# 3. Study Area Investigations

*In the 2004 RI/FS, this section described the RI activities that were conducted by New Horizons in 2002 and 2003. The data collected during investigation activities and presented in the 2004 RI/FS are included by reference and are summarized in this revision to present the starting point for the 2006 Site investigation. This section has been expanded to include a discussion of the halted 2004 remedial activities and subsequent data collected during the Site investigation by Stoller in 2006. New sections describing Site background investigations and determination of tentative Site action levels have been added. Section 3 has also been expanded to describe the bagged soil disposal in 2005, the 2006/2007 investigations in the flood plain area and the clay pits, and the 2007 installation of additional groundwater monitoring wells.*

## 3.1 Original Remedial Investigation/Feasibility Study

During the RI/FS Site characterization completed in 2003 (New Horizons), data were collected from a surface gamma survey, surface soil samples, test pits, and borings. These data were presented in the 2004 RI/FS and are usable to assist in characterizing the Site. The surface gamma survey in conjunction with the surface soil samples and samples collected from the surface in the test pits and borings demonstrate the concentrations and extent of surface contamination. The locations of the sample collection points are well documented and the data quality objectives are adequate. Due to the heterogeneity of the Site, the analytical results from the test pits and borings, however, do only a partial job of characterizing the extent of COCs in the subsurface. The borings and test pits were installed in areas suspected of highest impacts but were inadequate to delineate extent of all impacted subsurface areas, as demonstrated by the results of the halted 2004 remedial action. Nevertheless, the data are helpful to characterize the Site and plan the next stages of investigation.

Data from this investigation were evaluated to ensure usability and were plotted for ease of viewing. The plots of these data are presented in the following figures:

- Figure 3-1 shows borings, test pits, and surface sample locations.
- Figure 3-2 shows the extent of metals (As, Hg, Pb, Mo, and V) above the tentative cleanup goals (listed in Section 3.4).
- Figure 3-3 shows the extent of alpha-emitting radionuclides (Th, U) above the tentative cleanup goals.
- Figure 3-4 shows the extent of gamma-emitting radionuclides (Ra) above the tentative cleanup goals.

These figures depict the extent of impacts to the soil as delineated by the 2004 RI/FS data and with the tentative derived concentration guidance level (DCGLs) used for impact extent. The nature of the impacts to the soil is described by Tables 3-1 through 3-3.

**Table 3-1**
**Data Summary for 2004 RI/FS Soil Metals Exceedances Using Tentative Cleanup Goals**

| Metal | Tentative Cleanup Goal (mg/kg) | Number of Sample Exceed-ances | Maximum Detected Value in Soil (mg/kg) | Maximum Detected Value Location(s) | Deepest Exceedance (ft bgs) | Deepest Exceedance Location |
|---|---|---|---|---|---|---|
| Arsenic | 39* | 54 | 330 | CSM97 | 3 | CB13, CP13 |
| Lead | 400 | 55 | 14,000 | CSM113 | 6 | CP27 |
| Mercury | 23 | 9 | 400 | CSM30 | 1.5 | CP21 |
| Molybdenum | 390 | 5 | 980 | CSM136 | 1.5 | CP24, CP22 |
| Vanadium | 550 | 1 | 1,000 | CB6 | 1 | CB6 |

mg/kg – milligrams per kilogram
* 2006

**Table 3-2**
**Data Summary for 2004 RI/FS Alpha Activity Soil Exceedances**

| Radioisotope Group Spectroscopy | Radio-isotope | Tentative Cleanup Goal (pCi/g) | Number of Sample Exceed-ances | Maximum Detected Value in Soil (pCi/g) | Deepest Exceedance (ft bgs) | Deepest Exceedance Location |
|---|---|---|---|---|---|---|
| Alpha | Th-228 | 6.47 | 6 | 109 | 1.5 | CP24 |
| Alpha | Th-230 | 11.53 | 38 | 270 | 16 | CB28* |
| Alpha | Th-232 | 3.88 | 19 | 110 | 11 | CP4 |
| Alpha | U-235 | 4.97 | 3 | 5.8 | 7 | CB27 |
| Alpha | U-238 | 21.80 | 12 | 110 | 7 | CB27 |

pCi/g – picoCuries per gram
* This data was identified through lab report validation to be incorrectly reported in the original RI/FS, actual value was 1.153.

**Table 3-3**
**Data Summary for 2004 RI/FS Gamma Activity Soil Exceedances**

| Radioisotope Group Spectroscopy | Radio-isotope | Tentative Cleanup Goal (pCi/g) | Number of Sample Exceed-ances | Maximum Detected Value in Soil (pCi/g) | Deepest Exceedance (ft bgs) | Deepest Exceedance Location |
|---|---|---|---|---|---|---|
| Gamma | Ra-226 | 4.14 | 117 | 610 | 4 | CB5, CP23 |
| Gamma | Ra-228 | 4.60 | 8 | 9.4 | 2 | CB5 |

pCi/g – picoCuries per gram

## 3.2 2004 Remedial Action

The 2004 ROD selected the offsite disposal of the affected material at a combination of Resource Conservation and Recovery Act (RCRA) landfills, with the majority of affected material slated for disposal at the local Foothills Landfill and a minority of affected material slated for disposal at either the CSI Landfill in Colorado or the U.S. Ecology Landfill in Idaho. The remedial action began in the spring of 2004.

During the 2004 remedial action, six areas were excavated and a seventh area was partially excavated. A total of 1,870 cubic yards of soil were excavated from the Site and placed in super-sack bags. Several bags were shipped to an offsite disposal facility, and the remaining 1,776 cubic yards contained in 455 bags were stored onsite. (Note: the 455 bags of soil were subsequently transported offsite for disposal in December 2005, as described in Section 3.6.) Excavation of soil during the 2004 remedial action was guided by an Eberline In-Situ Object Counting System (ISOCS), a hand-held gamma probe, and visual observations. The ISOCS, a germanium-based spectroscopy system that is designed to provide information on the type and amount of radioactive material, was housed in an onsite trailer and was used predominantly as confirmation of excavation success. The hand-held gamma probe was used to guide the excavation, as were the visual observations. The resulting excavations had not been surveyed, and any data collected during the original RI/FS regarding soil that had been excavated had not been removed from the maps.

Traditional methods of Site investigation (surface samples, borings, and test pits) were used to calculate the nature and extent of these contaminants in the original RI/FS. However, after commencement of the remedial action field work to excavate the Class I soil, it became apparent that the nature and extent of the Class I soils and the Class II soils had been significantly underestimated in the 2004 RI/FS. In the field, the consultant reported encountering soils that exhibited higher concentrations of contaminants than previously calculated, and it reported finding a greater than expected volume of impacted soils. When asked to re-calculate the nature and extent of contamination based on existing data, the consultant stated that it could not do so without further Site characterization field investigations. CDPHE concurred with this conclusion, and the remedial action was halted.

Laboratory quality control samples were collected and locations surveyed, but no reliable confirmation sample results from either the laboratory or ISOCS had been identified for the 2004 remedial activities. No useable data were therefore recovered during the partial remediation of the Site.

## 3.3 Study of Site Background Levels

In September 2005, Stoller prepared a Background Evaluation Report for the Site (Stoller 2005b). This report summarized and assessed the results of three previous background studies, two by URS in 2000 and 2002, and one by New Horizons in 2004, which attempted to establish background concentrations for metals and radioisotopes:

- *Background Characterization Report,* prepared for Colorado School of Mines Environmental Health and Safety, prepared by URS Greiner Woodward Clyde International-Americas, Inc., July 7, 2000 (URS 2000)
- *Colorado School of Mines Research Institute Supplementary Background Characterization draft final report*, prepared by URS Corporation, January 28, 2002 (URS 2002)
- *Remedial Investigation/Feasibility Study and Proposed Plan, prepared for Colorado School of Mines Research Institute Site,* prepared by New Horizons Environmental Consultants, Inc., January 21, 2004 (New Horizons 2004)

The geologic complexity of the Site makes determining background concentrations difficult. Appropriate background levels of compounds of concern (COCs) are critical in that they are used to establish cleanup objectives. If these values are too low, cleanup may include native material, and if too high, cleanup may exclude target material.

Items considered during the assessment included quality of data collected, appropriateness of data analysis, formations sampled, and conclusions. A general concern with the previous background reports was the lack of subsurface sampling and subsurface background determination. In the *Proposed Soil Remediation Objectives*, CDPHE states that at least one background sample should be taken from each depth that will be sampled at the contaminated site. As described in Section 2, seven different geologic units underlie the Site. A complete background analysis would include a background evaluation for each geologic unit underlying the site. None of the three studies accomplished this.

The data from the URS 2000 and URS 2002 reports were combined to determine an estimate of the background levels for the contaminants of concern. Concerns with the methods used to select data representative of background levels in the New Horizons report led to the exclusion of some data from their final background calculation. Methods used to evaluate the data, after data deemed unusable due to lab QA problems and other concerns were excluded, were based on the CDPHE *Proposed Soil Remediation Objectives*, and results for radionuclides and metals are detailed below.

Background levels were calculated by taking the mean plus two times the standard deviation ($\mu+2\sigma$) of the data. In cases of log-normally distributed data, the $\mu+2\sigma$ value was found for the transformed data, and the antilogarithm of the result taken to determine the background level. Radionuclide background results are summarized in Table 3-4. Means and standard deviations are shown for raw data (before transformations of the data were applied) and for log-transformed data, where applicable. Stoller combined usable (reliably collected in an appropriate area) raw data from each of the reports and calculated the corresponding background concentrations.

Metals data were analyzed in the same manner as radionuclide data. As shown in Table 3-5, a value of the mean plus two times the standard deviation ($\mu+2\sigma$) is reported in addition to the 95% UCL for each metal. In cases of log-normally distributed data, those values were found for the transformed data, and the antilogarithm of the result was taken to determine the background level. Means and standard deviations are shown for raw data (before transformations to the data were applied) and for log-transformed data, where applicable.

CDPHE reviewed the Stoller background report and believed it was inadequate because each of the seven geologic formations present at the Site had not been characterized. CDPHE also commented that even if reliable background values were available for each formation, this would not aid in developing cleanup goals for the Site. Further, they felt that using the mean plus two standard deviations was not warranted because it overstates the background values and stated that lower cleanup levels have been successfully achieved at other sites in Colorado. In summary, CDPHE felt that the existing cleanup standards listed in the 2004 RI/FS for the CSMRI Site should be followed.

## Table 3-4
## Combined URS 2000 and URS 2002 Radioisotope Background Concentrations

| | Ra-226[c] | | Ra-228[a,b,c] | | Th-228 | | Th-230[a,c] | | Th-232[a,c] | | U-234[c] | | U-235[a,c] | | U-238 | | K-40 | | Pb-210[c] | | Th-234[c] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Norm | Log-norm | Norm | Log-norm | Norm | Log-norm | Norm | Log-norm | Norm | Log-norm | Norm | Log-norm | Norm | Log-norm | Norm | Log-norm | Norm | Log-norm | Norm | Log-norm | Norm | Log-norm |
| μ (pCi/g) | 1.9 | 0.48 | 2.3 | 0.74 | 2.2 | NA | 1.2 | 0.01 | 1.6 | 0.17 | 1.6 | 0.15 | 0.12 | -2.43 | 1.6 | NA | 23 | NA | 1.8 | 0.41 | 1.7 | 0.43 |
| μ (pCi/g) | 1.0 | 0.62 | 1.2 | 0.33 | 1.2 | NA | 0.78 | 0.70 | 1.1 | 0.86 | 1.1 | 0.87 | 0.13 | 0.81 | 0.90 | NA | 2.9 | NA | 0.99 | 0.67 | 0.71 | 0.45 |
| μ (pCi/g) | | 5.6 | | 4.0 | 4.7 | | | 4.1 | | 6.6 | | 6.6 | | 0.44 | 3.4 | | 29 | | | 5.8 | | 3.8 |

pCi/g - picoCuries per gram
μ  mean
σ standard deviation
[a]The larger of half the MDL and the value entered in the original table was entered for URS 2000 data below the MDL.
[b]Trimmed mean used to calculate background cleanup levels.
[c]Background levels calculated using log-normal statistics.

## Table 3-5
## Combined URS 2000 and URS 2002 Metals Background Concentrations

| | As[a,d] | | Cd[c,d] | | Pb[d] | | Ba[b,d] | | Cr[b] | | Hg[d] | | Mo[c] | | Se | | Ag[c,d] | | V[b,d] | | Zn | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Norm | Log-norm | Norm | Log-norm | Norm | Log-norm | Norm | Log-norm | Norm | Log-norm | Norm | Log-norm | Norm | Log-norm | Norm | Log-norm | Norm | Log-norm | Norm | Log-norm | Norm | Log-norm |
| μ (mg/kg) | 12 | 1.9 | 1.3 | -0.30 | 106 | 4.2 | 106 | 4.6 | 13 | NA | 0.23 | -1.95 | 4.7 | NA | 2.5 | NA | 2.2 | 0.00 | 19 | 2.9 | 350 | NA |
| σ (mg/kg) | 14 | 1.0 | 1.4 | 0.66 | 112 | 0.98 | 32 | 0.31 | 2.6 | NA | 0.23 | 1.05 | 3.4 | NA | 0 | NA | 2.5 | 0.92 | 4.1 | 0.19 | 245 | NA |
| μ+2σ (mg/kg) | | 51 | | 2.8 | | 478 | | 189 | 19 | | | 1.2 | 11 | | 2.5 | | | 6.4 | | 27 | 841 | |
| 95% UCL (mg/kg) | | 38 | | 2.4 | | 363 | | 178 | 18 | | | 0.92 | 11 | | 2.5 | | | 5.6 | | 26 | 787 | |

mg/kg - milligrams per kilogram
μ  mean
σ standard deviation
[a]Outlier flagged in URS 2000 report included in analysis.
[b]Mean, standard deviation and background level calculated without flagged outlying data points.
[c]Background levels calculated with trimmed data set.
[d]Background levels calculated using log-normal statistics.

In response to comments from the CDPHE pertaining to sampling each formation that would have been costly and time consuming to implement, the School opted to proceed as requested by the CDPHE while leaving future background studies on the table as an option if circumstances warranted further study. The background review effort did, however, result in adjusting the background level for arsenic to levels more appropriate for the Site as well as allow the use of the total mercury standard for field screening with speciated confirmatory sampling. The School and CDPHE agreed that the School may re-evaluate background concentrations for different formations if field observations during investigation excavation revealed that such re-evaluation was warranted. It turned out, however, that further study was not warranted.

## 3.4 Establishment of Tentative Site Cleanup Goals

Tentative cleanup goals for the Site were presented in the *CSMRI Creekside Site Final Site Characterization Work Plan* (Stoller 2006b), which was approved by CDPHE. The tentative cleanup goals for this Site characterization are presented in Table 3-6. The concentrations in Table 3-6 include background levels within the cleanup goal. For the most part, these are the levels agreed upon by the CDPHE and presented in the 2004 ROD. Mercury and arsenic have had their cleanup goals adjusted from the 2004 ROD. Mercury was adjusted to meet the ability of most laboratories to test for this metal, and a cleanup goal of 23 ppm total mercury has been established. Arsenic was adjusted due to elevated background levels in the Front Range area. A background concentration of 38 ppm is used with a target of 1 ppm above background to arrive at a cleanup goal of 39 ppm. (The previously proposed cleanup goal for arsenic was 13 ppm.)

**Table 3-6**
**Tentative Site Cleanup Goals**

| Constituent | Tentative Site Cleanup Goal |
|---|---|
| **Metals** | **mg/kg** |
| Arsenic | 39 |
| Barium | 5,277 |
| Cadmium | 76.1 |
| Chromium | 223 |
| Lead | 400 |
| Mercury (total) | 23 |
| Molybdenum | 390 |
| Selenium | 380 |
| Silver | 380 |
| Vanadium | 550 |
| Zinc | 22,825 |
| **Radioisotopes** | **picoCuries/gram** |
| Radium 226 | 4.14 |
| Radium 228 | 4.6 |
| Thorium 228 | 6.47 |
| Thorium 230 | 11.53 |
| Thorium 232 | 3.88 |
| Uranium 234 | 254.9 |
| Uranium 235 | 4.97 |
| Uranium 238 | 21.8 |

Based on previous sampling efforts on the Site, five of the metals listed above (arsenic, lead, mercury, molybdenum, and vanadium) were present at levels above these tentative DCGLs; therefore, these metals are considered COCs. Levels of the other metals onsite were already below the tentative DCGLs and no further analysis was conducted. The listed radioisotopes were also considered COPCs.

## 3.5 2005 Bagged Soil Disposal

As noted above, the previous consultant had stored 455 super-sack containers at the Site as a result of the 2004 halted remedy implementation. In December 2004, Stoller collected representative soil samples from a random subset of the 455 super-sack containers staged at the Site to generate a legitimate data set to evaluate potential disposal options of the containerized material. Results were submitted to CDPHE for review in the April 2005 report, *Dose Assessment for the Emplacement of the CSMRI Site Containerized and Remaining Subsurface Soil into a RCRA Subtitle D Solid Waste Landfill* (Stoller 2005a). After review of the dose assessment report, the CDPHE approved shipment of the bagged radioactive/metals-contaminated soils and up to 30,000 cubic yards of similar soils to a solid waste landfill in a letter dated August 26, 2005. Due to the high cost of managing the containerized material at the Site and the preference of CDPHE to ship the material from the Site (to eliminate the potential for dispersion to offsite neighborhoods during periods of high wind), this disposal was expeditiously implemented.

In order for the landfill to accept this waste stream, analytical data demonstrating the nature of the material were supplied to BFI for review. BFI agreed the material was not hazardous waste and along with the CDPHE approval for them to accept the material, BFI agreed to accept the bagged soils.

In October 2005, Stoller obtained a CDOT permit (Permit Request number 605167) to transport the bagged soil offsite via an access lane on Colorado Highway 6. Physical construction of this access was completed in 2004 under CDOT Access Permit No. 603100 by a previous consultant hired by the school.

All bagged soils from the Site were shipped to BFI Foothills Landfill during the period of December 12 through 15, 2005, in accordance with the approved *CSMRI Creekside Site Contaminated Soil Disposal Work Plan* (the Materials Transportation Plan is Appendix A of the work plan) (Stoller 2005c). A total of 112 truck loads containing bagged soil plus two trucks containing other debris from the Site were shipped. None of these loads tripped the gate sensors that are set to detect activity greater than two times background. The total tonnage from the landfill weigh tickets was 2,110.65 tons. Stoller summarized the bagged soil disposal in the *CSMRI Bagged Soil Disposal Summary Report* dated February 8, 2006.

## 3.6 2006 Site Soil Investigation: Main Site

The Site soil investigation completed during 2006 used the data generated during the previous RI/FS to guide further data collection while progressing the Site toward final closure. This was accomplished in several phases of fieldwork and only after detailed planning and analysis. A re-examination of Site data along with mechanisms of contaminant placement and regulatory framework were completed to evaluate the possible investigation options.

Due to the heterogeneous nature of Site contaminants generated by the numerous research projects conducted at this Site, which is unlike many other sites contaminated with radionuclides and metals, additional data were required to accurately determine the nature and extent of contamination within a confidence range to enable remedial cost estimates to be developed within the +50 percent to -30 percent range in the RI/FS stage and +15 percent to -10 percent range for the remedial design and implementation stage of the remedial action. Estimating a volume of impacted soil based on the data in the 2004 RI/FS and the data from the New Horizons excavation of Class I soils was not possible with the requisite degree of confidence.

Therefore, the question became what method to use for additional Site characterization. To attempt to determine the volume of impacted material onsite using traditional methods of Site investigation would have been comparable in cost to the technique selected but would have provided less certainty in volume estimates.

The investigative method selected was to excavate the impacted soil and stockpile it onsite to determine the nature and extent of contamination. This excavation method is analogous to the method used by EPA to address the former settling pond at the Site. EPA had excavated the former settling pond down to cleanup goals and then stockpiled the soil at another location on the Site for further characterization work for disposal purposes. The New Horizons' baseline risk assessment has already demonstrated that some proactive remedial action was necessary at the Site for the remaining contaminated soils. New Horizons' excavation of the Class I soil showed that the nature and extent of contamination was greater than previously estimated. Accordingly, it was clear that the "no action" alternative must still be rejected because the "no action" alternative could not have been found to be protective of the human health and the environment when the scope of the problem was believed to be greater than before when the "no action" alternative was rejected.

Therefore, excavation of the contaminated soils was inevitable to implement the eligible alternative remedies (Alternatives 4 and 5) considered in the 2004 RI/FS and the offsite disposal remedy selected in the ROD. Only Alternative 2 did not involve excavation of the contaminated soils, but that alternative was much less likely to be selected than the other remedies that met more of the NCP remedy selection criteria.

Furthermore, the estimated cost of using this excavation investigative method was comparable to the cost for using the traditional method of borehole site investigation to complete the subsurface site investigation. In addition, the excavation method simultaneously performs the likely inevitable task of soil excavation and guarantees the requisite degree of confidence to determine the nature and extent of the contamination to reliably estimate remediation costs, unlike the traditional investigation method of boreholes. It was as cost effective as the traditional method, but it was expected to produce more reliable results than the traditional method.

To maintain fiscal responsibility and attain the requisite degree of confidence to estimate nature and extent of contamination, the Site characterization technique of excavating and stockpiling impacted material was adopted. Data from the 2004 RI/FS were used to guide initial soil excavation activity. Field screening tools were used to guide additional excavation. Laboratory analyses were used to confirm that tentative cleanup goals were met and to determine the lateral and vertical extent of contamination.

This section describes the Site investigation conducted during 2006 on the main portion of the Fenced Area, excluding the flood plain, the former pond area, and the area of the former Clay Pits. The extent of impacts to Site soils was successfully determined during this investigation. The investigation was conducted in several phases, each phase described separately below, that together successfully delineated the extent of impacts. This investigation was conducted in accordance with the approved Site Characterization Work Plan (Stoller 2006b).

Each phase of the Site investigation used data collected during a previous phase to further develop the understanding of the extent of impacts to Site soils. The phases of this investigation included:

- Initial Excavation of Known Impacted Soil and Segregation
- Radiological Land Survey
- Instrument Bias/Correlation
- Iterative Lateral and Vertical Extent Determination and Excavation
- Confirmatory Sampling

The heterogeneity of contamination at the Site complicated efforts to determine highly accurate correlations between field screening data and laboratory data. However, the use of reasonably accurate correlations allowed for the use of field screening methods and instrumentation that were critical to allow timely determination of excavation end points. The co-location of many of the COCs along with overlapping use of the different field instruments helped to ensure that the correlations used were effective.

### 3.6.1 Phase 1: Initial Excavation of Known Impacted Soil

Analytical data generated from samples collected during the 2004 RI/FS led to the identification of areas exhibiting elevated levels of contamination. These areas of known impacts were excavated and placed into two onsite soil stockpiles: one containing soil greater than 100 pCi/g total activity and one containing soil below 100 pCi/g total activity but above the DCGL. The surface soil excavation also allowed access to deeper soil so that it could be more readily evaluated. The 100 pCi/g total activity soil was excavated during this phase to further reduce the potential for worker exposure while maintaining flexibility when choosing a remedial alternative.

The soil was excavated using an excavator that loaded the impacted soil into a transport that moved the material to the appropriate stockpile. The extent of the initial soil excavation is shown on the following figures and detailed in Tables 3-4 and 3-5.

- Figure 3-5 shows those areas identified as containing material whose remedial options may be limited. This was determined to be material in excess of 100 pCi/g of total activity. This material totals approximately 141 cubic yards.

- Figure 3-6 shows a combined extent of all the COCs and depicts the extent of the initial soil excavation activity. This material totals approximately 4,330 cubic yards.

These figures depict the extent of contaminants as delineated by these data and inferred by the data. Stoller used a different method to delineate the contamination than the past consultant used. The past consultant used krieging to infer the extent of contamination. Stoller used a geologist to meticulously evaluate each data point and determine whether the extent was successfully delineated. Stoller's method determined a known volume of impacted soil of approximately half of the total impacted volume estimated by the past consultant. However, it is important to clarify that Stoller was only using this method to delineate the known areas of contamination for the purpose of performing the initial excavations without further field screening for cost-efficiency purposes. Unlike the past consultant, Stoller was not trying to estimate the full nature and extent of Site contamination during this initial excavation process. The limited purpose was to excavate the known areas of contamination as an initial investigative phase to allow for further Site characterization to occur. The figures and following tables do not account for any soil previously excavated by New Horizons.

Tables 3-7 and 3-8 depict the depth and quantity for each excavation.

**Table 3-7**
**Depth and Estimated Excavation Quantity for Material above 100 pCi/g of total activity as depicted on Figure 3-5**

| Excavation Location ID | Intervals to be Excavated (feet) | Volume (cubic yards) |
|---|---|---|
| #1 | 0 to 1 | 3 |
| #2 | 0 to 1<br>6 to 8 | 3<br>6 |
| #3 | 0 to 1 | 3 |
| #4 | 0 to 1 | 13 |
| #5 | 0 to 1 | 44 |
| #6 | 0 to 1 | 3 |
| #7 | 0 to 2 | 6 |
| #8 | 0 to 1 | 23 |
| #9 | 0 to 1<br>1 to 2 | 11<br>6 |
| #10 | 0 to 2 | 6 |
| #11 | 0 to 2 | 11 |
| #12 | 0 to 1 | 3 |
| Total | | 141 |

**Table 3-8**
**Depth and Estimated Excavation Quantity for Initial Soil Excavation as depicted on Figure 3-6**

| Removal Location ID | Depth (feet) | Cubic Yards |
|---|---|---|
| #1 | 0 to 1 | 601 |
| #2 | 0 to 1 | 3 |
| #3 | 0 to 1<br>1-3 west<br>1-3 east | 2,834<br>298<br>16 |

**Table 3-8**
**Depth and Estimated Excavation Quantity for Initial Soil Excavation as depicted on Figure 3-6**

| Removal Location ID | Depth (feet) | Cubic Yards |
|---|---|---|
| #4 | 0 to 1 | 3 |
| #5 | 0 to 1 | 3 |
| #6 | 0 to 1 | 13 |
| #7 | 0 to 1 | 8 |
| #8 | 0 to 3 | 39 |
| #9 | 0 to 1 | 3 |
| #10 | 0 to 1<br>10-12 | 34 |
| #11* | 0 to 3 | 132 |
| #12 | 0 to 1 | 21 |
| #13* | 0 to 1 | 55 |
| Total | | 4,330 |

* Areas may have been addressed by New Horizons

### 3.6.2 Phase 2: Radiological Land Survey

After completion of the initial soil excavation, Eberline Services performed a radiological survey of the surface of the entire Site using Global Positioning Environmental Radiological Surveyor (GPERS-II). This survey produced a real-time picture of the relative intensity of gamma emitters in the remaining surface soil at the Site, including areas that were previously under the surface and now considered surface soil. The purpose of the land survey was to provide a new baseline of areas that may be considered impacted and areas that may be considered non-impacted, after known impacted soils had been excavated. Figure 3-7 presents the results of the initial GPERS survey.

### 3.6.3 Phase 3: Instrument Bias/Correlation

During Site characterization activities, field and laboratory screening instruments and visual observations were used to guide excavations. These instruments included a hand-held gamma scintillator, a field x-ray fluorescence (XRF) spectrometer, and two shielded sodium iodide (NaI) counting systems located in an onsite laboratory. To confirm the effectiveness of these instruments for detecting contaminants above the tentative cleanup goals, samples were taken for radiochemical and metals analyses by an approved offsite laboratory. Data generated using different field techniques were cross-correlated, as well as compared to laboratory data. After the initial data were compiled, a thorough data review and comparison were made to determine if any biases exist and, if so, whether there was a correlation between the different measurement results. The bases for determining the correction factors were documented in laboratory and field logs, as applicable for the instrument. The initial correction factors were refined and adjusted as necessary based on additional data collected during the ongoing characterization activities. Results of this study indicated the screening instruments allowed reliable semi-quantitative assessment of contaminant levels.

### 3.6.3.1 Gamma Detector Correlation

When sufficient data were accumulated from the gamma characterization survey, 20 grab samples (total) were taken from three types of areas: areas identified as being contaminated (count rate greater than two times background), "gray areas" (count rate between background and two times background), and potentially non-impacted areas (approximately background count rate). The potentially non-impacted areas were located onsite in areas adjacent to impacted areas.

Prior to collection of each sample, *in-situ* gamma measurements using a hand-held field gamma scintillator (FGS) were taken. The collected samples were analyzed in the field laboratory using the NaI detector. The samples were also submitted to an offsite laboratory for radionuclide analyses. Radium 226/228 analyses performed for correlation purposes used the EPA 901.0M screening to achieve a two-day turnaround. Data generated from these measurements were used to establish correlations between characterization gamma survey data, *in-situ* hand-held gamma survey meter readings, and data obtained with the NaI detector in the field laboratory. Whenever possible, these locations were co-located with the samples taken for the Metals XRF Bias Determination to evaluate the potential for using *in-situ* metals data as a surrogate for identifying locations of radiological contamination.

The results of this correlation study indicated that a field laboratory NaI reading of 5.5 or below would be below the Site tentative DCGL of 4.14 pCi/g Ra-226 (using the offsite laboratory). A field screening level for the field gamma scintillator was initially set at 50,000 counts per minute (cpm), as this level was found to always exceed the site tentative DCGL. A high field screening level was established to ensure that this instrument did not result in placement of soil in Stockpile B that is below the tentative cleanup guideline. This field screening level was later refined to 40,000 cpm as further data points refined the correlation. Nevertheless, the field gamma scintillator was never used by itself to guide excavation; it was used as a guide for collection of samples run by the field laboratory NaI for confirmation before further excavation proceeded.

A summary of the initial data used to make these correlations is presented in Table 3-9, and the correlation between the offsite laboratory Ra-226 and field laboratory NaI is shown graphically in Figure 3-8.

**Table 3-9**
**Initial Correlation Between Offsite Laboratory, Field Laboratory, and Field Gamma Scintillator Data**

| Sample ID | Field Lab NaI (RA-226) (pCi/g) | Field Gamma (cpm) | Lab Screen (Ra-226) (pCi/g) |
|---|---|---|---|
| CSM20060607-001 | 4.68 | 26727 | 1.77 |
| CSM20060607-002 | 7.69 | 20401 | 4.79 |
| CSM20060607-003 | 2.78 | 15402 | 1.15 |
| CSM20060607-004 | 23.61 | 37488 | 20.2 |
| CSM20060607-005 | 20.78 | 83611 | 13.1 |
| CSM20060607-005A | 17.56 | 83611 | 11.2 |
| CSM20060607-006 | 3.15 | 14989 | 1.77 |

**Table 3-9**
**Initial Correlation Between Offsite Laboratory, Field Laboratory, and Field Gamma Scintillator Data**

| Sample ID | Field Lab NaI (RA-226) (pCi/g) | Field Gamma (cpm) | Lab Screen (Ra-226) (pCi/g) |
|---|---|---|---|
| CSM20060607-007 | 4.62 | 16811 | 3.21 |
| CSM20060607-008 | 3.51 | 15557 | 1.79 |
| CSM20060608-009 | 3.1 | 16703 | 1.66 |
| CSM20060608-010 | 3.11 | 17225 | 1.04 |
| CSM20060608-011 | 3.95 | 16597 | 2 |
| CSM20060608-012 | 6.35 | 22287 | 5.86 |
| CSM20060608-013 | 11.49 | 27354 | 6.6 |
| CSM20060608-014 | 5.97 | 18725 | 4.26 |
| CSM20060608-015 | 10.23 | 25645 | 9.9 |
| CSM20060608-016 | 4.27 | 17356 | 2.24 |
| CSM20060608-017 | 3.64 | 15912 | 1.19 |
| CSM20060608-018 | 3.08 | 16379 | 0.84 |
| CSM20060608-019 | 3.76 | 17224 | 1.36 |
| CSM20060608-020 | 4.21 | 18229 | 2.01 |
| CSM20060608-020A | 4.31 | 18229 | 1.36 |

At the completion of the characterization activities, a final correlation between the offsite laboratory and field laboratory NaI was plotted. These data included the initial 20 samples plus an additional 92 samples. This final correlation is shown in Figure 3-9. This final correlation yields a value of 5 for the onsite NaI when the offsite laboratory value is 4.14. (The actual correlation value is 4.57 for the NaI, which is rounded to 5.) No correction for bias was applied to field laboratory NaI data when determining final survey statistics.

#### 3.6.3.2 XRF Bias Determination

*In-situ* metals analyses were performed using a field portable XRF spectrometer. *In-situ* XRF measurements may differ from, but have the ability to be directly correlated to, laboratory results. The magnitude of this bias was dependent on Site/sample conditions. To quantify this bias for the materials on this Site, soil was evaluated by the field XRF and also submitted to an offsite laboratory for metals analyses. Twenty sampling locations representing a range of field readings were selected based on historical data and field XRF readings. After the laboratory data were obtained, a correlation curve was generated for each element in question, and *in-situ* measurements were corrected using the applicable correlation factor. If the correlation was not well defined, a conservative correction factor was used. Whenever possible, these locations were co-located with the samples taken for the Gamma Detector Method Correlation to evaluate the potential for using *in-situ* metals data as a surrogate for identifying locations of radiological contamination.

Initial results indicated that the correlation was not well defined, and conservative correction factors were used. Only two compounds, arsenic and lead, yielded sufficient data to make the correlation which, fortunately, were the two metals of most concern on the Site. Initial field XRF tentative DCGLs were set as shown in Table 3-10.

**Table 3-10**
**Initial Metals Correlation**

| Metal | Site Tentative DCGL | Initial Field XRF Tentative DCGLs |
|---|---|---|
| Arsenic | 39 ppm | 25 ppm |
| Lead | 400 ppm | 300 ppm |
| Mercury | 23 ppm | 50 ppm |
| Molybdenum | 390 ppm | 390 ppm |
| Vanadium | 550 ppm | 550 ppm |

The metals and radionuclides were not always co-located, making the use of one as a surrogate for the other less practical.

At the completion of the characterization activities, a final correlation between the offsite laboratory metals data and XRF was calculated. These data included the initial 20 samples plus an additional 70 samples. The final metals correlation results are presented in Table 3-11.

**Table 3-11**
**Final Metals Correlation**

| Metal | Correction Factor (Field XRF/lab value) | Tentative DCGLs | Field XRF Tentative DCGL |
|---|---|---|---|
| Arsenic | 1.3 | 39 ppm | 30 |
| Lead | 1.76 | 400 ppm | 225 |
| Mercury | None | 23 ppm | 23 |
| Molybdenum | 1.497 | 390 ppm | 260 |
| Vanadium | None | 550 ppm | 550 |

These correction factors were applied to field XRF values when determining final survey statistics for metals. These correction factors are shown graphically for arsenic and lead in Figures 3-10 and 3-11, respectively.

### 3.6.4 Phase 4: Iterative Lateral and Vertical Extent Determination and Excavation

Extent determination commenced only after necessary adjustments to field operations and field screening instruments were made, based upon data collected during the instrument bias/ correlation phase of the project.

#### 3.6.4.1 Soil Sampling Protocol

Each sample location was marked with a pin flag that was labeled with the sample number. The field gamma reading at each sample location was recorded on the sample log sheet. XRF readings and global positioning system (GPS) readings were taken at each sample location, and the results were recorded in the instrument data loggers.

Soil samples were collected in 8-oz plastic sample containers. Soil was collected in a stainless steel bowl using a shovel or plastic scoop. Large rocks and vegetation were removed. Duplicate and composite samples were well mixed in the bowl prior to filling the sample jars. The sample numbers were written on the container lids with permanent marker. Duplicate samples were given consecutive sample numbers and identified as such on the sample log sheet. Filled sample containers were brought to the boundary of the exclusion area, where their exterior surfaces were cleaned using wet wipes. Containers were then smeared for contamination, and the smears were counted in the onsite laboratory for alpha and beta. After containers were verified to be free of contamination on the exteriors, labels were applied to each container. Labels contained the following information:

- Date
- Time
- Sample number
- Name of sampler
- Required analysis
- Required preservative (if any)
- Sample type (grab or composite)

Samples for the onsite laboratory NaI instrument were transferred directly into the onsite laboratory. After counting, these samples were stored on shelves in the onsite conex. Samples for offsite laboratory metals and radiological analysis were placed in the sample refrigerator. Only the metals required refrigeration, but they were kept together for ease in sample management.

#### 3.6.4.2 Initial Radiological Sampling

After the initial Eberline survey was completed, a map was completed showing areas of elevated gamma activity. The GPS was used to locate the boundaries of these areas, which were marked on the ground with paint. The field gamma instrument was then used to locate the area(s) of highest activity within and near the boundaries of these marked areas. Soil samples were collected from the highest activity areas and also from areas of lower activity surrounding the high activity areas in an attempt to delineate the material requiring excavation to the stockpile. Laboratory NaI results exceeding the Site tentative DCGLs for Ra-226 were marked on the ground with paint, establishing areas for excavation. The material was excavated in approximately 1-foot lifts and placed in the appropriate stockpile.

#### 3.6.4.3 Continuing Radiological Sampling

Following initial soil sampling, onsite laboratory NaI analysis, and subsequent soil excavation, each area was resurveyed using the field gamma instrument. If any readings exceeded the Site field gamma action level (approximately 40,000 cpm), then soil samples were collected from the highest activity areas, and also from areas of lower activity surrounding the high activity areas, in an attempt to delineate the material requiring excavation to a stockpile, as before. If no readings exceeded the Site field gamma action level, then one or more samples were collected to confirm whether or not the area met the Site tentative DCGLs. Soil continued to be excavated in approximately 1-foot lifts based on the field laboratory NaI results, followed by subsequent rounds of sample collection conducted in the same iterative manner. This procedure was repeated until field laboratory NaI readings were below the Site tentative DCGLs for Ra-226 and until corresponding XRF readings were below the Site tentative DCGLs for all five metals.

#### 3.6.4.4 Final Radiological Sampling

The final confirmation samples collected in each area that demonstrated the Site tentative DCGL had been met were used as final survey samples. The number of final survey samples for each of the four survey units was verified to be enough to satisfy Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) (Abelquist 2001) criteria by using Visual Sampling Plan software. Results of the final survey sampling are presented in Section 4.

#### 3.6.4.5 Initial Metals Sampling

After the radiological sampling was completed, two general areas were identified from previous New Horizons' data that contained elevated metals readings but did not have elevated gamma readings. One area was along the western roadway and had primarily elevated arsenic readings. The other area was a large area in the center of the Site, which had primarily elevated arsenic and lead readings. These areas were located using the GPS, and the XRF was used to further refine the area of concern. These areas were sampled on an approximately 20 ft by 20 ft grid, using the same sampling protocol as described above.

#### 3.6.4.6 Continuing Metals Sampling

Based on XRF results from the initial metals sampling described in Section 3.6.4.5, soil exceeding tentative Site DCGLs for any of the five metals of concern was excavated to a stockpile in approximately 1-foot lifts. Each area was then resampled on an approximately 20 ft by 20 ft grid. This procedure was repeated until XRF and field laboratory NaI readings were below the Site tentative DCGLs for all five metals and Ra-226.

#### 3.6.4.7 Final Metals Sampling

A total of 62 confirmation samples from locations that were not excavated further were sent to the offsite laboratory for metals analysis (50 samples and 12 duplicates). The work plan called for 24 final metals samples, one (composite) sample from each quarter acre. Results of the final metals sampling are presented in Section 4.

#### 3.6.4.8 Stockpile Sampling

After soil had been excavated, two stockpiles of impacted material remained. Stockpile A contains soils with total activity in excess of 100 pCi/g, and Stockpile B contains soils above tentative Site action levels but below 100 pCi/g total activity. Composite samples were collected from Stockpile B at approximately 500 cubic yard intervals. The stockpile contains approximately 12,500 cubic yards, for a total of 25 samples plus one duplicate sample. Composites were collected from five random points on the stockpile corresponding with each 500 cubic yard interval, which was the working face or top of the pile at the time the sample was collected. Three composite samples were collected from Stockpile A. The approximate volume of Stockpile A is 175 cubic yards. All stockpile samples were analyzed in the onsite laboratory for Ra-226, and all were submitted to the offsite laboratory for metals and radionuclide analyses. XRF and GPS readings were not taken for stockpile samples. Results of the stockpile sampling are summarized in Section 4.

### 3.6.5 Phase 5: Confirmation Sampling and Final Status Survey

At the conclusion of characterization activities, confirmation sampling of the *in-situ* soils remaining at the Site was performed that served both confirmation of attainment of cleanup goals (i.e., nature and extent determination) and as the final status survey.

Following excavation of the contaminated soil to the stockpiles, a final gamma survey was completed over the entire site. The results of this survey are shown on Figure 3-12. This final survey showed a few remaining impacted spots, which were sampled to confirm that they were indeed above the tentative Site action levels and then excavated to Stockpile B.

The final survey for radionuclides was performed in accordance with MARSSIM. Based on data generated by the Site characterization, MARSSIM-defined Class 1 and Class 2 areas were identified. After removal of the Class 1 soils, the entire Site, except for the stockpiled soils, was classified as a Class 2 area. The six-acre site was divided into four survey units. (The minimum required was three based on the maximum size of a Class 2 survey unit of 10,000 square meters.) Visual Sampling Plan software was used to calculate the required number of sampling locations in each survey unit. Decisions regarding whether or not the Site had achieved the cleanup goals was made in accordance with *Methods for Evaluating the Attainment of Cleanup Standards, Volume 1: Soils and Solid Media* (EPA 1989).

The final survey for metals was performed using the same sample locations as the final radionuclide survey. Decisions regarding whether or not the Site had achieved the cleanup goals was made in accordance with *Methods for Evaluating the Attainment of Cleanup Standards, Volume 1: Soils and Solid Media* (EPA 1989). Results of the confirmation sampling for radionuclides and metals are summarized in Section 4.

Final survey decisions were made jointly by Stoller, the School, and CDPHE during weekly site meetings and walks. Upon completion of activities, CDPHE walked the site with a hand-held gamma survey meter (micro-R meter) and agreed the effort was appropriate and successful. They further confirmed this success after reviewing confirmatory data.

## 3.7 Flood Plain Investigation

The Site is bounded on the north by Clear Creek and consists of an upper and lower terrace. The lower terrace is the active flood plain of Clear Creek and the focus of the flood plain characterization effort. A settling pond formerly located on the west end of the flood plain was cleaned up and closed by the EPA in 1997 as part of an Emergency Removal Action under CERCLA.

In the vicinity of the Site, the 100-year flood elevation is 5,682 feet. The elevation of the lowest point of the Site is approximately 5,670 feet (former settling pond area next to Clear Creek on lower terrace is within the 100-year flood plain). Figure 3-13 shows the location of the flood plain portion of the Site.

Stoller conducted a Wetlands Delineation Study in July 2006 (Appendix B). The study was conducted to determine if the area qualifies for wetland status and would therefore need additional controls, possibly including a U.S. Army Corps of Engineers' Section 404 permit, to conduct soil segregation. The results indicated that based on soil, vegetation, and hydrology, some of the flood plain is categorized as a wetland. However, based on Section 404 Permit guidance, no permit was required, because the following guidelines were followed:

- No fill material was placed within the wetlands.
- Soil to be excavated was scooped out rather than pushed or bulldozed.
- The temporary access road was not constructed in the wetlands.

Data collected during the original RI/FS in 2004 indicated elevated concentrations of Ra-226 on the flood plain east of the former settling pond. All other site COCs were below the regulatory limits.

Stoller collected additional samples in September 2006 at 15 locations in the flood plain. At 10 of these locations, surface samples were collected, and at five locations, samples were collected at the surface and at 6-inch intervals until rock, roots, or water was encountered. These sample locations are shown in Figure 3-13, and the sample results along with previously existing data are shown in Table 3-12. The previous data include sample numbers CSM155 through CSM161 shown at the bottom of the table. Samples were analyzed by a shielded NaI detector, identical to that used for Site characterization activities in June through August 2006.

**Table 3-12**
**Flood Plain Characterization Data**

| Sample Location | Depth (Inches) | Sample Number | Ra-226 (pCi/g) |
|---|---|---|---|
| 1 | 0 | 1207 | 3.81 |
| 2 | 0 | 1208 | 4.00 |
| 3 | 0 | 1211 | 5.70 |
| 4 | 0 | 1212 | 2.29 |
| 4 | 6 | 1213 | 2.50 |
| 4 | 12 | 1214 | 2.60 |
| 4 | 18 | 1229 | 4.65 |
| 4 | 24 | 1230 | 3.69 |
| 4 | 36 | 1231 | 2.18 |
| 5 | 0 | 1216 | 3.05 |
| 5 | 6 | 1217 | 3.04 |
| 5 | 12 | 1218 | 2.99 |
| 5 | 18 | 1219 | 3.23 |
| 6 | 0 | 1215 | 2.93 |
| 7 | 0 | 1209 | 4.19 |
| 8 | 0 | 1225 | 3.68 |
| 9 | 0 | 1202 | 8.23 |
| 10 | 0 | 1203 | 5.15 |
| 10 | 6 | 1204 | 6.27 |
| 10 | 12 | 1205 | 6.60 |
| 10 | 18 | 1206 | 7.18 |
| 10 | 24 | 1226 | 3.14 |
| 10 | 36 | 1227 | 3.90 |

**Table 3-12**
**Flood Plain Characterization Data**

| Sample Location | Depth (Inches) | Sample Number | Ra-226 (pCi/g) |
|---|---|---|---|
| 10 | 48 | 1228 | 2.61 |
| 11 | 0 | 1201 | 4.81 |
| 12 | 0 | 1197 | 9.71 |
| 12 | 6 | 1198 | 8.60 |
| 12 | 12 | 1199 | 6.32 |
| 12 | 18 | 1200 | 5.07 |
| 13 | 0 | 1210 | 4.72 |
| 14 | 0 | 1224 | 2.36 |
| 15 | 0 | 1220 | 1.11 |
| 15 | 6 | 1221 | 3.73 |
| 15 | 12 | 1222 | 2.67 |
| 15 | 18 | 1223 | 3.07 |
| CSM155 | | | 4.90 |
| CSM156 | | | 20.00 |
| CSM157 | | | 4.70 |
| CSM158 | | | 9.30 |
| CSM159 | | | 28.00 |
| CSM160 | | | 5.00 |
| CSM161 | | | 8.60 |

Based on this initial characterization data, Stoller prepared the *CSMRI Site Flood Plain Characterization Work Plan* dated November 21, 2006. The characterization activities on the flood plain included vegetation removal, temporary access road construction, and segregation of contaminated soil to existing stockpiles. Inclement weather resulted in delays and two mobilizations to the Site. Results of the flood plain investigation are included in Section 4.3.

## 3.8 Clay Pits Investigation

As discussed in Section 1.6, Clay Pits History, a subsurface investigation in 1998 by New Horizons and URS Consultants did not encounter CSMRI pond sediment material. In 2007, Stoller implemented another subsurface investigation using 1977 survey information to relocate the reported burial site of the sediment material. This investigation, which was conducted at the request of CDPHE, was conducted to support the School in assessing risk to public health and the environment, if any, consistent with the NCP 40 CFR 300 420.

In accordance with the CDPHE-approved work plan, six boreholes were continuously cored to a depth of at least 40 feet bgs. Exposed cores were scanned using a NaI gamma scintillation meter. Samples for laboratory analysis were selected based on field activity, material appearance, or sample depth, with the goal being to sample above, within, and below the settling pond sediments.

A Prosonic sonic drill rig was contracted to collect the subsurface cores. The first five boreholes (CP1 through CP5) were drilled within the confines of the rectangular model based on the 1977 survey where the pond sediment was reportedly buried. The sixth borehole (CP6) was drilled to the north, outside of the rectangular box to extend the area of investigation after the coring of the first five boreholes did not indicate any type of dredged sediment material, ore, or field screening activity above background conditions (12,000 to 18,500 cpm with a Ludlum NaI detector for gamma activity).

Boreholes were drilled to bedrock or native material and depths ranged from 40 feet bgs to 56 feet bgs. Borehole CP4 was drilled at an angle of 30 degrees to the south-southwest to extend the limits of the investigation underneath the berm of the storm water retention pond. This borehole was extended to a length of 65 feet but the net depth at which it was terminated is 56 feet bgs.

Core recovery varied widely given the heterogeneous nature of the fill and debris encountered below the ground surface. The nature of the fill and debris ranged from bricks, lumber, plywood, clay, concrete, #10 rebar (1¼-inch), scrap metal, plastic sheeting, and coal clinker. Core runs ranged from 5 feet to 10 feet in length, depending on the rate of progress through the fill and debris and the material that may have been jammed in the core barrel. Cores were encased in plastic sleeves and placed on the ground for field scanning of gamma activity, documentation in a photo log, and field observation descriptions. Slight amounts of water, ranging from moist to wet, were encountered immediately above bedrock in boreholes CP2, CP3, and CP4. Figure 3-14 presents a series of figures depicting the final drill pattern in plan view (A), profile view looking east (B), and isometric view looking to the southeast (C). Analytical results from the clay pits boreholes are presented in Section 4.4.

## 3.9 Groundwater Investigation

Groundwater occurs under unconfined conditions in the alluvium/colluvium of the Site. Depth to the water table ranges from about 3 to 30 feet bgs, depending on distance to the creek and depth to bedrock. Based on surface and bedrock topography, groundwater generally flows to the northeast toward Clear Creek. The alluvial/colluvial deposits are mainly recharged by infiltration of precipitation and to a limited extent by Clear Creek during periods of high flow. The alluvial/colluvial system naturally discharges to Clear Creek.

Five groundwater monitoring wells were initially installed at the Site in the 1990s. During the 2003 RI, two additional monitoring wells were installed using two of the borings drilled during the subsurface investigation. The purpose of the installation was to provide additional groundwater (upgradient and downgradient) data for the Site. Wells have been sampled on a monthly basis, with quarterly monitoring reports being provided and submitted to CDPHE. The upgradient well (CSMRI-06) location was positioned along the north-south boundary with the baseball field. The downgradient well (CSMRI-07) was positioned north of the former Building 101N foundation and above the former settling pond. CSMRI-06 is 43.5 feet deep and CSMRI-07 is 20 feet deep.

Groundwater in the shallow alluvium/colluvium has been shown to contain elevated levels of uranium, a contaminant of concern that occurs naturally in the bedrock formations and in the surficial deposits that comprise the Site. The elevated groundwater concentrations in question have been attributed to migration of radionuclides from source materials that were formerly located on the Site and are now residing in lined stockpiles or have been removed off site.

In February 2007, Stoller installed seven additional groundwater wells to track the effectiveness of uncontained source removal in addressing elevated uranium concentrations in groundwater beneath the Site, augment the characterization data, and provide a better understanding of the geohydrologic conditions in the alluvial/colluvial aquifer at the Site. These wells were installed in accordance with the approved work plan, *Groundwater Monitoring Well Installation Work Plan, CSMRI Site* (Stoller 2006d). Sample reports for new wells are not available at the time of this writing.

## 3.10 Air Monitoring

Four air monitoring stations were used during the characterization activities conducted from June-August 2006. The monitoring stations were located surrounding the work area to ensure adequate monitoring in the event of directional wind changes. Airborne radioactivity samples were obtained on 2-inch diameter glass fiber filters at a sampling rate of 60 to 80 liters per minute. Samplers were run continuously during the characterization field work. Operational hours of the samplers were recorded for use in calculating air volume. Filters were changed and analyzed on a weekly basis when active soil sampling/excavation was being conducted. During inactive periods, filters were changed monthly.

Samples were counted in the field laboratory using a Ludlum Model 2929 alpha/beta scaler with a Model 43-10-1 detector in accordance with procedure SOP-RAD-031, *Counting Systems Operation*. Measured count rates (cpm) were converted to disintegrations per minute (dpm) using the efficiency of the detector. The measured dpm values were converted to microcuries and divided by the total volume of air sampled in milliliters for comparison to the effluent concentration standard. Table 3-13 shows the Colorado effluent concentration limits for the radionuclides of concern on the Site, along with a calculated effluent concentration limit for the mixture. The chemical form of the radionuclides on the Site is unknown; therefore, the limits for Class W compounds, which are the most restrictive, are shown in the table.

**Table 3-13**
**Effluent Concentration Standards[1]**

| Isotope (Class W) | Concentration (microcuries per milliliter) |
|---|---|
| Ra-226 | 9 E-13 |
| Ra-228 | 2 E-12 |
| Th-228 | 3 E-14 |
| Th-230 | 2 E-14 |
| Th-232 | 4 E-15 |
| U-234 | 3 E-10 |
| U-235 | 3 E-10 |
| U-238 | 1 E-12 |
| Limit for mixture | 4.8 E-14 |

[1] 6 CCR 1007-1 Part 4, Appendix 4B, Standards for Protection Against Radiation

The concentration limit for the mixture was derived from the following equation:

$$\text{Concentration limit for mixture} = \frac{1}{\sum_i \frac{f(i)}{C(i)}}$$

Where:

*f(i)* is the fraction of activity of nuclide *i* in the mixture (using mean plus 95% UCL data from bagged soil data), and
*C(i)* is the effluent concentration limit for nuclide *i*.

Samples were held for a minimum of 72 hours prior to counting to allow the radon and progeny to decay. If the gross alpha activity indicated that an effluent standard could have been exceeded, the sample would be submitted for laboratory analysis of specific isotopes. All air sample results were an order of magnitude beneath the limit for the mixture; therefore, no filters were submitted to the laboratory. All filters were saved in the event future laboratory sampling was deemed necessary. A summary of final air sample results are presented in Table 3-14, and detailed results are presented in Appendix C.

**Table 3-14**
**Air Monitoring Summary CSMRI Creekside Site Characterization**
**June – August 2006**
**(results in uCi/m$^3$)**

| | June 16 - 23 | June 23 - 30 | June 30 – July 10 | July 10 - 17 | July 17 - 24 | July 24 - 31 | July 31 – Aug 7 |
|---|---|---|---|---|---|---|---|
| AS North | 2.65E-15 | 3.25E-15 | 3.25E-15 | 4.21E-15 | 4.67E-15 | 5.46E-15 | 2.15E-15 |
| AS East | 1.41E-15 | 9.30E-16 | 3.79E-15 | 7.18E-16 | 4.88E-15 | 4.98E-15 | 2.78E-15 |
| AS South | 2.17E-15 | 2.75E-15 | 2.58E-15 | 3.83E-15 | 3.18E-15 | 2.72E-15 | 3.91E-16 |
| AS West | 7.97E-16 | 2.03E-15 | 1.67E-15 | 3.02E-15 | 2.03E-15 | 2.90E-15 | 2.69E-15 |


Figure 3-1

RI/FS Borings, Test Pits, and Surface Sample Locations From 2004 RI

Explanation

- Surface Sample
- Boring
- Test Pit
- CSMRI Creekside Site
- Fences
- Topography (1 ft Intervals)
- Topography (5 ft Intervals)
- Roads

Scale: 1" = 75'

Feet

0 50 100 200

CSMRI
2007 Revised
Remedial Investigation /
Feasibility Study

Stoller

J:\projects\CSMRI2\rifs_nhlocs.mxd

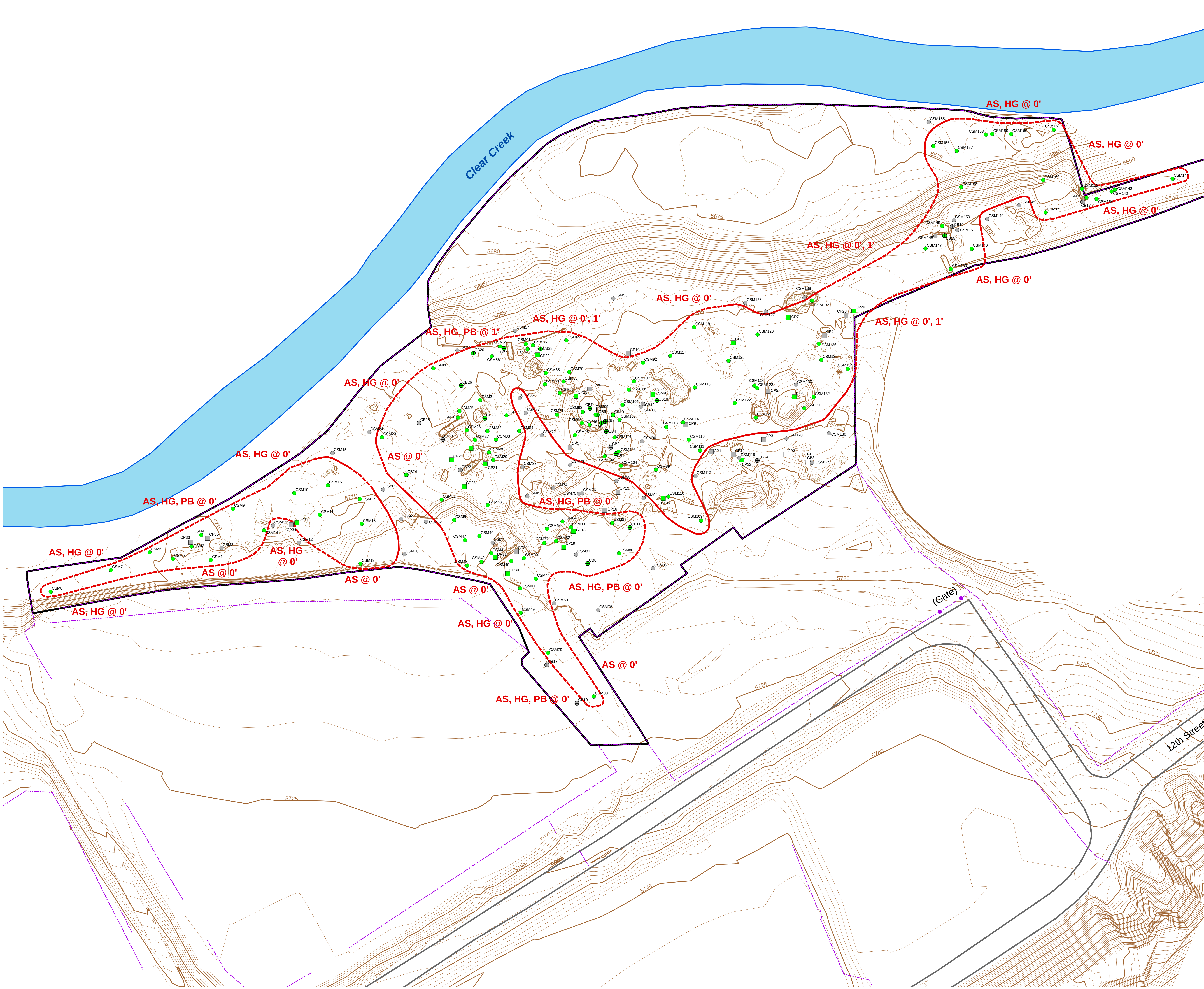



Figure 3-2

Extent of Metals (As, Hg, Pb, Mo, V)
Above the Tentative Cleanup Goals
Based on 2004 RI Data

Explanation

Surface Samples
- Not Sampled
- Sampled - All Results Below Tentative Cleanup Goal
- Sampled - Some Results Exceed Tentative Cleanup Goal

Borings
- Not Sampled
- Sampled - All Results Below Tentative Cleanup Goal
- Sampled - Some Results Exceed Tentative Cleanup Goal

Test Pits
- Not Sampled
- Sampled - All Results Below Tentative Cleanup Goal
- Sampled - Some Results Exceed Tentative Cleanup Goal

- CSMRI Creekside Site
- Fences
- Topography (1 ft Intervals)
- Topography (5 ft Intervals)
- Roads

N W E S

Scale: 1" = 75'

Feet

0 50 100 200

CSMRI
2007 Revised
Remedial Investigation /
Feasibility Study

Stoller

J:\projects\CSMRI\rifs_nhlocs.mxd

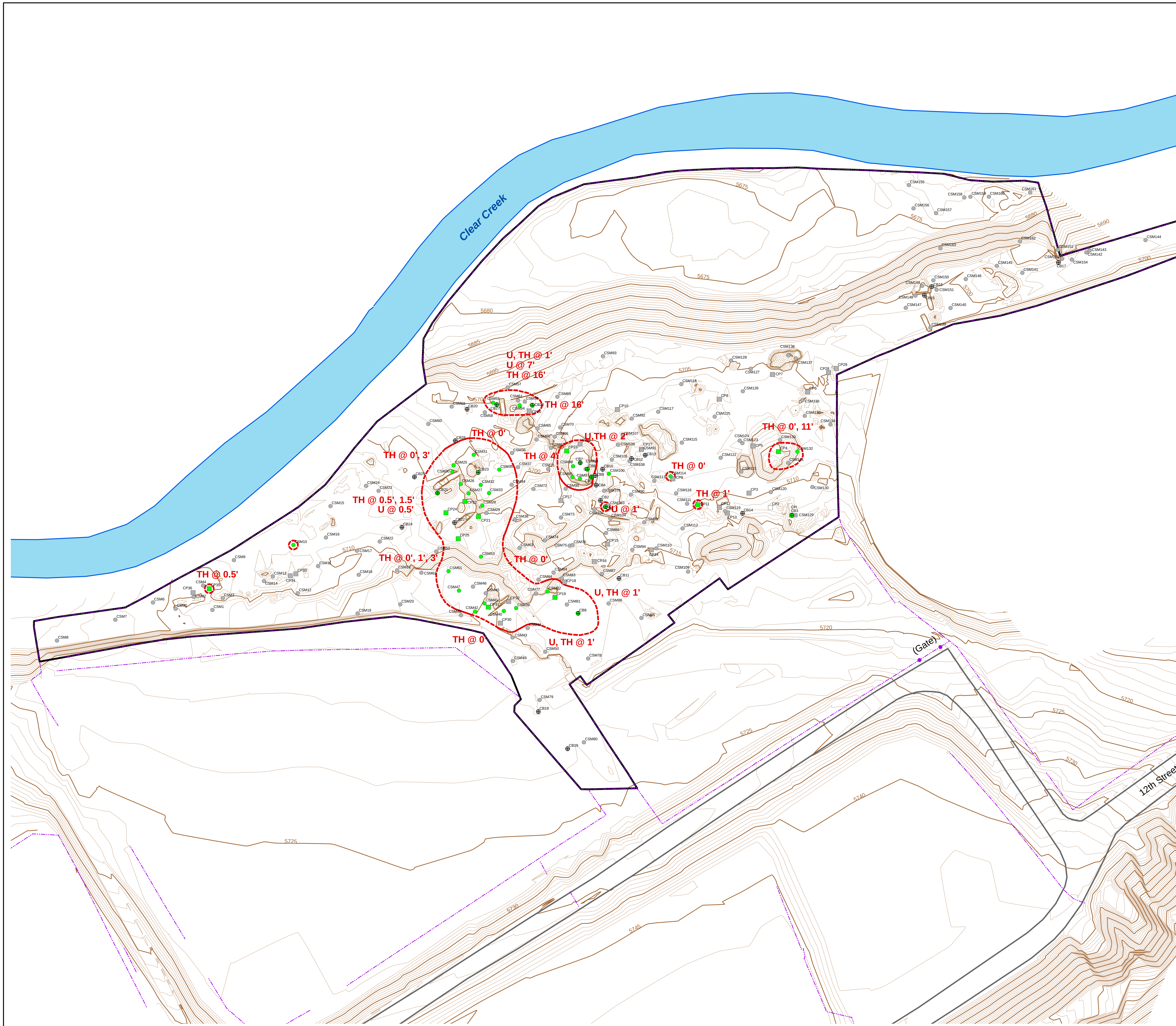



Figure 3-3

Extent of Alpha-emitting Radionuclides (Th, U)
Above the Tentative Cleanup Goals
Based on 2004 RI Data

Explanation

Surface Samples
- Not Sampled
- Sampled - All Results Below Tentative Cleanup Goal
- Sampled - Some Results Exceed Tentative Cleanup Goal

Borings
- Not Sampled
- Sampled - All Results Below Tentative Cleanup Goal
- Sampled - Some Results Exceed Tentative Cleanup Goal

Test Pits
- Not Sampled
- Sampled - All Results Below Tentative Cleanup Goal
- Sampled - Some Results Exceed Tentative Cleanup Goal

- CSMRI Creekside Site
- Fences
- Topography (1 ft Intervals)
- Topography (5 ft Intervals)
- Roads

N
W E
S

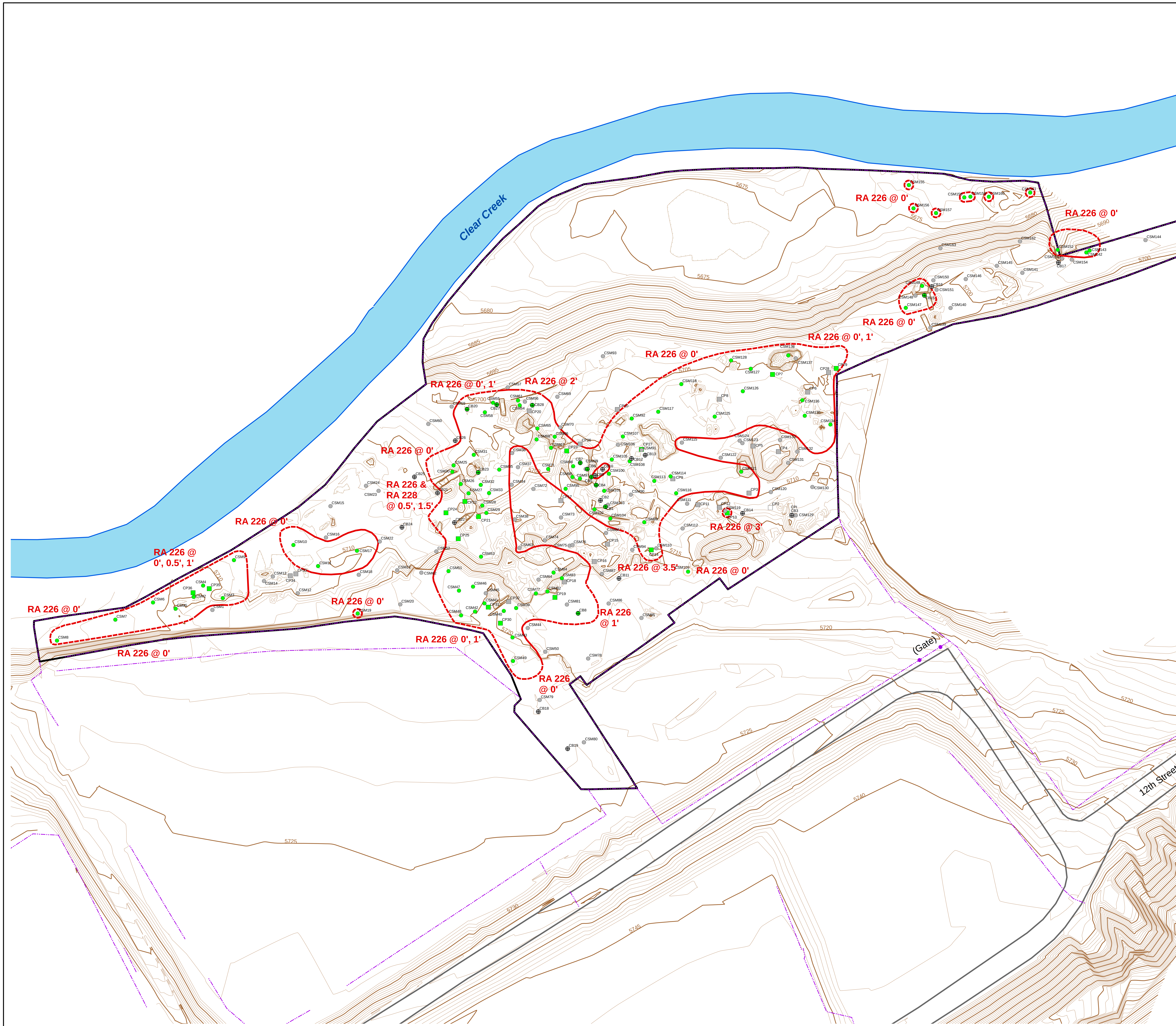
Scale: 1" = 75'

Feet
0 50 100 200

CSMRI
2007 Revised
Remedial Investigation /
Feasibility Study

Stoller

J:\projects\CSMRI\nfs_nhalpha.mxd




# Figure 3-4

Extent of Gamma-emitting Radionuclides (Ra)
Above the Tentative Cleanup Goals
Based on 2004 RI Data

## Explanation

**Surface Samples**
- Not Sampled
- Sampled - All Results Below Tentative Cleanup Goal
- Sampled - Some Results Exceed Tentative Cleanup Goal

**Borings**
- Not Sampled
- Sampled - All Results Below Tentative Cleanup Goal
- Sampled - Some Results Exceed Tentative Cleanup Goal

**Test Pits**
- Not Sampled
- Sampled - All Results Below Tentative Cleanup Goal
- Sampled - Some Results Exceed Tentative Cleanup Goal

- CSMRI Creekside Site
- Fences
- Topography (1 ft Intervals)
- Topography (5 ft Intervals)
- Roads

N W E S

Scale: 1" = 75'

Feet
0 50 100 200

CSMRI
2007 Revised
Remedial Investigation /
Feasibility Study

Stoller

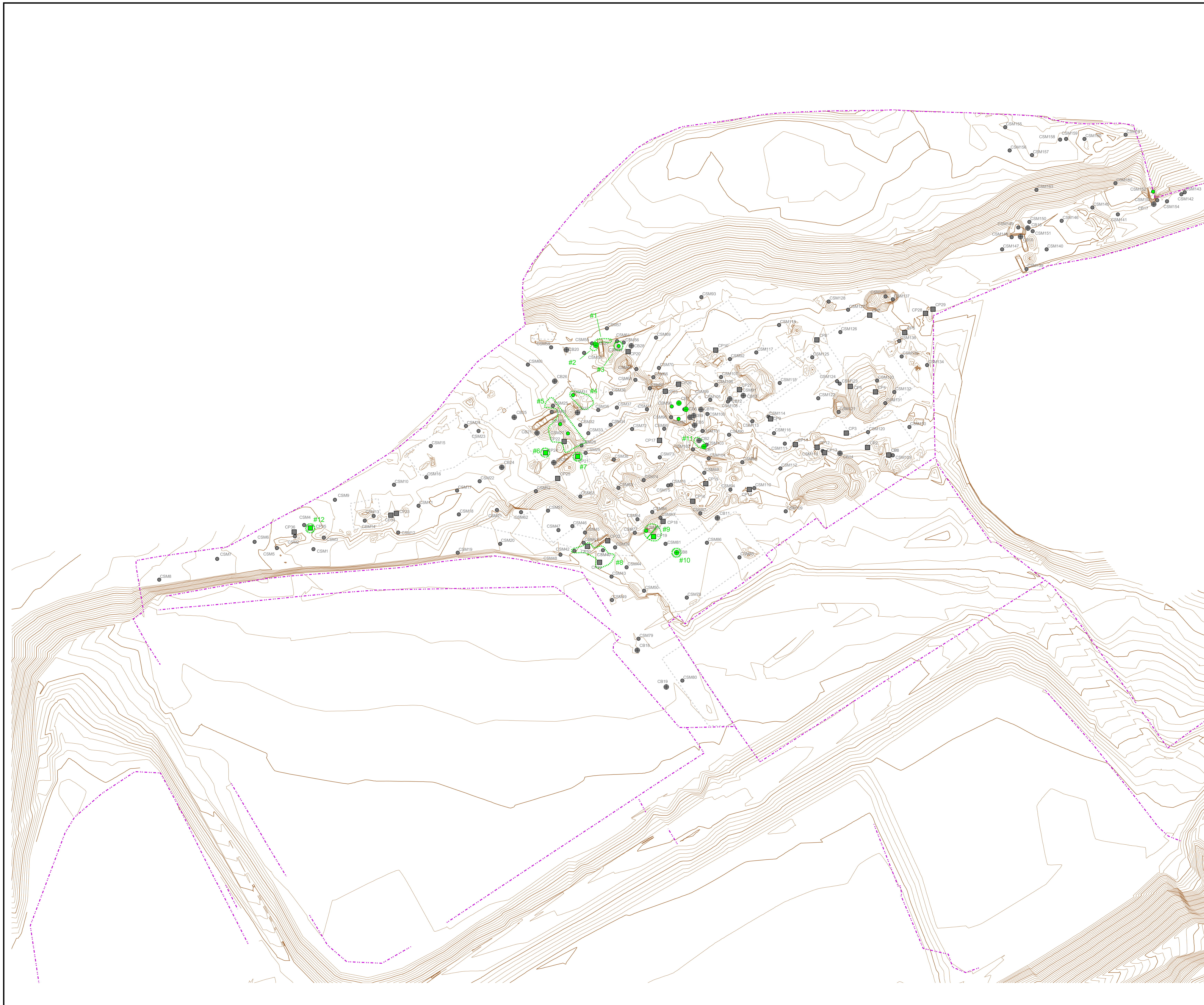


Figure 3-5

Areas Containing Material Above 100 PicoCuries per Gram Total Activity Based on 2004 RI Data

## Explanation

Surface Samples
- Sampled - All Results Below DCGL
- Sampled - Some Results Exceed DCGL

Borings
- Sampled - All Results Below DCGL
- Sampled - Some Results Exceed DCGL

Test Pits
- Sampled - All Results Below DCGL
- Sampled - Some Results Exceed DCGL

Hot Spot
Fences
Old Building Footprints
Topography (1 Foot Contour Interval)

Note: The hot spot numbers correspond to details on table 5-1

N

Scale: 1" = 75'

0 100 Feet

CSMRI
2007 Revised
Remedial Investigation /
Feasibility Study

Stoller


Figure 3-6

Combined Extent of all COCs and Extent of the Initial Soil Excavation Based on 2004 RI Data

## Explanation

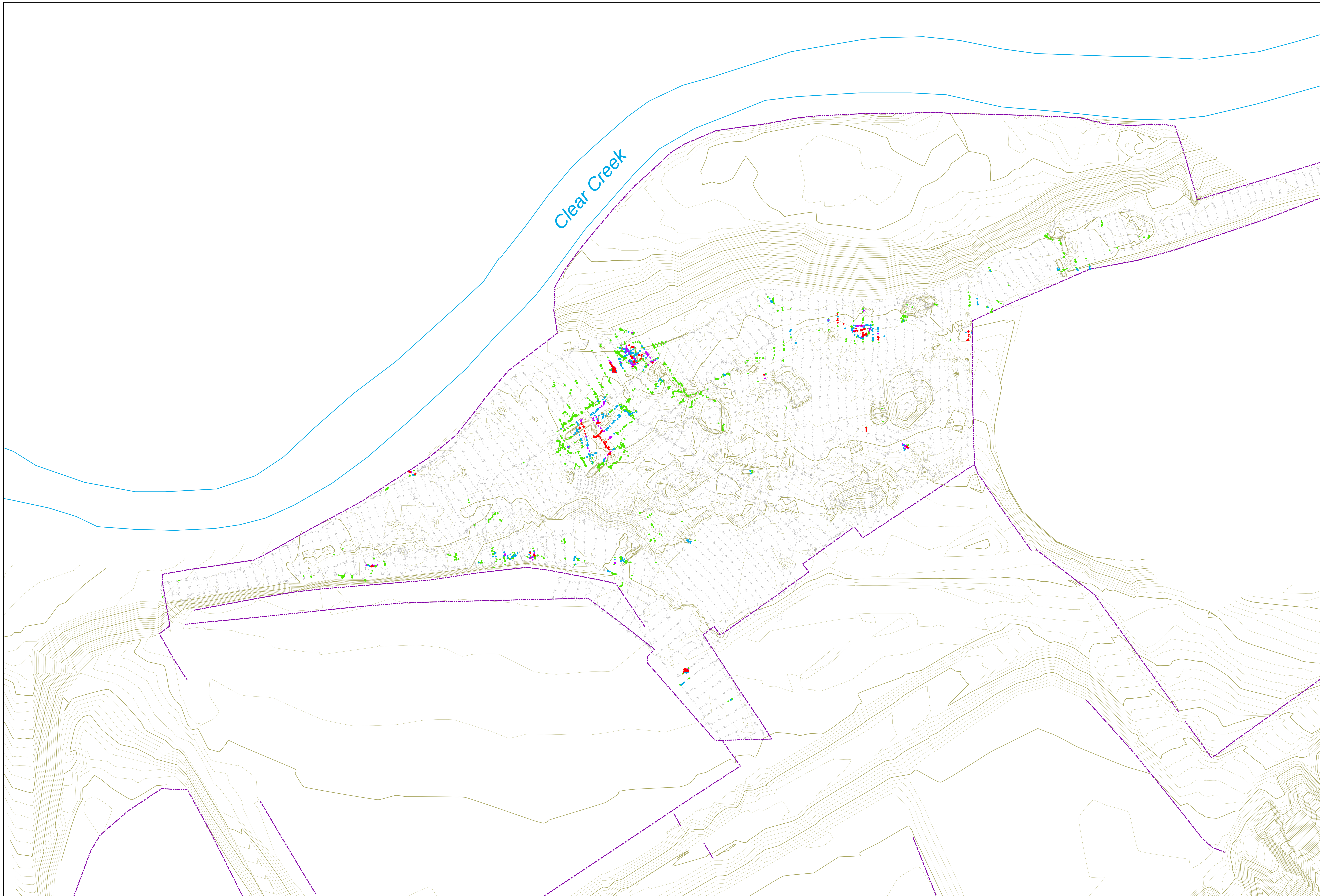
- Surface Samples
- Borings
- Test Pits
- Gamma Extent
- Metal Extent
- Alpha Extent
- Combined Extent - 1' Depth
- Combined Extent - 3' Depth
- Fences
- Old Building Footprints
- Topography (1 Foot Contour Interval)

Scale 1" = 75'

0 50 100 200 Feet

CSMRI
2007 Revised
Remedial Investigation /
Feasibility Study

Stoller




Explanation

- Clear Creek
- Fences
- Contours: 1 Foot Interval

Eberline Gamma Counts Per Minute

- >=60,000
- 50,000 - 59,999
- 40,000 - 49,999
- 30,000 - 39,999
- < 30,000

1 inch equals 50 feet

0 25 50 100 Feet

Figure 3-7

Results of Initial Gamma Survey

CSMRI
2007 Revised
Remedial Investigation /
Feasibility Study

Stoller

J:\projects\CSMRI2\GPERS_round01.mxd

**Figure 3-8**
**Initial Correlation between Offsite Laboratory Ra-226 and Field Laboratory NaI**

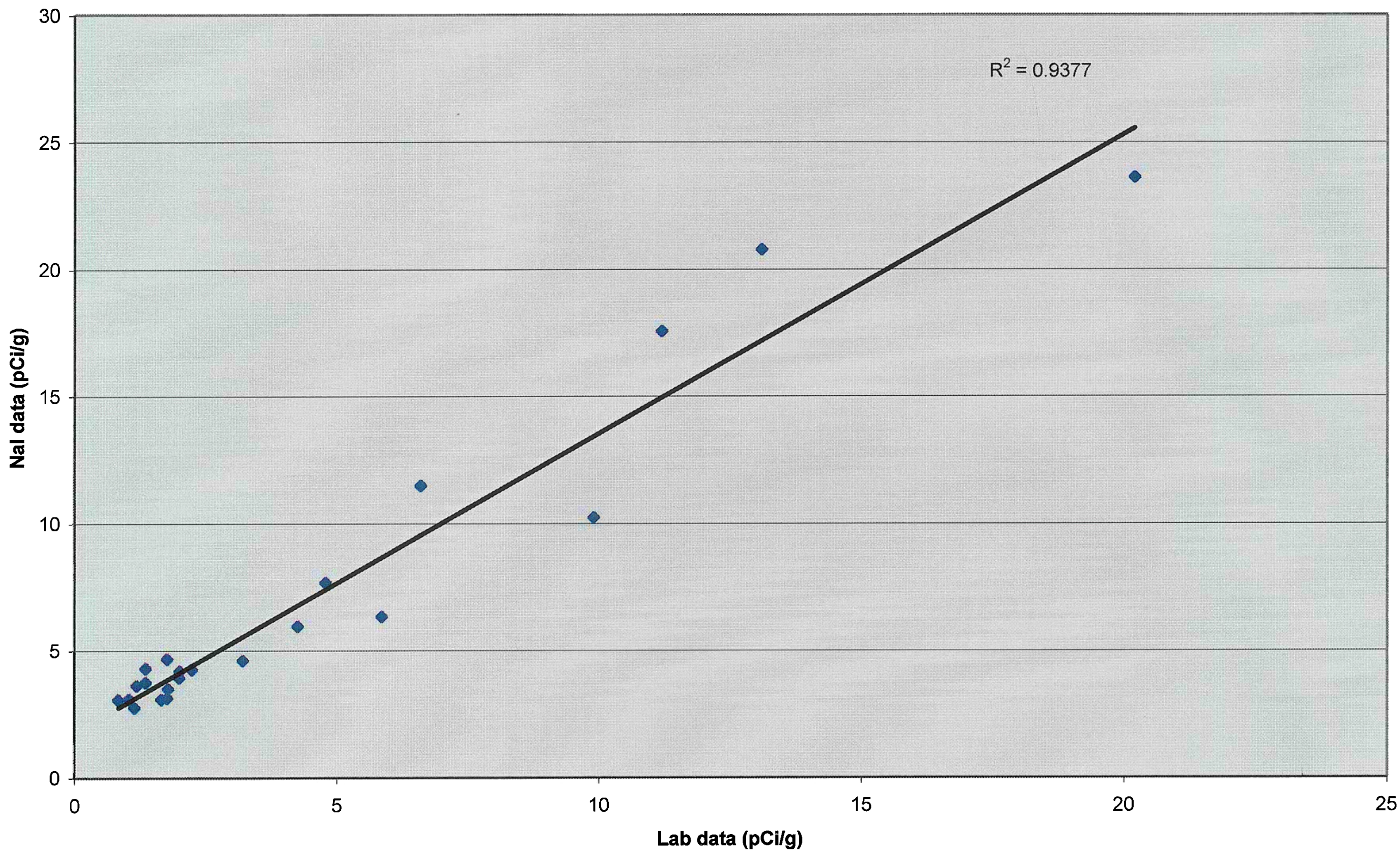
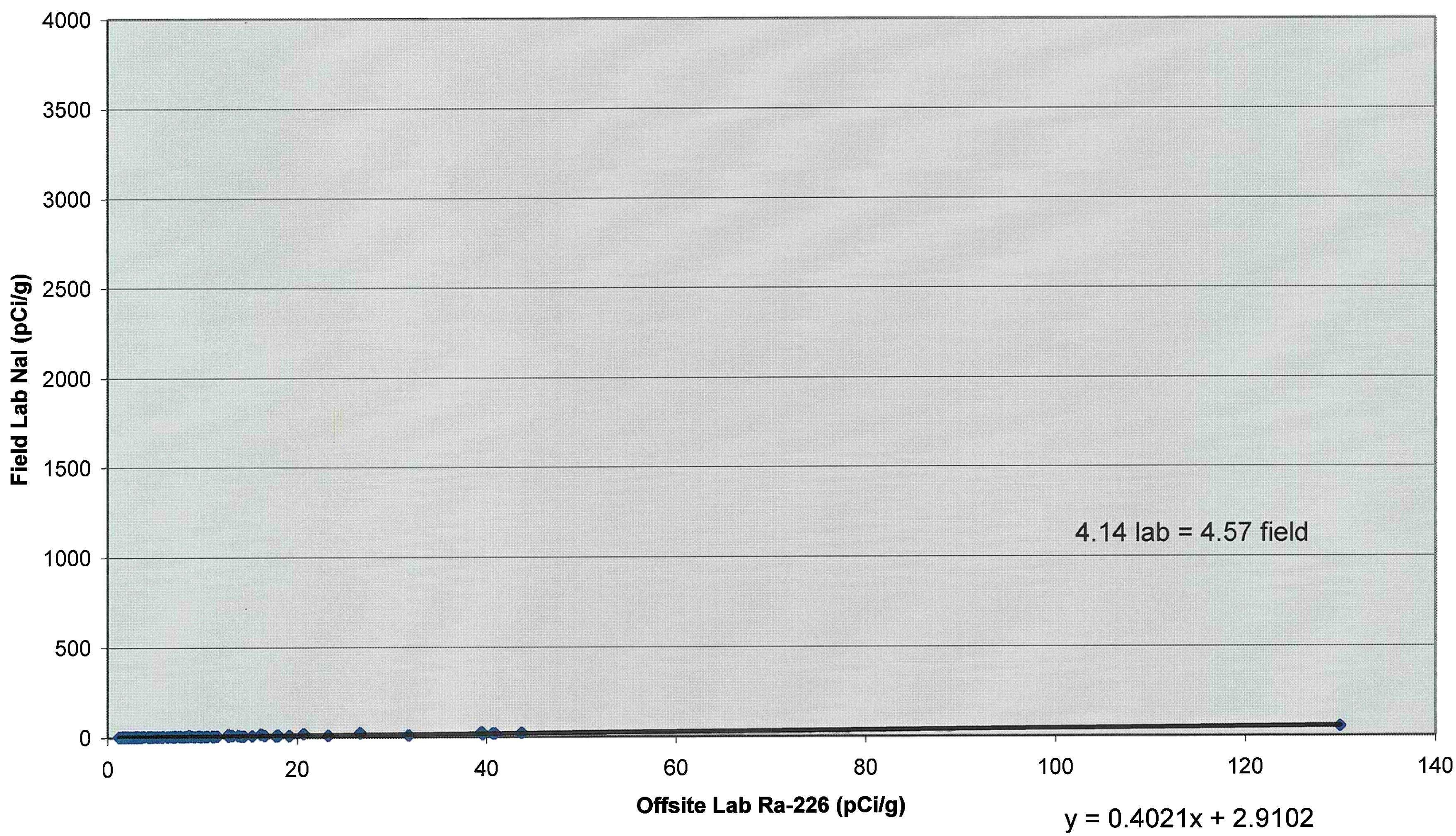


**Figure 3-9**
**Final Rad Correlation**
**(for all samples)**



## Figure 3-10
## Revised Final Arsenic Correlation

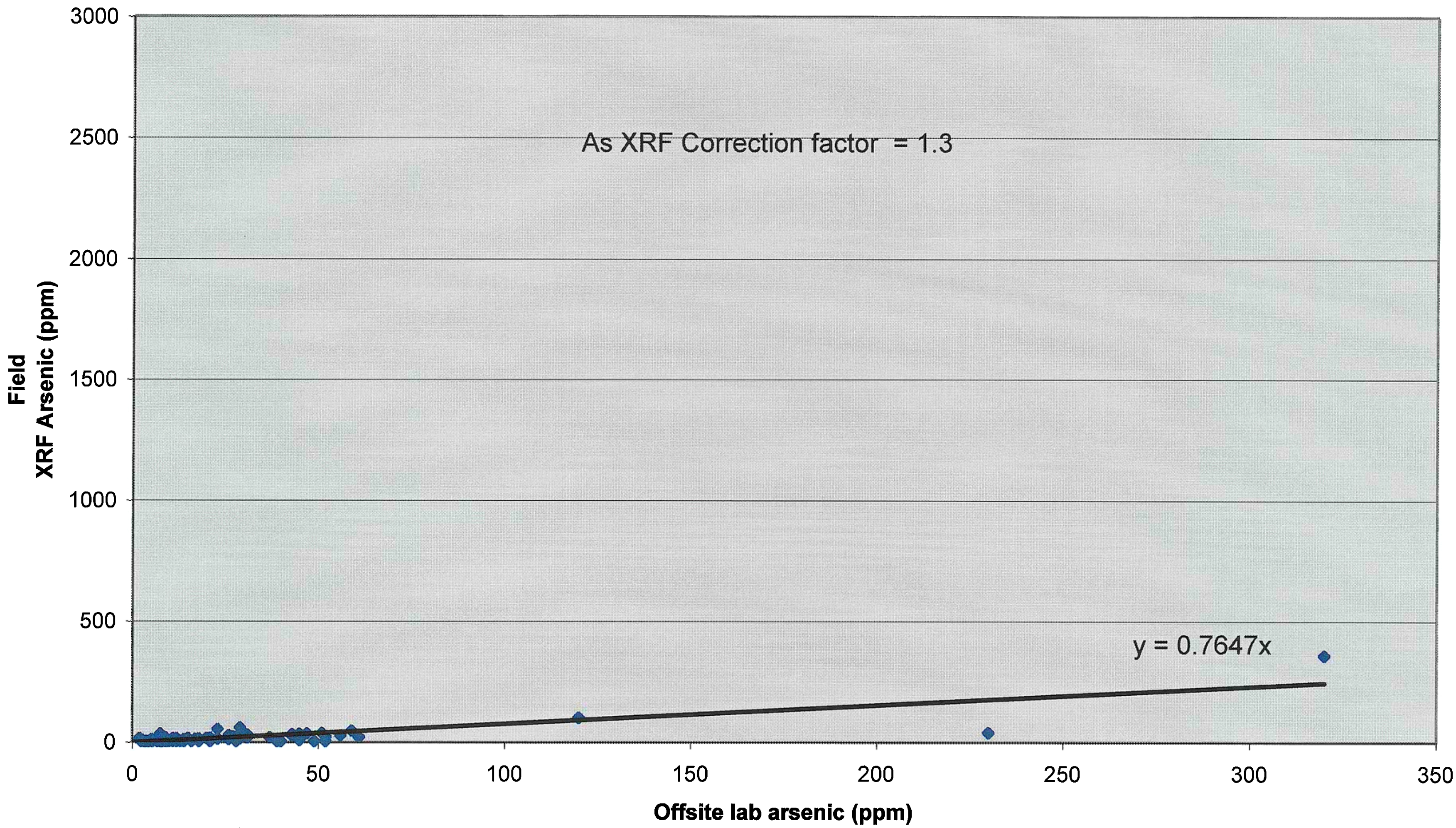
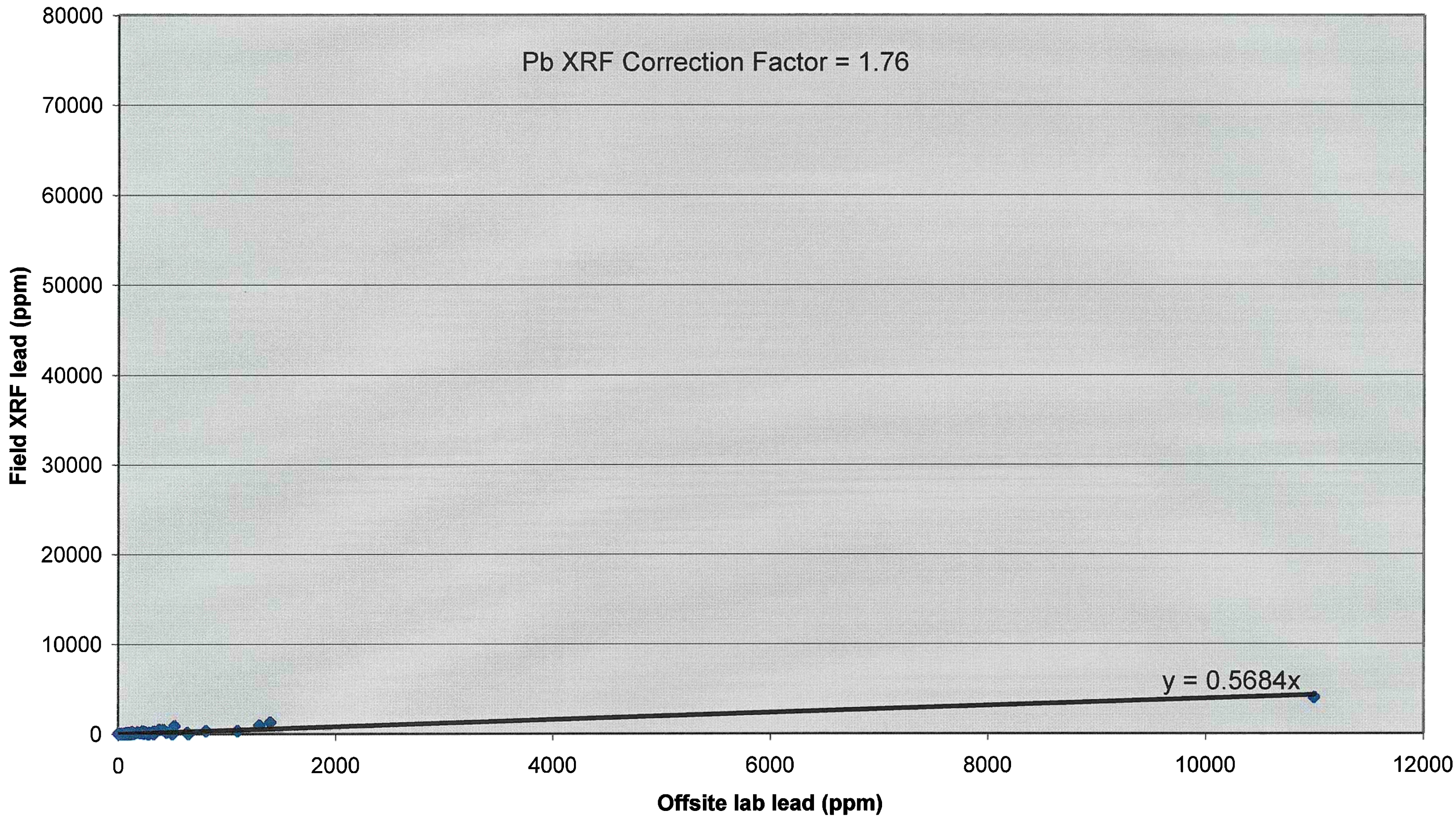


**Figure 3-11**
**Revised Final Lead Correlation**
**for XRF less than 1000 ppm**



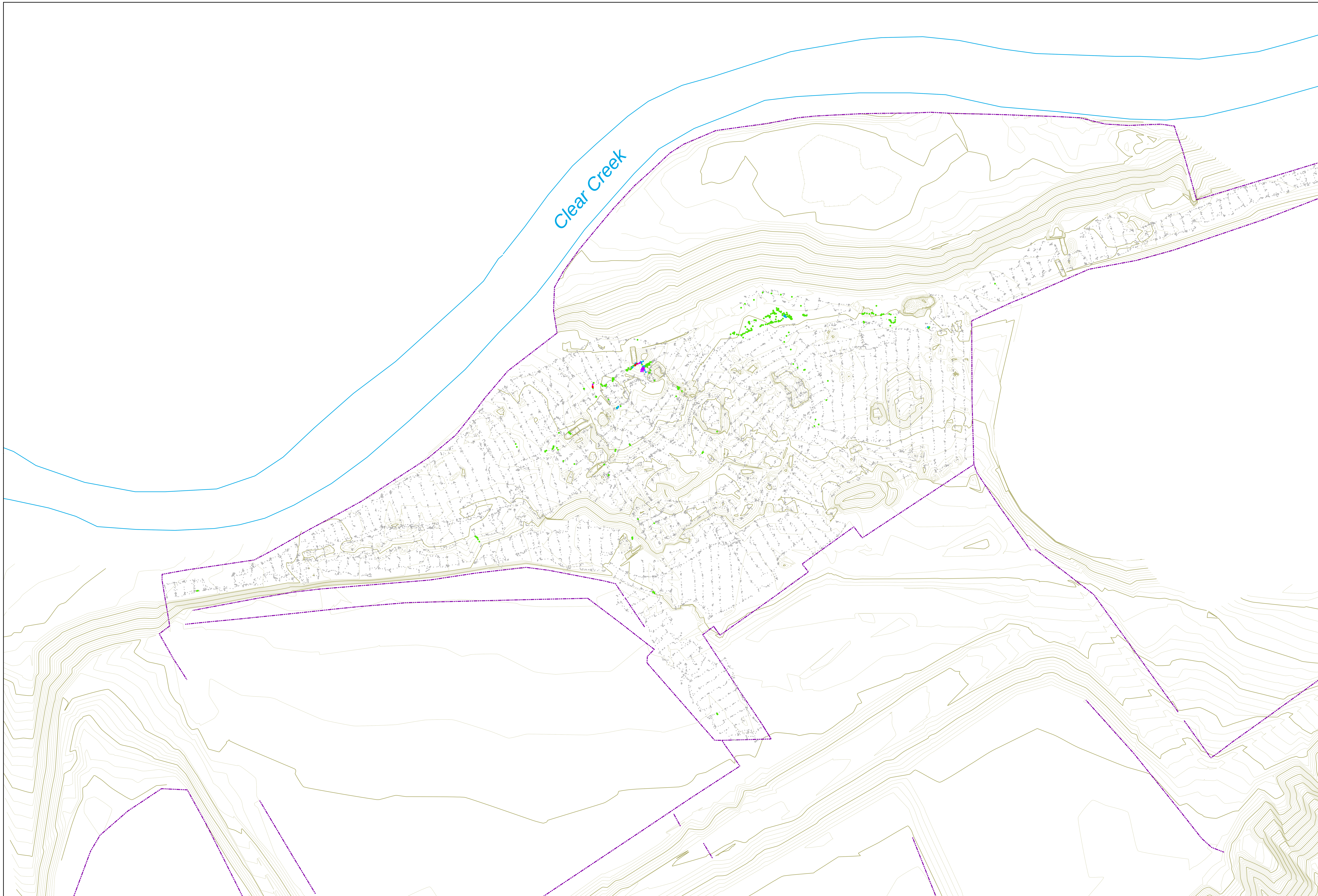



Figure 3-12

Results of Final Gamma Surface Soil Survey

CSMRI
2007 Revised
Remedial Investigation /
Feasibility Study

Stoller

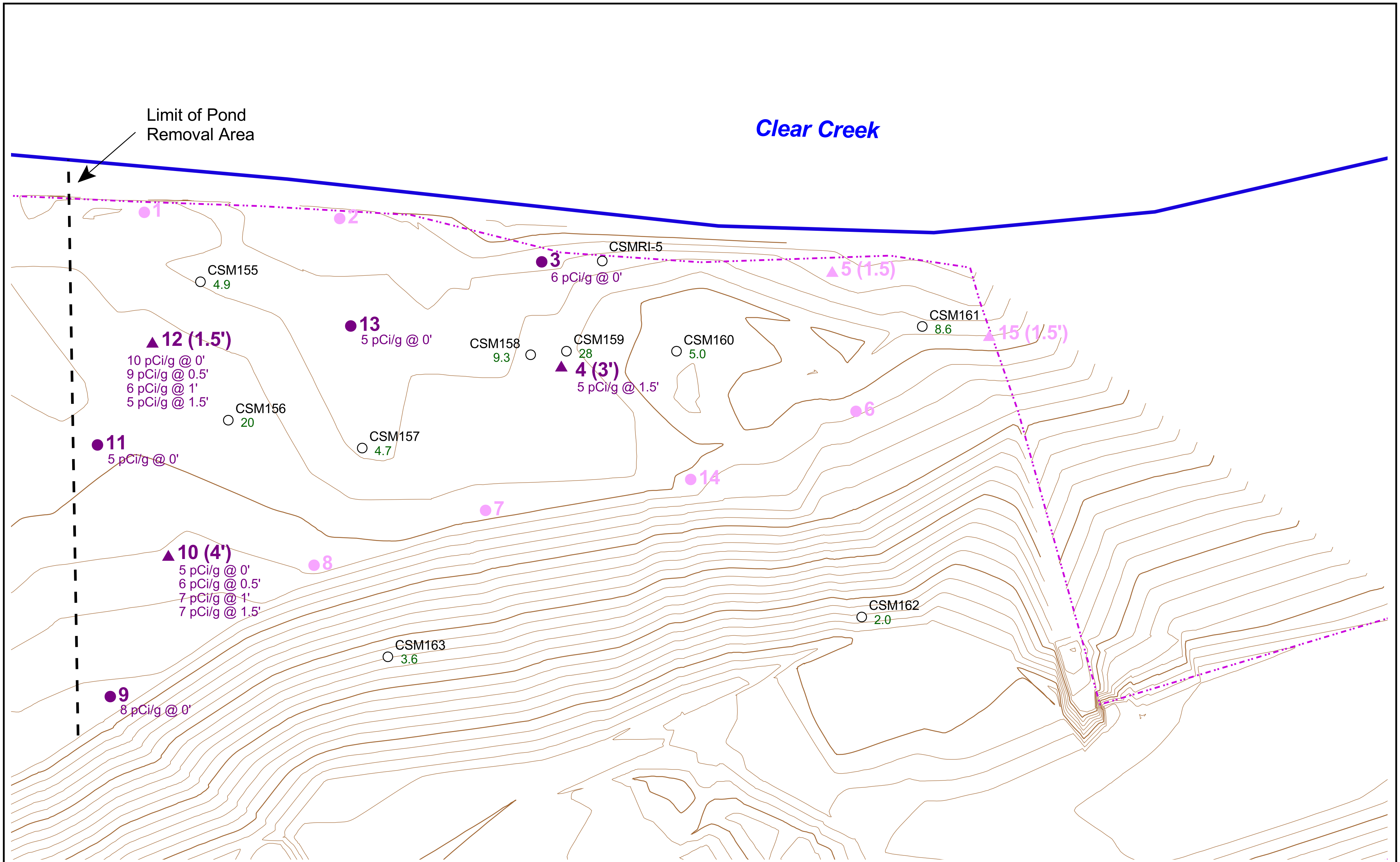



Figure 3-13

Floodplain Sample Locations

## Explanation

- ▲ Surface and Subsurface Sample Location
- ● Surface Sample Location
- ▲ Surface and Subsurface Sample Location Ra-226 >= 5 pCi/g
- ● Surface Sample Location Ra-226 >= 5 pCi/g
- ○ New Horizons Sample Location with Ra226 Concentration
- Fences
- Topography (1 Foot Contour Interval)
- Riverbank

Scale: 1" = 25'

0 25 50 Feet

CSMRI
2007 Revised
Remedial Investigation /
Feasibility Study

Stoller

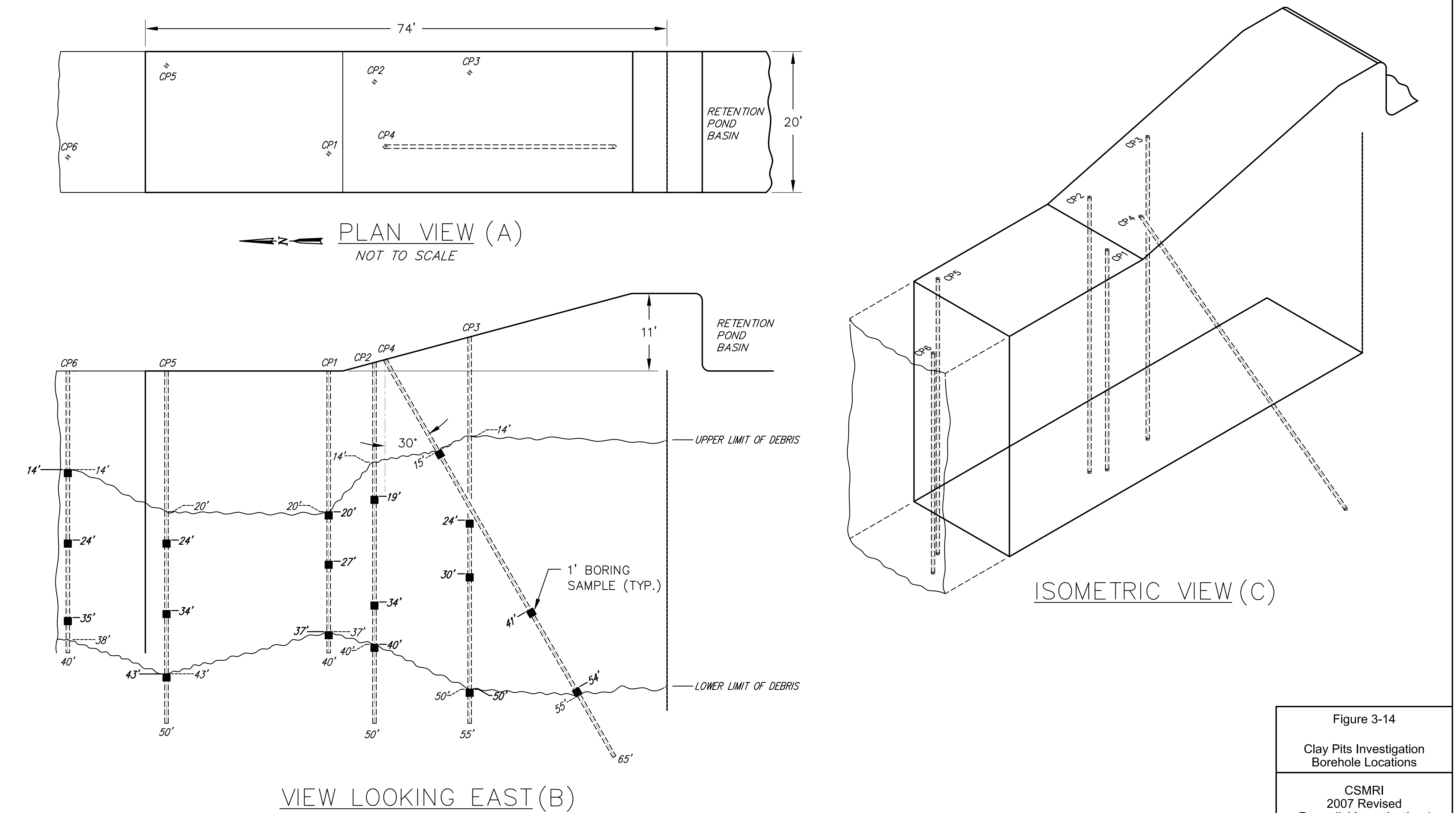



Figure 3-14

Clay Pits Investigation
Borehole Locations

CSMRI
2007 Revised
Remedial Investigation /
Feasibility Study

Stoller