample tubes were cut into 3-inch-long segments, PID-screened, and then capped and taped to seal in their contents. The samples were transported under chain-of-custody (COC) control by the RP technician to the sample-processing trailer at the PBRF site.

LABORATORY PRE-SCREENING

The 3-inch-long samples obtained were subjected to a laboratory pre-screening process, performed by the PBRF on-site laboratory. The 3-inch-long samples were provided to the laboratory in their tubes, as sealed in the field. The tubes were placed in a holder, and were counted for 900 seconds, or 15 minutes. At least one sample out of every 20 was re-counted by the same method.

As a complete calibration for this geometry was not performed, the results obtained could only be considered qualitative. Accordingly, the numerical results obtained for the 3-inch samples were only to be used to make relative comparisons of activity, for the purpose of identifying the layer(s) with the highest relative activity.

Slurry samples were screened for shipping, following PBRF procedure RP-021.

The laboratory screening results were also intended to permit identification of the radioactive isotope(s) present, expected to be mostly Cs-137. The possibility of the presence of 7 other radionuclides of interest was also considered, if laboratory screening indicated that this was warranted. It was desirable to assess the possible presence of other radionuclides of interest, particularly cobalt-60 (Co-60).

QUANTITATIVE LABORATORY ANALYSIS

The tube samples were analyzed by gamma spectroscopy in the PBRF onsite laboratory following PBRF procedure RP-021. As the PBRF onsite laboratory did not have a calibrated geometry to handle the slurry samples, 11 slurry samples were sent to the Severn-Trent Laboratory (STL) in St. Louis, Missouri for quantitative testing.

STL separated the water from the solids by filtering the slurries through a 0.45-micron filter. Once the achievable minimum detectable activity (MDA) or minimum detectable concentration (MDC) was determined, selected samples were analyzed for Cs-137 activity. Tests at STL were performed by gamma spectroscopy using EPA Method 901.1 Modified.

The STL testing results were reviewed for the radionuclides of interest that could be detected by gamma spectroscopy testing, as were the PBRF results for composite samples.

DATA REDUCTION, INTERPRETATION, AND REPORTING

Initial sample screening results were reviewed for any indication that Cs-137 was detected. Based upon the levels at which screening indicated Cs-137 was detected, Bob Haag proposed necessary MDAs to STL. After preliminary analysis of the samples, STL reviewed the achievable MDAs with Bob Haag, and only samples with a useful MDA were to be carried all the way through the analytical reporting process.

Results were posted on maps that were presented to NASA personnel in weekly briefings.

ASSESSMENT OF BACKGROUND WELLS

After testing of sediment from wells near the PBRF demonstrated that Cs-137 could be detected, it was determined that background wells should be located and tested. Hydrogeologist Bob Haag directed Geologist Phil Weimer in a review of PBOW well logs. Their ideal objective was to locate 2 or 3 wells that met the following criteria: (1) were drilled into the same formation as the wells near the PBRF, (2) were open-rock holes, that would readily admit sediment from limestone fractures, (3) contained sediment that could be sampled, and (4) were located as far upgradient from the PBRF as possible.

Because of the dip of the geologic strata, the first criterion could not be achieved. After many candidate wells were identified, Weimer located them in the field, to determine their characteristics. In this process, he observed that most of the wells that met criteria (2) and (3) on paper had been modified. He discovered that all of the wells that appeared to be good candidates had been fitted with 2-inch-diameter plastic casings and screens, set inside the original 4-inch-diameter open-rock holes. The 2-inch screen installations were not recorded on the drilling logs, and it was interpreted by HaagEnviro that they had been installed later, specifically to exclude sediment from groundwater samples. Weimer attempted to obtain sediment from some of these re-screened wells, and found that he could not retrieve any. At last, Weimer found 3 very shallow wells, that had not been re-screened. He was able to obtain sediment samples from these wells. It could be said that these wells met criteria (3) and (4), as they contained sediment that could be sampled, and they were located as far upgradient from the PBRF as possible.

The selected upgradient background wells were so far from the PBRF that they would not appear on Figures 3 and 4. Figure 5 illustrates the relative distance of these wells from the site.

Sediment samples were obtained from these wells by the same methods that had been used for wells near the PBRF. A sufficient amount of solid material was obtained, that it was possible to quantitatively analyze these samples at the PBRF onsite laboratory. Bob Haag directed that two of the well samples be tested, to provide some assessment of variability. The third well sample was retained in the event it should be needed.

ASSESSMENT OF SURFACE CONTAMINATION IN WELLS

Under chain-of-custody control administered by MOTA RP Technicians, Hydrogeologist Bob Haag obtained samples from PBRF storage, and examined the samples under a microscope at 4x and 10x magnification. The samples contained sediment that had been obtained from well EB-RA-1, and well Rx-01. Well EB-RA-1 had a protective pipe that extended up from the ground, so it was unlikely that surface sediment could have washed into this well. The opening to well Rx-01 was flush with the ground surface, and was covered only by an unsealed circular plate. It was considered very likely that surface sediment had entered this well. The purpose of the examination was to determine whether material could be identified that was clearly derived from the surface.

The samples were observed with transmitted light from below, and with reflected light from above. A polarized light microscope was not available.

OBSERVATIONS

OBSERVATIONS DURING INITIAL ROUNDS OF SAMPLING

The following wells produced LEL readings above 20%, when the wells were opened:

- BED-MW-22 (also H_2S>IDLH*, off-gassing was visible)
- BED-MW-23 (free product was present, well was not sampled)
- BED-MW-15
- RA-07D (also H_2S>IDLH)

*IDLH = Immediately Dangerous to Life and Health

After venting, the LEL levels in all but one of these wells eventually dropped below 20%, and sampling could proceed. The exception was well BED-MW-22, which was eventually sampled with all non-sparking tools, while the well-head was continuously ventilated with a fan, and continuous air monitoring was performed during sampling.

The following non-background PID readings were obtained:

- BED-MW-15: 70 parts per million (ppm) in well after LEL reduced to 4%
- Rx-01: 64.2 ppm from sediment in tube
- Rx-15: 51.3 ppm from sediment in tube
- Rx-25: 28 ppm from slurry in jar

All field radioactivity screening produced only background results.

The following wells produced solid sediment samples for analysis in the PBRF onsite laboratory:

- EB-RA-01
- Rx-01
- Rx-15
- Rx-25

Strictly speaking, Rx-15 and Rx-25 were Reactor Building sumps and not wells. It was anticipated that these sumps would be contaminated from Reactor Building operational or decommissioning activities that occurred over the years.

The following wells produced slurry samples for analysis at STL:

- MW-15
- MW-06

(Wells producing slurry samples for analysis at STL, continued)

- MW-22
- Rx-02
- RA-03
- MW-03
- Rx-04
- Rx-03
- RA-07S
- RA-07D
- RA-02

OBSERVATIONS FROM PRE-SCREENING

Based upon a very large number of samples pre-screened during the earlier Bay sampling effort, it was noted that laboratory pre-screening was producing a very high rate of false positives. Accordingly, positive GW pre-screening results were not considered reliable, and are not discussed here.

OBSERVATIONS FROM QUANTITATIVE ANALYSIS OF WELLS NEAR PBRF

The sediment from 4 of the 15 wells or sumps tested produced detectable results for Cs-137, as follows:

- Rx-03: 0.37 pCi/g (by STL)
- Rx-04: 0.39 pCi/g (by STL)
- Rx-15: 0.27 pCi/g (by PBRF onsite)
- Rx-01: 1.32 pCi/g (by PBRF onsite, marked "Qualitative Analysis Only")

These wells are highlighted in red on Figure 12. It is interesting to note that the sediment in sump Rx-25 did not appear to be contaminated.

Cs-137 activity values for the sediment obtained from other wells were all below the achievable MDAs. In part because of the very small sample volume, some of those MDAs were too high to be of use in this study. Wells with MDAs that were not low enough to be useful are highlighted in yellow on Figure 12.

Screening results that reported Cs-137 detections were judged unreliable, as they were generally not confirmed by quantitative results. The screening results were set aside, and the screening method was not continued in later work. Duplicate quantitative results were not available for comparison.

STL reported a LCS spike recovery of 107% for solids, and 105% for water, which were in the acceptable range of 80-120%.

With one exception, no activity was reported in blanks.

Other PBRF radionuclides of concern are defined in Table A-7 within Attachment A of the PBRF Final Status Survey Plan (FSSP). Radionuclides from FSSP Table A-7 that were identified by STL, beyond Cs-137, included the following, plus an unexpected detection of Plutonium:

SAMPLE DESCRIPTION	LAB SAMPLE ID	MATRIX	COMPOUND NAME	RESULT (pCi/g)	MDC (pCi/g)
PBRF/PASS2/GW/RX03/092006	F6K100239016	SOLID	Europium 154	0.33±0.42	0.1
PBRF/PASS1/GW/PB-BED-MW15/091806	F6K100239002X	SOLID	Europium 154	1.7±2.3	0.5
PBRF/PASS2/GW/MW-03/092006	F6K100239013	LIQUID	Plutonium 239/240	0.000164± 0.000088	0.000074

Europium-154 was also detected in STL's solid method blank, at a level of 1.2E-07 uCi/g. The detection reported for lab sample ID F6K100239002X was a duplicate, in which the original sample result was less than the minimum detectable concentration (MDC). The Europium-154 result of 3.3E-07 uCi/g was for a sample with a reported Cs-137 result of 3.7E-07 uCi/g, or 0.37 pCi/g.

The PBRF onsite laboratory did not identify any of the other radionuclides from the Table A-7 list, except in screening samples that were discounted. The screening results were set aside due to a previously demonstrated high rate of false positives from this qualitative procedure.

Although not central to this sediment evaluation, STL also reported testing results for the water fraction of slurry samples. As these water-fraction samples had been passed through a 0.45 micron filter, any radionuclides detected were considered to be dissolved, not entrained with sediment. No Cs-137 was detected in any of those samples. Figure 13 shows the locations of the wells in which water testing was performed.

The highest MDA/MDC reported by STL for these dissolved Cs-137 tests was 0.02 pCi/mL; the lowest reported MDA/MDC was 0.0075 pCi/mL.

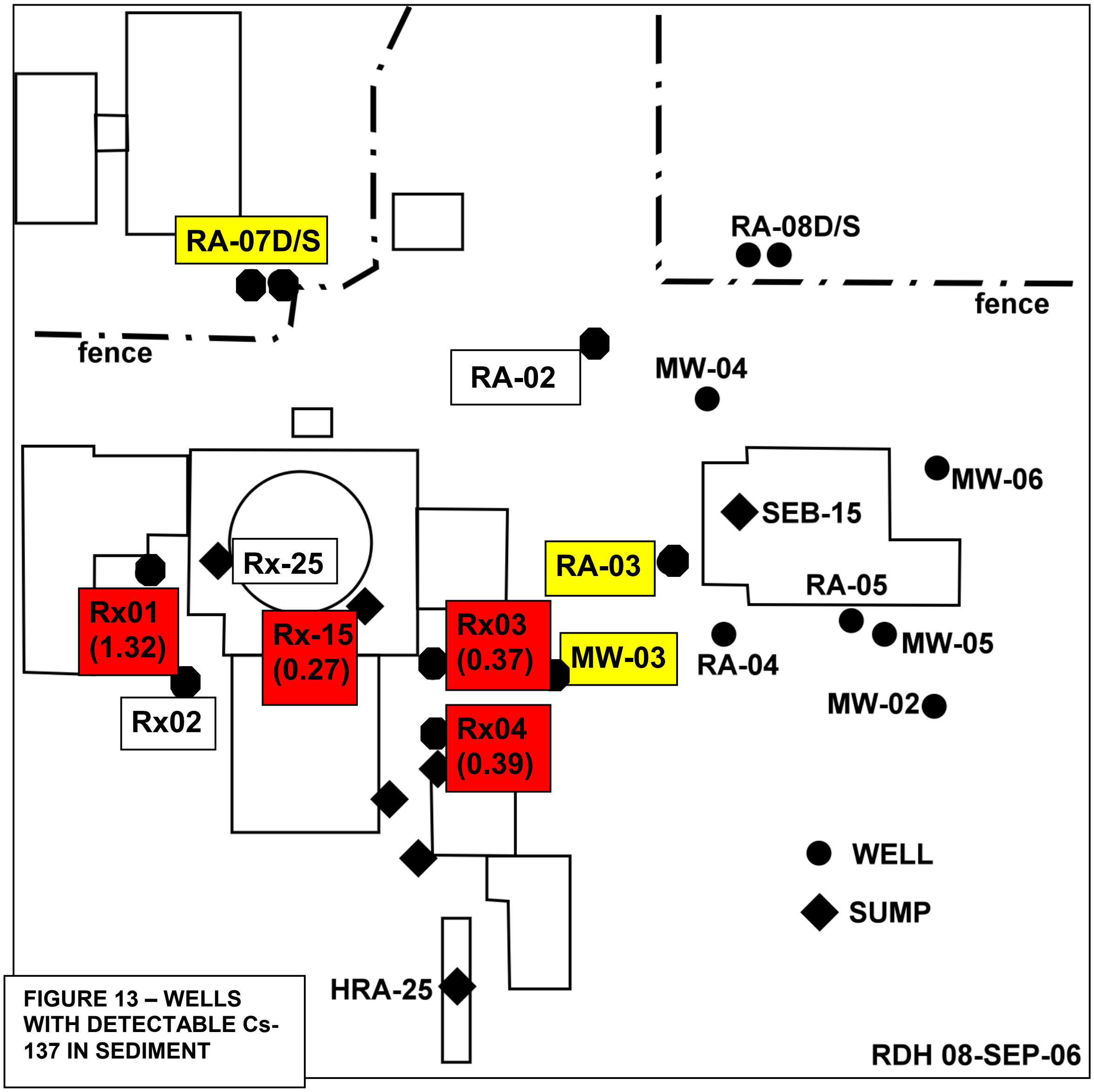


FIGURE 13 – WELLS WITH DETECTABLE Cs-137 IN SEDIMENT

RDH 08-SEP-06

● 🟥 **WELL ID** Wells with detectable Cs-137

● 🟨 **WELL ID** Wells Sampled, Cs-137 < MDA, But MDA> 0.3

● ☐ **WELL ID** Wells Sampled, Cs-137 < MDA < 0.3

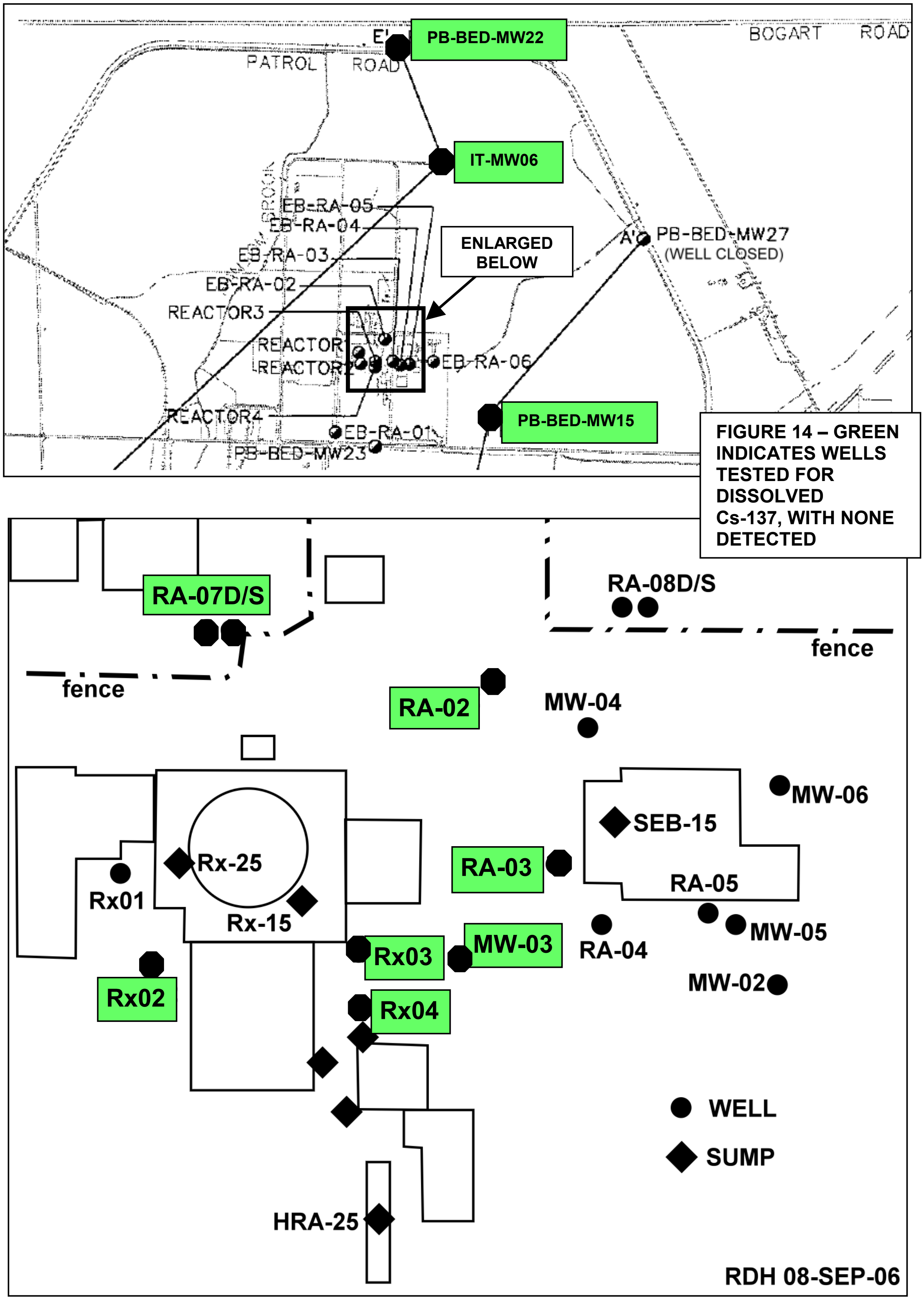


FIGURE 14 – GREEN INDICATES WELLS TESTED FOR DISSOLVED Cs-137, WITH NONE DETECTED

OBSERVATIONS FROM SAMPLING AND TESTING BACKGROUND WELLS

Many of the open-rock wells that might have been selected to represent background conditions were found to have been re-fitted at some time with plastic screens and riser pipes. These wells were all found to have no sediment accumulations to be sampled and tested. The only open-rock holes in appropriate locations that were found to be without screens were labeled GCL-MW01, GCL-MW02 and GCL-MW03. These were all shallow wells, drilled to only 10-25 feet in depth. Because of the dip of the beds illustrated in Figure 5, this meant that these wells did not draw water from the same geologic strata as the wells sampled near to the PBRF. Although these wells did not represent the same strata as those near the PBRF, they did produce sediment, and that sediment could be considered to be affected by the same atmospheric processes that affected wells near the PBRF. Unfortunately, these background wells had standard riser pipes, and could not be considered to have suffered the same potential for inflow of surface sediment during floods that was probably sustained by wells near the PBRF. Many wells near the PBRF had well-heads that were flush with the ground, giving a greater possibility of surface water inflow during floods.

Only two of the background wells, GCL-MW01 and GCL-MW03, were quantitatively tested, in the PBRF onsite laboratory. Quantitative analysis of the sediment from these two background wells achieved the minimum detectable activity (MDA), or minimum detectable concentration (MDC), of 0.3 pCi/g considered necessary for comparison with wells near the PBRF. Both of these wells produced results less than the MDA.

OBSERVATIONS OF SURFACE CONTAMINATION OF WELLS

The microscopically-examined sample from well Rx-01, which was open to surface influx, revealed the following materials that were not expected in a limestone aquifer:

1. A white-to-brown fiber, that did not appear to be plant material
2. A shred of white Teflon™ tape
3. Some twig-like particles

Materials observed in the Rx-01 sediment sample that might reasonably be expected in the aquifer were as follows:

1. Black, reflective grains with a conchoidal fracture surface (magnetite or glass)
2. Gray grains with a yellow surface coating (limonitic-appearing)
3. Red grains
4. Clear reflective grains
5. Clear grains with striated fracture surfaces (calcite-like)

The microscopically-examined sample from well EB-RA-1, which was not open to surface influx, revealed fewer materials not expected in an aquifer. However, the following were noted:

1. Two translucent hair-like features, one twisted
2. A bright green object, possibly plastic

Materials observed in the EB-RA-1 sediment sample that could reasonably be expected in the aquifer were as follows:

1. Mostly translucent, smooth, clear grains (appearing like calcite or quartz)
2. A few similar grains with flat cleavage surfaces (most likely calcite)

INTERPRETATIONS

The key interpretation derived from this study is that some very small levels of Cs-137 do appear to be present in the sediment in monitoring wells very near to the PBRF.

RADIONUCLIDES OTHER THAN Cs-137

After careful evaluation, including consultation between Rod Case and STL, NASA judged that the results for Eu-154 and Pu-239/240 were false positives.

BACKGROUND LEVELS OF Cs-137 IN WELL SEDIMENT

Based upon the results obtained in two upgradient wells, it is judged that the background level of Cs-137 in sediment in wells at the Plum Brook Ordnance Works is less than 0.3 pCi/g.

DISSOLVED VERSUS ADSORBED TRANSPORT OF Cs-137

There is no evidence, nor any reason to expect, that significant amounts of Cs-137 would be transported from this site dissolved in groundwater.

If the levels of dissolved Cs-137 in groundwater were to be evaluated, it would be necessary to compare the dissolved values found in wells to the value that the FSSP's RESRAD model predicts. That model used a soil/water K_d of 447 mL/g, and settled on a Derived Concentration Guideline Level (DCGL) of 14.7 pCi/g. This implies that the standard of comparison for a dissolved Cs-137 concentration would be 14.7/447 = 0.03 pCi/mL. Any field-measured value less than 0.03 pCi/mL would satisfy the RESRAD assumptions for the exposure received by a Resident Farmer. The values obtained through testing were less than this, showing that Cs-137 dissolved in groundwater is not an issue.

MECHANISM OF Cs-137 TRANSPORT

Clays bearing Cs-137, found at the bottom of GW wells, might have arrived there by at least two mechanisms, as follows:

1. Flooding may have carried clays down into the wells from the ground surface.

2. Cooling water might have been released through cracks in underground structures, and then have traveled to the wells via bedrock fractures.

In the first scenario, the wells would likely serve as catchbasins. The volume of sediment bearing Cs-137 would be restricted to the size of the wells, and no further migration would be expected.

In the second scenario, the wells would represent small windows on a larger phenomenon. Migration of Cs-137 would take place mostly by the movement of very small clay particles in suspension, often referred to as colloids. These clay particles would be carried by groundwater, through cracks in the limestone bedrock.

It is clear that the sediment in well Rx-01 has had a significant contribution from the ground surface. Even the sediment in well EB-RA-1 has had some surface material introduced, presumably during well installation and/or sampling. Both of these observations showed that the wells near the PBRF have suffered contamination from the surface. Neither of these observations rules out the possibility that clay carrying Cs-137 contamination has traveled via subsurface fractures.

ACCOUNTING FOR Cs-137 KNOWN TO BE RELEASED

If the first migration scenario is correct, and the wells serve as catchbasins for surface sediment, then these wells would contribute a very small amount to the sum of Cs-137 activity in the seven depositional environments.

If the second migration scenario is correct, and the wells are small windows into a larger migration phenomenon, then the scale of the phenomenon is yet to be assessed. The key question would be to determine whether the Cs-137 found near the PBRF represents a contamination gradient with its highest values at the structure, or represents a remnant left near the structure when the bulk of the contamination moved downgradient.

IDENTIFICATION OF Cs-137 DEPOSITS STILL IN TRANSIT

If the first migration scenario should be correct, then no further migration would be expected. If the second migration scenario should be correct, then the clays bearing Cs-137 could have migrated in fractures, toward Wagner Quarry.

FINAL RESTING PLACES OF Cs-137 NOT IN TRANSIT

Potential resting places for Cs-137 considered in this study include:

1. In the bottoms of wells near the PBRF
2. In fractures between the PBRF and Wagner Quarry
3. In sediment deposition areas downgradient from the PBRF

This study showed that the bottoms of wells have captured Cs-137 at low levels. This study has not evaluated the remaining scenarios, although it appears unlikely that detectable Cs-137 would be found downgradient from the PBRF.

CHARACTERISTICS OF Cs-137 DEPOSITS THAT AFFECT REMOVAL

Clay carrying Cs-137 could easily be removed from the bottoms of wells near the PBRF, although it does not appear to be present at levels of concern. If clay carrying Cs-137 were distributed in fractures, it would be very difficult to locate and remove. If clay carrying Cs-137 were to have accumulated in downgradient deposition areas, it would be difficult to separate and remove only the affected clay, without removing other sediments.

UNCERTAINTIES AND DATA GAPS

The following issues contribute uncertainty to the interpretations given above:

1. The levels of Cs-137 detected in this study were all less than 3 pCi/g, which was considered the project's practical quantitation limit for the total measurement system (sampling plus analysis) in other related studies.

2. An MDA of 0.3 pCi/g is needed in order to detect the low levels of radioactivity discussed here. With the sample sizes that could be obtained, and the count times employed, it was sometimes difficult to achieve the necessary MDA.

3. There is no simple health-based criterion that can be applied in this study, to assert that the levels of Cs-137 reported in wells are acceptable or unacceptable. It is not reasonable to compare the activities found in the wells to the project's effective DCGL of approximately 12 pCi/g.

RECOMMENDATIONS

Recommendations were provided to NASA in the course of weekly briefings on this project. As it was concluded that Cs-137 dissolved in groundwater is not an issue, this leaves only Cs-137 transported by clays or colloids as an issue to be resolved within the intent of the present inquiry. HaagEnviro's outstanding recommendations on the issue of sediment in the groundwater environment are as follows:

1. Test sediment in existing PBRF dewatering wells
2. Drill holes through PBRF walls and floor below the water table; draw in water and sediment, and test
3. Install soil and rock borings along outside walls of the PBRF; test sediment and water
4. Although it would be physically possible to install new rock holes downgradient from the PBRF, HaagEnviro does not recommend this approach, due to a limited potential to obtain useful results
5. Gently clean out existing wells, then surge them to draw sediment in from fractures, test the fracture sediment for radionuclides
6. Sample offsite areas, to rule out the possibility of migration through fractures to those locations

Many issues were beyond the scope of this investigation. In particular, it was beyond the scope of this initial study to determine whether the small amounts of Cs-137 detected raise any concerns. That determination should be made in subsequent evaluations.

RECOMMENDATIONS (continued)

To comply with requirements specified in NUREG 1757, Appendix F, additional work would be necessary, as described by the following excerpts from that document:

"… Characterization of ground water contamination, including all significant radiological constituents, along with inorganic and organic constituents and related parameters, should be adequate to determine the following:

a. Extent and concentration distribution of contaminants;
b. Source (known or postulated) of radioactive contaminants to ground water;
c. Background ground water quality;
d. Rate(s) and direction(s) of contaminated ground water migration;
e. Location of ground water plume and concentration profiles (i.e., maximum concentration in the vertical and lateral extent);
f. Assessment of present and potential future effects of ground water withdrawal on the migration of ground water contaminants;
g. Potential safety and environmental issues associated with remediating the surface and ground water;
h. Effect of the nonradiological constituents on the mobility of the radionuclides;
i. Whether the remediation activities and radiation control measures proposed by the licensee are appropriate for the type and amount of radioactive material present in the surface and ground water;
j. Whether the licensee's waste management practices are appropriate; and
k. Whether the licensee's cost estimates are plausible.

Typical analytical parameters include ... specific radionuclide concentrations, gamma spectrum analysis for all gamma-emitting radionuclides suspected to be present, sulfate, chloride, carbonate, alkalinity, nitrate, TDS, Total Organic Carbon (TOC), Eh, pH, calcium, sodium, potassium, iron, and dissolved oxygen...geochemical conditions that enhance or retard contaminant transport should be given special consideration. Geochemical data should include information on solid composition, buffering capacity, redox potential, sorption (represented as a range of distribution coefficients (Kd) for each radiological constituent), and other relevant geochemical data. Piper and Stiff diagrams may be useful for visualizing the geochemistry of the water..."

APPENDIX A
FIELD PROCEDURES

PROCEDURE FOR SAMPLING EQUIPMENT DECONTAMINATION

This procedure describes the general method to be used for decontamination of sampling devices that are re-used, such as water level indicators or sampling pumps. The purpose of decontamination is to remove all solid and liquid residues from prior samples before taking a new sample.

PRIOR PROCEDURES REQUIRED

- None

EQUIPMENT REQUIRED

- Metal wash tub
- Boot sprayer
- Distilled water
- Detergent
- Sample gloves
- Paper towels
- Trash bag
- Knife or scissors
- Plastic sheeting

PROCEDURE

1. Don sample gloves, use knife or scissors to detach all sample string, and completely disassemble the sampling device.
2. Place device in tub, with a small amount of detergent and 1 gallon of distilled water.
3. Scrub all parts with detergent and distilled water to remove visible solid residues.
4. Run detergent and water through interior of sampling equipment.
5. Remove equipment and rinse off detergent with distilled water.
6. Place equipment on clean plastic sheeting.
7. Dry equipment with paper towels, or allow to air dry.
8. Place all solid waste (sampling gloves, paper towels, string, etc.) into trash bag, to return to PBRF. Discard water on ground after screening with NaI meter.

PROCEDURE FOR WELL SAMPLING WITH INNER TUBE OF GEOPROBE DUAL-TUBE SYSTEM

Sampling well-bottom sediment to a depth of 4 feet will be accomplished with the inner plastic tube of a Geoprobe dual-tube system.

PRIOR PROCEDURES REQUIRED

- Sampling Equipment Decontamination

EQUIPMENT REQUIRED

- Clear 48” Geoprobe sampling tubes
- Four red and four black sampling tube end caps per 12” of sample
- Geoprobe adapter from sampler to 1” drill rod
- 3’ long by 1” diameter drill rods
- 10.6 eV photoionization detector (PID), for organics
- Sodium Iodide (NaI) detector, for Cs-137 activity
- Decontamination supplies
- Sharpie fine point marker
- Tape measure
- Utility knife

PROCEDURE

For each 48-inch sample, the following steps will be performed.

1. Warm up and calibrate PID
2. Decontaminate all metal parts
3. Allow parts to air dry, or dry with paper towel
4. Pre-screen inner plastic sampling tube with PID and NaI meters to verify background readings
5. Assemble sampler consisting of inner plastic tube, adapter, and drill rods
6. Allow weight of rods to drive sampler into sediment
7. Extract plastic tube, with sample inside
8. Use PID to screen bottom of sample
9. Cap bottom of clear tube with red cap
10. Measure 3” from end of core and cut with utility knife, label plastic tube with sample location and depth interval
11. Cap the top of the 3” core with a black cap
12. Screen next “bottom” section and cap with red cap
13. Measure 3” from end of “new” core and cut with utility knife, label plastic tube with sample location and depth interval
14. Continue steps 9 through 13 until every section is screened and capped.
15. Perform NaI screening on every 3” sample, using a one-minute count
16. Record findings

PROCEDURE FOR BAILER SAMPLING OF WELL-BOTTOM SEDIMENT

This procedure describes the method by which sediment samples are to be taken by lowering a bailer into a well. This method is appropriate when the sediment is too fluid to be retrieved using solid-coring methods.

PRIOR PROCEDURES REQUIRED

- Sampling equipment decontamination

EQUIPMENT REQUIRED

- Sample string
- Knife
- Sample gloves
- Paper towels
- Trash bag
- Stainless-steel bailer
- Sample containers
- Rods or weight on cable

PROCEDURE

1. Don sample gloves.
2. Cut enough string to reach the bottom of the well.
3. Tie a knot with the string around the harness of the bailer.
4. Lower the bailer to the bottom of the well.
5. Use rods, or a weight suspended from a cable, to gently press the bailer to the bottom of the sediment that has collected at the bottom of the well.
6. Retrieve the bailer by pulling up the string.
7. Empty the bailer into the sample container.
8. Label and document the sample.
9. Once the sample has been taken, place used string, gloves and paper towels in trash bag, which will be secured onsite for disposal.

APPENDIX B
LABORATORY TESTING RESULTS
(Provided as a separate computer file named 298GW-ResultsSpreadsheetBAP5RDH3rsh1.xls)