SAMPLING AND ANALYSIS PLAN

CSMRI SITE REMEDIATION

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CSMRI Site Remediation

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1.0 INTRODUCTION AND SCOPE

This *Sampling and Analysis Plan* (SAP) addresses activities to be performed by or under the direction of New Horizons Environmental Consultants, Inc. (New Horizons) to obtain field measurements and/or samples of environmental media from the former CSMRI facility located in Golden, Colorado (Site) during Site remediation. The Site is defined as the fenced area and the Clay Pits area (see Figure 1) but excludes the former settling pond area (previous cleared by the U.S. Environmental Protection Agency).

The 6-acre Site is located on the south side of Clear Creek, east of U.S. Highway 6, in the northeast quarter of the northwest quarter of Section 33, Township 3 South, Range 70 West. The main entrance to the Site is located about 475 feet northwest of the intersection of Birch and 12^{th} Street in Golden, Colorado. A chain-link fence restricts access to the Site, except for a small area located south of 12th Street known as the Clay Pits area.

Prior cleanup activities at the Site have included the removal and stockpiling of material from a former settling pond, off-site disposal of the stockpile, building cleanup and demolition, and removal of concrete and asphalt associated with floors and foundations of the former buildings. A soil characterization study was performed during 2002 through 2003. The purpose of this SAP is to control the remediation process for the off-site disposal of the affected soils and verify that remediation goals have been met.

The purpose of the SAP is to provide the necessary guidance to properly identify specific waste classifications, control excavation volumes, and perform the final status survey (using portable field radiation meters and verification samples). The document also will be part of the Site Decommissioning Plan.

The SAP is a planning document only and may be changed as necessary to meet project requirements.

1.1 Material Classification

Characterization data that was generated during the Remedial Investigation/Feasibility Study (RI/FS) indicated that two primary types of material (primarily soil) were located on the Site. Laboratory analysis showed that these materials could be classified technologically enhanced naturally occurring radioactive material (TENORM) and solid waste. The TENORM material has been designated Class 1 area material as defined by the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) guidance and is located in a number of discrete areas around the Site. A minimal amount of this waste was above the toxicity characteristic leaching procedure (TCLP) limits, but on average the material would not be classified as hazardous waste because of metals concentrations. Site specific metals of concern include arsenic, cadmium, lead, and mercury. The remainder of the Site contains areas with elevated concentrations of metals (but below TCLP limits) and potential areas with limited radionuclide activity. This material has been classified as solid waste and because of the potential for some radionuclide activity it has been classified as Class 2 area material (MARSSIM defined Class 2 areas).

1.2 Field Operations

The remedial phase of the project will include the following field operations:

- Perform monitoring required to measure and control employee and worker exposure to radioactivity during the performance of field operations (continued throughout project),
- Excavation and packaging of the Class 1 areas material (TENORM and metals affected material).
- Sampling and monitoring the Class 1 area material to ensure that the material will meet the selected landfill acceptance criteria (American Ecology, Grand View, Idaho and/or Waste Management - CSI, Bennett, Colorado),
- Sampling the soil remaining under the Class 1 areas to ensure that sufficient material (TENORM) has been removed,
- Removal of soil with Site specific metals of concern and potential radionuclide activity (MARSSIM Class 2 areas) for disposal at a waste disposal facility with compatible waste acceptance criteria (BFI - Foothills, Golden, CO and/or Waste Management - CSI),
- Sampling and monitoring of metals affected / Class 2 soil to determine if it meets the guidance provided by in the Colorado Department of Public Health and Environment (CDPHE) memorandum dated February 25, 2004 for radionuclide activity,
- Verification sampling and monitoring of property after soil removal is complete (radionuclides and metals),
- Monitor surface and ground water to document natural attenuation of radionuclides (see Ground- and Surface-Water Sampling Plan).

The SAP establishes methodologies for obtaining field measurements, describes techniques for identifying sampling locations, specifies sample collection methodology, and defines sample analysis requirements. The use of screening (gamma meters, etc.) and sampling instrumentation (In Situ Object Counting System - ISOCS) also is described in this plan. Sample hold times and packaging requirements for the designated laboratory are provided.

The SAP is a planning document only and may be changed as necessary to meet project requirements.

2.0 FINAL STATUS SURVEY PLAN

Because of the activities covered by the SAP, the Final Status Survey Plan has been incorporated into this document. Aspects of the final status survey include:

- Selecting/verifying the survey unit classification,
- Demonstrating that the potential dose or risk from the remaining material is below the release criteria for each survey unit, and
- Demonstrating that the potential risk from residual elevated areas is below the release criteria for each survey unit.

The sampling plan also includes information about the final disposition of the material, which must meet specific landfill acceptance criteria.

The following sections describe the decision process and data quality objectives for the final status survey.

2.1 Problem

Characterization data collected as part of the Site Remedial Investigation/Feasibility (RI/FS) completed in January 2004 identified elevated radionuclides and metals. Following community and regulatory input to the RI/FS a remediation alternative was selected that required the affected material to be removed from the Site and disposed of in an appropriate landfill. Following meetings with the Colorado Department of Public Health and Environment (CDPHE), a specific plan was adopted that required a portion of material to be sent to a specialized landfill with the remainder going to a Subtitle D landfill.

Based on data generated by the Site characterization, MARSSIM defined Class 1 and Class 2 areas were identified. Class 1 areas are identified in Figure 1. After the removal of the Class 1 areas, the entire Site is a Class 2 area (see Appendix D and E). The Class 1 or TENORM material is to be excavated and shipped to American Ecology in Grandview, Idaho and/or Waste Management - CSI in Bennett, Colorado (a landfill specific risk assessment must be completed prior to material acceptance at CSI). Class 2 material included soils affected by metals concentrations that also had the potential for radionuclide contamination. CDPHE provided a memorandum that detailed the allowable levels of radionuclides that could be accepted by the Subtitle D landfill (BFI-Foothills located north of Golden, Colorado). Waste acceptance criteria for the individual landfills are provided in section 4.0.

Following the removal activities the final survey and verification samples must meet the requirements of the Site specific DCGLs and the proposed Tier 2 soil standards (with the exception of the Site specific standard for arsenic) (see section 4.3).

2.2 Decision

The final survey and verification samples must demonstrate that the DCGLs are met or area averaging (small areas) provides sufficient protection to allow free release of the property. Proposed Tier 2 soil standards also must be met. Sufficient data must be available to show that the requirements have been met.

2.3 Inputs to the Decision

Inputs to the decision include the characterization data (RI/FS), sampling and survey requirements in accordance with MARSSIM (section 4.3), modeling and sampling software (section 4.3), proposed Tier 2 soil standards (section 4.3), survey equipment needs (section 3.0), and analytical needs (section 4.6). All data will be collected and reviewed in accordance with the quality assurance / quality controls requirements as specified in the project Quality Assurance Project Plan (QAPP).

2.4 Boundaries

Spatial boundaries for the remedial operations are limited to the Site as described in section 1.0 (see Figure 1). Temporal boundaries modeled during the RI/FS included up to 1,000 years into the future.

2.5 Decision Rules

The decision rules for the Site include the following:

- DCGLs predicted for a maximally exposed urban resident that uses the Site ground water for drinking water and watering and consumes produce from a backyard garden,
- Proposed Tier 2 soil standards for metals (includes Site specific limit for arsenic),
- Landfill acceptance criteria that include the ANSI/HSP N13.12-1999 standard for the Subtitle D landfill and the American Ecology/CSI criteria, and
- Transportation limitations as specified by the 49 CFR 173.443.

2.6 Limits on Decision Errors

For purposes of determining sample number requirements, the Site will be assumed dirty with decision errors for the final Site verification samples of 5-percent for the false rejection rate (alpha) and 10-percent for the false acceptance rate (beta).

2.7 Sampling Design

The design of the sampling plan is detailed in the remainder of the SAP.

3.0 SAMPLING AND MONITORING EQUIPMENT

The following sections describe the sampling and monitoring equipment that will be used to ensure the Site is safely cleaned up to regulatory standards. Equipment includes hand held radiation detectors, an on-site gamma spectrometer, air monitoring equipment, positional surveying equipment, and sample collection equipment.

3.1 Portable Field Radiation Measurement

Hand-held gamma detectors will be used during excavation activities as an initial screen to determine areas of elevated activity and assist in the determination of the limits of excavation. Hand-held alpha detectors will be used to survey equipment moving on and off the Site. Counting equipment also will be used on site to determine if air-monitoring samples fall within acceptable ranges.

Screening equipment will include sodium iodide (NaI) gamma scintillation detectors, such as the Ludlum model 44-10 2-inch NaI detector matched with a suitable counting instrument such as the Ludlum model 2221 or 2350-1. A lead collimator will be used during screening surveys to minimize shine. Alpha detectors will include silver-activated zinc sulfate [ZnS(Ag)] phosphor scintillation counters such as the Ludlum Model 43-5, 50 square centimeter scintillation detector, again coupled with a suitable counting instrument (e.g., Ludlum model 2221 or 2350-1). A Ludlum model 44-9 pancake (halogen quenched) alpha, beta, gamma detector will be used in conjunction with a Ludlum model 12 rate meter for frisking and general surveys.

Radiation detectors will be rented from certified vendors (e.g., Duratek) and will arrive on site with required calibration documentation.

National Institute of Standards and Technology (NIST) approved standards (calibration/check sources) will be used for all on site instrument calibrations. Sources used for the project portable field instrument calibration are documented in the New Horizons' *Radioactive Materials License Application for Waste Brokers and Consultants Handling Radioactive Materials.* The standards will be stored in a locked metal box and placed in a metal cabinet as far from the instruments as possible inside the laboratory trailer. The storage requirements are to ensure that the standards do not interfere with the instrument background and calibration checks.

3.1.1 General Instrument Functionality Checks

All field instruments will be checked daily to ensure proper operation. The following checklist will be used to determine if the instruments are operational.

- Battery check - perform battery check to ensure batteries have sufficient power for at least eight hours of operation (change batteries if in doubt),
- Connection check - visually examine all cables and connections to ensure the detectors and meters are properly communicating,
- Probe check - examine all membranes to verify there are no pin holes or other damaged areas,
- Audible signal test - use instrument specific test or pass probe over a source to determine if the audible signal is working, and
- Analog or scaler readout - turn the instrument on to verify display unit(s) is working.

3.1.2 Site Background Determination

Instrument local background will be determined on a weekly basis and checked daily. Local background measurements will be obtained in the laboratory trailer at the Site (with the exception of the gamma detectors).

A weekly background value for on-site alpha detectors will be determined in the following manner:

- The detectors should be maintained in the configuration that will be used during the field measurements (shielded or unshielded),
- Obtain one 10-minute background count (may be longer but at least 10 minutes),
- Obtain at least ten one-minute background counts,
- Determine the mean one-minute background count assuming a normal distribution,

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

  where x_I is the one minute background count, *I* is the specific count, and *n* is the total number of background counts,
- Determine the sample standard deviation of the ten counts assuming a normal distribution and a small sample set

  $$s = \sqrt{\frac{n\sum_{i=1}^{n} x_i^2 - \left(\sum_{i=1}^{n} x_i\right)^2}{n(n-1)}}$$

  where *s* is the sample standard deviation (can be calculated using the Microsoft Excel function STDEV).
- An acceptable background range for the specific instrument can be calculated as follows:

  $$Range = \bar{x} \pm 2s$$

  $\bar{x} + 2s$ approximately corresponds to the upper 95-percent confidence level for the measurement.
- The 10-minute background count can be compared to this range to determine if the instrument is performing properly.
- A one-minute daily background check will be performed to determine if the instrument is within the proper range.

- Background determinations and checks will be documented in accordance with the Quality Assurance Project Plan (QAPP).
- If instrumentation problems are identified during the background determination/checks (values out of range), corrective action will be performed in accordance with the QAPP.

A specific background area will be identified for the Site to check the performance of the gamma detectors. Initially 10 one-minute counts will be performed in this area to determine the average background value and the range (see above calculations). Daily checks will be performed to determine if the instrument is performing properly. The background gamma measurement is more of a qualitative measurement to determine if the instrument is performing properly. All background checks will be documented in accordance with the QAPP.

All background data will be evaluated by the Radiation Safety Officer and to determine its applicability.

3.1.3 Instrument Calibration Check

The field instruments will be calibrated using project specific calibration sources that are NIST certified. Instrument calibrations will be performed on a weekly basis and checked daily. Calibrations will be performed the laboratory trailer at the Site.

A weekly calibration for the on-site alpha detectors will be determined in the following manner:

- The detectors should be maintained in the configuration that will be used during the field measurements (shielded or unshielded),
- Obtain one 10-minute calibration count (may be longer but at least 10 minutes),
- Obtain at least ten one-minute calibration counts,
- Determine the mean one-minute calibration count assuming a normal distribution,
- Determine the sample standard deviation of the ten counts assuming a normal distribution and a small sample set,
- The acceptable calibration range for the specific instrument is equal to the mean plus or minus two times the standard deviation,
- The 10-minute calibration count can be compared to this range to determine if the instrument is performing properly,
- A one-minute daily calibration check will be performed to determine if the instrument is within the proper range,
- Instrument calibrations will be documented in accordance with the Quality Assurance Project Plan (QAPP), and
- If instrumentation problems are identified during the calibration determination/checks (values out of range), corrective action will be performed in accordance with the QAPP.

3.1.4 Determine Instrument Efficiency

Instrument efficiency is determined by exposing the instrument to a known-value radioactive source for a fixed period of time, correcting for instrument and source geometry.

Instrument and source geometry are addressed using the probe area correction, which is calculated as follows:

$$q_{2\pi,sc} = q_{2\pi} \frac{physical\ detector\ area\,(cm^2)}{calibration\ source\ area\,(cm^2)}$$

where $q_{2\pi,sc}$ is the emission rate [(decays per minute (dpm)]corrected for the detector and source and $q_{2\pi}$ is the source emission rate (dpm) (this equation assumes a 2π geometry that may need to be modified for specific detectors and sources).

The on-site instrument efficiency is determined as follows:

$$\varepsilon_i = \frac{R_g - R_b}{q_{2\pi,sc}}$$

where ε_i is the instrument efficiency, R_g is the gross count rate [counts per minute (cpm)] and R_b is the background count rate (cpm).

The on-site efficiency is then compared to the documented vendor efficiency for the instrument. The average efficiency should be within ±15-percent of the listed vendor efficiency. If the efficiency falls out of acceptable ranges, corrective action measures will be performed in accordance with the QAPP.

The efficiency may be used to covert measured decays per minute (dpm) to counts per minute (cpm) as follows:

$$dpm = \frac{cpm}{\varepsilon_i}$$

The instrument efficiencies will be calculated weekly and documented in accordance with the QAPP.

3.1.5 Calculate the Lower Limit of Detection/Minimum Detectable Contamination

The lower limit of detection (LLD) for each instrument is the smallest amount of net activity above background that will be registered as positive with a given level of confidence (typically a probability of 0.05 or an upper confidence level of 95-percent), assuming a normal distribution. Previously published methods of determining the LLD [also referred to as the detection limit (DL)] have been recently challenged and several guidance documents and standards are adopting new equations [*Multi-Agency Radiological Laboratory Analytical Protocols Manual and* ISO-11929 Part 1 (2000)]. The following equation (or slightly modified versions) has been proposed for general use:

$$DL_{McCroan}\left(R_{n,\alpha}\right) = \frac{k_\alpha^2}{2t_b} + \frac{k_\alpha}{2}\sqrt{\frac{k_\alpha^2}{t_\alpha^2} + 4R_b\left(\frac{1}{t_g} + \frac{1}{t_b}\right)} \quad \text{(McCroan's Rule)}$$

where k_α is the statistical z score for a specific level of confidence (type I error), t_g is the gross count time, and t_b is the background count time (Strom, D.J. and MacLellan, J.A., 2001, *Evaluation of eight decision rules for low-level radioactivity counting,,* Radiation and Health Protection, Pacific Northwest National Laboratory, Richland, WA). . Or rewriting the equation for the 95-percent confidence level.

$$DL = \frac{2.706}{t_b} + 0.823\sqrt{\frac{2.706}{t_b^2} + 4R_b\left(\frac{1}{t_g} + \frac{1}{t_b}\right)}$$

To determine the minimum detectable contamination (MDC), the detection limit must be corrected for instrument efficiency, or:

$$MDC_{Cont} = \frac{DL}{\varepsilon_i}$$

This equation assumes that the efficiency includes the probe area correction factors (Martin, J.E., 2000, *Physics for Radiation Protection*, John Wiley & Sons, New York, pg. 483).

The MDC_{Cont} data will be correlated with analytical data produced by the on-site In Situ Object Counting System (see section 3.1.2) and laboratory data to provide a screening tool for soil excavation and off-site shipment.

The MDC_{Cont} equation may be modified for specific applications such as air monitoring samples. The basic equation may be modified to determine the minimum detectable concentration (MDC_{Conc}) by including correction factors for filter efficiency, chemical recovery, and flow rate.

The MDC data will be correlated with analytical data produced by the on-site In Situ Object Counting System (see section 3.1.2) and laboratory data to provide a screening tool for soil excavation and off-site shipment.

3.2 In Situ Object Counting System

An In-Situ Object Counting System (ISOCS) will be used in combination with laboratory samples to determine soil activity for material to be shipped off site and for the final verification samples. The ISOCS equipment also may be used to refine the delineation of elevated activity areas that were determined using geostatistical techniques (Kriging) coupled with the characterization survey data. Canberra Industries will provide qualified personnel to operate the ISOCS equipment. Sample location selection will be determined using the information generated by Visual Sampling Plan (see section 3.2) but may be modified as required by Site conditions or the outcome of hand-held meter or ISOCS survey data.

ISOCS data will be correlated to actual laboratory data to ensure reported radionuclide activities are accurate. The correlation process will be completed during the initial stage of the project, but additional random samples will be sent to the laboratory for the duration of the project to ensure proper detection levels are maintained. At least 20-percent of the verification samples will be submitted to the laboratory to maintain quality control.

Archived samples collected during the characterization phase of the project will be used for the initial ISOCS setup. An initial level of confidence will be established using these samples, but actual cleanup samples will be used to determine the actual correlation between ISOCS and laboratory data.

The ISOCS equipment will be operated in accordance with the Canberra Industries practices and procedures. Equipment specific method detection limits (MDL) will be in accordance with the ISOCS statement of work (Appendix A). The MDLs may be modified as necessary in response to on site conditions and equipment limitations. The ISOCS instrument will be calibrated daily using a Site-specific standard.

3.3 Air Monitoring Equipment

Perimeter and personal air samples will be collected to determine if air quality standards for metals and radionuclides are maintained during the remedial operations. Four perimeter air monitors will be operated for sufficient hours to determine air quality in the vicinity of the Site. At a minimum this will include continuous operation during hours of Site occupation. Personal air monitors will be worn by a representative sample of Site workers to document air quality in the vicinity of the actual excavation and transport activities.

3.3.1 Perimeter Air Monitors

Airborne radioactivity samples will be obtained on a 2-inch diameter glass fiber filter at a sampling rate of 60 liters per minute. Air sampling will be conducted during hours of site occupation. Additional hours may be monitored during the initial phases of the project to generate a baseline.

Four air monitor stations will be used to provide for directional wind changes during operational hours. The proposed locations for the high-volume radioactive air samplers are shown in Figure 1. Meteorological conditions will be monitored via an on-site weather station. Monitoring locations may be modified if necessary by the Site Safety Officer (SSO) or Radiation Safety Officer (RSO).

Sampling will be conducted each day that Site activities are performed. Samples will be submitted for laboratory analysis of specific radionuclides whenever on-site analysis of the airborne radioactivity sample indicates that an effluent standard (6 CCR 1007-1, Part 4 - Standards for Protection against Radiation) could have been exceeded. All air samples will be archived until laboratory analyses confirm on-site radionuclide measurements.

3.3.2 Personal Exposure Air Samplers

Representative Site workers will be monitored periodically for exposure to airborne contaminants, specifically total dust and radionuclides. Samples for radionuclides will be obtained using glass fiber filters and personal sampling pumps operating at one liter per minute for the entire time the worker may be exposure to airborne radioactivity. Samples will be collected at the end of the shift and analyzed on site for airborne radioactivity. If the on-site analysis indicates any exposure to airborne radioactivity other than radon, the sample filter will be submitted for off-site analysis of specific radionuclides.

Dust samples will be obtained using pre-weighed filter cassettes. These samples will be obtained from representative Site workers and submitted for off-site gravimetric analysis of airborne dust. Any samples exceeding the standard for airborne dust exposure will then be submitted for analysis of airborne radionuclides as well.

Personal exposure monitoring will be conducted daily for the first week of intrusive Site activities. If the preliminary results of exposure monitoring do not indicate exposures greater than one half the applicable standard (6 CCR 1007-1, Part 4 - Standards for Protection against Radiation), personal sampling frequency may be reduced to once weekly at the discretion of the SSO/RSO. Personal airborne radioactivity samples will then be sent to an off-site laboratory for analysis only if the on-site laboratory analysis indicates that exposure to airborne radionuclides may have occurred.

At the option of the SSO/RSO, work area exposure samples may also be obtained for airborne dust or airborne radionuclides. These samples would be obtained from locations most likely to exhibit maximum exposure to these airborne constituents.

3.4 Positional Surveying Equipment

Colorado licensed professional land surveyors provided by Flatirons Surveying, Inc. of Boulder, Colorado will document all sample collection locations. Flatirons also will verify soil removal depths and document positions of previously unidentified areas of elevated activity, if encountered. Control points were established during the characterization study and these points will be used as control for the sampling and remediation operations. Additional control points may be required depending on-site conditions and satellite constellation positions. A combination of standard survey equipment and global positioning system (GPS) equipment will be used for the survey operations. Flatirons has indicated that the following types of equipment may be used during the project:

Trimble 5800/5700 GPS RTK Base/Rover Set up with Trimble TGO software, or
Trimble 5600 DR 200 Robotic Total Station with Trimble TGO software, or
Topcon GTS 300 series Total stations with TDS Software

Sample locations will be identified within ±0.01 foot for the x and y coordinates and ±0.05 foot for the z coordinate. Excavation area and depth will be documented within ±0.05 foot for the x and y coordinates and ±0.05 foot for the z coordinate.

3.5 Sample Collection Equipment

Soil samples will be collected using hand-digging equipment including trowels, spades, pickaxes, or manually driven augers. Composite samples will be homogenized in a 5-gallon plastic bucket (preferably white or clear). Because of the heterogeneity of the soil, screens or other methods may be used to produce relatively consistent samples. Radionuclide samples will be placed in 500-milliliter polypropylene jar and then double-bagged in resealable plastic bags. Additional soil will be placed in additional resealable bags (double bagged) if additional analyses are required (e.g., alpha spectroscopy or metals). Detailed sample collection procedures are provided in section 3.3.

3.5.1 Sample Collection Equipment - Decontamination Procedures

All sampling equipment - trowels, buckets, augers, etc. - shall be cleaned between sample collection sites. Cleaning may include brushing or scrapping followed by washing with an approved detergent and water, followed by rinsing with clean water.

4.0 SAMPLING REQUIREMENTS

A variety of sampling requirements will apply to the Site. Samples fall into three categories:

- Characterization samples necessary to ensure that all landfill waste acceptance criteria are met. These samples will be collected from the appropriate stockpiles/Lift Liner™ bags for ISOCS and/or laboratory analysis,
- Verification samples necessary to ensure that sufficient material has been removed from the Site. Samples will be collected from MARSSIM Class 1 and Class 2 areas. Verification samples will be analyzed by the ISOCS instrumentation and/or the certified laboratory (metals samples will be laboratory analysis only), and

- The final category includes areas that could not be properly characterized during the RI/FS such as the area around the then active City of Golden water mains or new areas discovered during the remediation operations.

On site instrumentation including hand-held survey meters and ISOCS will be used in addition to the samples to verify sufficient material has been removed and ensure proper material classification (Class 1 or 2).

All sample collection procedures and sample analysis will conform to established practices for precision, accuracy, representativeness, comparibility, completeness, and sensitivity. Details of these specific aspects of the project are covered in the Quality Assurance Project Plan.

The following sections describe the sampling practices and procedures.

4.1 Sampling Data Quality Objectives

According to MARSSIM, the data quality objectives (DQO) process should be used to determine data quality and develop sampling designs. DQO's are qualitative and quantitative statements derived from the outputs of the DQO process that:

- clarify the study objectives,
- define the most appropriate type of data to collect,
- determine the most appropriate conditions for collecting the data, and
- specify limits on decision errors that will be used as the basis for establishing the quantity and quality of data needed to support the decision.

Information gathered during the characterization phase of the RI/FS study identified on site radionuclides and metals of concern and the associated media (soil). Characterization data showed that samples will need to be collected throughout the remediation process to provide sufficient data to meet landfill acceptance criteria and cleanup levels. Decision errors are largely driven by regulatory requirements and will be addressed in the following sections.

The primary DQO (or decision rules) that needs to be addressed is the purpose of the various types of samples. Class 1 area material must be sufficiently characterized to meet the appropriate landfill acceptance criteria and transportation requirements. The Class 1 areas also require additional samples to determine if sufficient material has been removed. Material from the metals affected / Class 2 areas requires sufficient characterization to ensure the landfill acceptance criteria guidance received from CDPHE has been met. Final verification samples need to be collected from the Class 1 and Class 2 areas to ensure the Site meets the agreed upon Site specific derived concentration guideline levels (DCGLs). Previously inaccessible or unidentified areas must be properly characterized to determine proper material disposition.

All of the samples must be of sufficient quality to ensure that accurate Site data has been collected.

4.2 Waste Characterization Samples

The waste characterization samples fall into two categories, the Class 1 area material and the metals affected / Class 2 area material. A statistically significant number of samples (about 30) will be collected from each category and analyzed for radionuclides to ensure the appropriate landfill acceptance criteria and transportation regulations are met.

4.2.1 Waste Characterization Samples - Data Quality Objectives

All Class 1 area material transported from the Site to American Ecology or CSI must meet the requirement of less than 2,000 picocuries per gram of total activity to allow transportation without special controls and placarding. The material also must meet landfill acceptance criteria such as those provided by American Ecology (see Appendix B). CSI must complete a landfill specific risk assessment to accept this material. A minimum of 30 random samples will be collected from the material placed in the Lift Liner™ bags. These samples will be primarily analyzed for radionuclides.

All metals affected / Class 2 area material transported to BFI - Foothills must meet the CDPHE specified requirement detailed in their memorandum of February 25, 2004. Materials above the CDPHE specified limits would require a landfill specific risk assessment. A minimum of 30 random samples will be collected from the stockpiles generated during the excavation.

4.2.2 Waste Characterization Samples - Sample Locations, Numbering, and Documentation

During loading operations into the Lift Liner™ bags (see Material Transport Plan) about 30 random samples will be collected from the Class 1 areas material. The purpose of these samples is to ensure that the facility acceptance criteria are met. These samples will not require positional information, but the general area that the material was excavated from will be noted in the field notebook. Data required for all samples includes a description of soil type (e.g., silt, clay, sand) and the estimated percentages of the type. Soil color also shall be noted in the field notebook.

About 30 random samples will be collected from the metals affected / Class 2 area stockpiles. This data set will be generated to verify that the average radionuclide activities are within the limits designated by CDPHE. These samples will not require positional information, but the general area that the stockpile came from should be noted in the field notebook. At least 10 percent of all samples will be split samples.

Sample numbering will be as follows. Samples from the Lift Liner™ bags (Class 1 area materials) will be sequentially numbered as follows: AE1001, AE1002, AE1003, etc. Split samples from the bags will be labeled with an S suffix (e.g., AE1002-S). Samples from the Class 2 area material stockpiles will be sequentially numbered as follows: BF1001, BF1002, BF1003, etc. Split samples from the Class 2 area material will be labeled with an S suffix (e.g., BF1002-S). Sample numbers will be legibly written on the sample containers (see section 3.2.3) and the chain-of-custody applicable (COC) form. Company name (NHEC), sample number, date, and time of collection will be marked with permanent ink on each sample container.

All samples will be documented on the internal COC form and/or the laboratory specific COC form. The COC form must accompany the sample when the sample is transferred between the sampling personnel and ISOCS or laboratory personnel. If the sample is not under the direct supervision of sampling, ISOCS, or laboratory personnel, it will be maintained in a secure location. Sample COC forms are provided in Appendix C.

4.2.3 Waste Characterization Samples - Sample Collection Methodology

Waste characterization samples will be collected by compositing five aliquots of about 500 cubic centimeters into a clean plastic container (preferably white or clear plastic) and homogenized. Cobbles, gravel, and organic material will be minimized in the samples. Because of the quantity of clay on site, screens or other methods may be required to produce an acceptable sample. After the samples have been homogenized, the soil will be placed in a 500-milliliter plastic jar filled to the top. The jar will be shaken, etc. to maximize the amount of soil in each jar. Split samples will be collected from least 10 percent of all the waste characterization samples. If a split sample is required, a second 500-milliliter jar will be filled as previously described. Company name (NHEC), sample number, date, and time of collection will be marked with permanent ink on the sample jar lid. If the sample is to be submitted to the analytical laboratory, a circled "L" will be written on the jar lid (preferably in red ink). Samples will then be placed inside two resealable plastic bags. Laboratory samples also will include an additional 250 to 500 cubic centimeters of soil placed inside two resealable plastic bags. The additional material is necessary for alpha spectroscopy and/or metals analysis. Company name (NHEC), sample number, date, and time of collection will be marked with permanent ink on the sample bag (directly on the bag or on a sample label applied to the bag). A plastic bag will be used to keep the laboratory sample jars and bags together. Certified clean sample containers shall be used for all samples.

The waste disposal facilities may request additional toxic characteristic leaching procedure (TCLP) data. If required, the appropriate containers will be obtained from the laboratory and filled with homogenized soil. If TCLP samples are requested the sample numbering protocol described in section 3.2.2 will be followed.

4.3 Verification Samples

The verification samples fall into two categories, verification that sufficient material has been removed from the Class 1 areas and the final verification samples that show the metals affected / Class 2 material has been removed. The final verification samples ensure the agreed upon cleanup levels have been met (both radionuclides and metals) and the Site can be available for unrestricted use. The verification samples will be used in conjunction with on-site portable field radiation meters to determine if the material identified during the RI/FS has been excavated and removed from the Site.

The following guidance documents and software were used to determine sampling frequency and location for the verification samples:

- *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM), NUREG-1575, Rev. 1, EPA 402-R-97-016, Rev. 1, DOE/EH-0624, Rev. 1
- *RESRAD*, Version 6.21 software, U. S. Department of Energy and U.S. Nuclear Regulatory Commission, developed by Environmental Assessment Division of Argonne National Laboratory, September 2002.
- *The Superfund Lead-Contaminated Residential Sites Handbook*, U.S. Environmental Protection Agency, OSWER 9285.7-50, August 2003
- *Visual Sampling Plan* (VSP), Version 2 software, Pacific Northwest National Laboratory, Contract DE-AC06-76RL01830.

4.3.1 Verification Samples - Data Quality Objectives

The verification sample DQOs include requirements for both radionuclides and metals. The following sections describe the regulatory requirements for both types of materials.

4.3.1.1 Verification Samples - Data Quality Objectives - Radionuclides

The primary data quality objective of the verification sampling process is to ensure that the Site has been cleaned up to agreed upon regulatory standards, which are defined for the Site soils by derived concentration guideline levels (DCGLs). Site appropriate DCGLs have been determined for the following radionuclides: lead-210, polonium-210, radium (226 & 228), thorium (228, 230, 232), and uranium (234, 235, & 238). Because low method detection limits are not possible on the ISOCS instrument for polonium-210 and thorium-230, sufficient analytical data also will be collected to determine proportional relationships between these radionuclides and other decay chain radionuclides. The following table summarizes the Site specific DCGLs.

Radionuclide	**Urban Resident – 15 mrem/yr**
Lead-210	4.44
Polonium-210	192
Radium-226	1.44
Radium-228	2.20
Thorium-228	3.77
Thorium-230	9.83
Thorium-232	1.48
Uranium-234	253
Uranium-235	4.88
Uranium-238	20.2

Note: All units in picocuries per gram

All samples must be collected, handled, documented, analyzed, and reported in a defensible manner. The following sections provide the procedures to properly address these issues.

4.3.1.2 Verification Samples - Data Quality Objectives - Metals

The primary data quality objective of the verification sampling process is to ensure that the Site has been cleaned up to agreed upon regulatory standards, which are defined for the Site soils by the proposed Tier 2 soil standards. Metal concentrations will be compared to the proposed Tier 2 soil standards with the exception of arsenic. Background arsenic concentrations in the vicinity of the Site are naturally elevated with the 95-percent upper confidence limit for the Site being 13 milligrams per kilogram. The Tier 2 soil standards for the Site metals of concern are as follows:

Metal	**Proposed Standard (mg/kg)**
Arsenic	13[1]
Cadmium	76.1
Lead	400
Mercury (elemental)	1.1
Mercury (compounds)	23

[1] Site specific arsenic standard.

All samples must be collected, handled, documented, analyzed, and reported in a defensible manner. The following sections provide the procedures to properly address these issues.

4.3.2 Verification Samples - Sample Locations, Numbering, and Documentation

Samples locations were selected in accordance with MARSSIM guidance. VSP software was used to assist with the sample location selection process. *The Superfund Lead-Contaminated Residential Sites Handbook* was used to determine the verification sampling requirements for metals.

For purposes of determining sample number requirements, the Site will be assumed dirty with decision errors for the final Site verification samples of 5-percent for the false rejection rate (alpha) and 10-percent for the false acceptance rate (beta).

4.3.2.1 Verification Samples - Sample Locations, Numbering, and Documentation - Radionuclides (TENORM/Class 1 area material)

After the Class 1 area material has been removed the underlying soil must be evaluated to determine if all of the TENORM material has been removed. The VSP designated "hotspot" sampling was assumed to determine the required sampling grid. RESRAD 6.21 was used in combination with RI characterization data to determine the size of the hotspot that needed to be evaluated. The residential maximally exposed individual receptor was assumed with a limiting dose of 15 millirem per year (mrem/yr). Using the radionuclides of concern a 1.8-meter diameter hotspot was determined. Assuming a triangular grid, about 55 samples would be required to adequately address the Class 1 areas. Ten to twelve additional samples may be required to adequately characterize the sidewalls of the excavation needed for the extraction(s) of this soil. Additional samples may be collected if previously unidentified areas of elevated activity are discovered during the remedial operations. At least 10 percent of all samples will be split samples.

Details of the VSP calculations and the associated sample location diagrams are provided in Appendix D. Sample collection methods are provided in following section.

Sample numbering for the former Class 1 areas will be as follows. Samples will be sequentially numbered as follows: C1001, C1002, C1003, etc. Split samples from the areas will be labeled with an S suffix (e.g., C1002-S). Sample numbers will be legibly written on the sample containers (see section 3.2.3) and the chain-of-custody applicable (COC) form. Company name (NHEC), sample number, date, and time of collection will be marked with permanent ink on each sample container. If the sample is to be submitted to the analytical laboratory, a circled "L" will be written on the jar lid (preferably in red ink).

A general description of the sample material will be noted in the field notebook. Data required for all samples includes a description of soil type (e.g., silt, clay, sand) and the estimated percentages of the type. Soil color also shall be noted in the field notebook.

Prior to the Class 1 area sample collection, the surveyors will determine the sample locations using a random start triangular grid (1.8 meters between locations) for the Class 1 areas. Each sample location will be recorded electronically and cross-referenced by sample number in a bound field notebook. Location markers labeled with the appropriate sample number will be placed at each sample location.

All samples will be documented on the internal COC form and/or the laboratory specific COC form. The COC form must accompany the sample when the sample is transferred between the sampling personnel and ISOCS or laboratory personnel. If the sample is not under the direct supervision of sampling, ISOCS, or laboratory personnel, it will be maintained in a secure location. Sample COC forms are provided in Appendix C.

4.3.2.2 Verification Samples - Sample Collection Methodology - Radionuclides (Class 1 areas)

Prior to the collection of any soil sample a 10-second gamma measurement of the location will be made and recorded along with the sample number in the field notebook. A gamma measurement for each associated composite location also will be made and recorded.

Radionuclide soil samples will be obtained from the uppermost 15 centimeters of surface soil. The sample should be approximately cylindrical in cross section so that all horizontal components are equally represented in the sample. The soil at the selected sample location will be composited with four additional samples (equal volume) collected randomly within a radius of two meters. The five aliquots (about 500 cubic centimeters each) will be composited into a clean plastic container (preferably white or clear plastic) and homogenized. Cobbles, gravel, and organic material will be minimized in the samples. Because of the quantity of clay on site, screens or other methods may be required to produce an acceptable sample. After the samples have been homogenized, the soil will be placed in a 500-milliliter plastic jar filled to the top. The jar will be shaken, etc. to maximize the amount of soil in each jar. Samples will then be placed inside two resealable plastic bags. Laboratory samples also will include an additional 250 to 500 cubic centimeters of soil placed inside two resealable plastic bags. The additional material is necessary for alpha spectroscopy and/or metals analysis. A plastic bag will be used to keep the laboratory sample jars and bags together. Certified clean sample containers shall be used for all samples. Sampling equipment decontamination procedures are provided in section 2.5.1.

All relevant sampling data will be entered on an on-site chain-of-custody form that will be kept with the samples to monitor the transfer of sample control (i.e., field technician to ISOCS personnel). A separate chain-of-custody form will be filled out for all samples submitted to the laboratory. No special preservatives are required for the radionuclide samples.

4.3.2.3 Verification Samples - Sample Locations, Numbering, and Documentation - Radionuclides (Class 2 area material)

VSP was used to develop the sampling requirements for the Class 2 areas (only the radionuclide portion of the waste was addressed with VSP), which will include the entire Site with the exception the Class 1 areas. MARSSIM limits Class 2 areas to a maximum size of 10,000 square meters to ensure sufficient sampling density. Excluding the Class 1 areas, about 19,000 square meters of property remain, which requires two Class 2 areas. Dividing the Site along the former main street produces the required Class 2 areas. The sampling goal was to compare the average concentration to a fixed threshold, assuming the data was not normally distributed, and use systematic grid sampling. The Wilcoxon signed ranks test was used for comparison to the Site background activities. Assumptions used for the Class 2 sampling area included: the Site was assumed to be dirty, a 5-percent false rejection rate, a 10-percent false acceptance rate, an action level ($DCGL_W$) of 1 (multiple radionuclides - sum of the fractions), width of the gray region (delta) of 0.5 (half of the $DCGL_W$), and an estimated standard deviation of 1.8 (estimated from characterization survey data). Because the comparison of the ISOCS and laboratory data still needs to performed, no measurement quality objectives were selected. VSP indicates that about 130 verification samples will need to be collected from each Class 2 area (about 260 samples total). Additional samples may be collected if previously unidentified areas of elevated activity are discovered during the remedial operations. At least 10 percent of all samples will be split samples.

Details of the VSP calculations and the associated sample location diagrams are provided in Appendix E. Sample collection methods are provided in following section.

Sample numbering for the former metals affected / Class 2 areas will be as follows. Samples will be sequentially numbered as follows: C2001, C2002, C2003, etc. Split samples from the areas will be labeled with an S suffix (e.g., C2002-S). Sample numbers will be legibly written on the sample containers (see section 3.2.3) and the chain-of-custody applicable (COC) form. Company name (NHEC), sample number, date, and time of collection will be marked with permanent ink on each sample container. If the sample is to be submitted to the analytical laboratory, a circled "L" will be written on the jar lid (preferably in red ink).

A general description of the sample material will be noted in the field notebook. Data required for all samples includes a description of soil type (e.g., silt, clay, sand) and the estimated percentages of the type. Soil color also shall be noted in the field notebook.

After the completion of the Site excavation and prior to verification sample collection, the surveyors will determine the sample locations using a random start triangular grid [about 2.7 meters (8.7 feet) between locations]. Each sample location will be recorded electronically and cross-referenced by sample number in a bound field notebook. Location markers labeled with the appropriate sample number will be placed at each sample location.

4.3.2.4 Verification Samples - Sample Collection Methodology - Radionuclides (Class 2 areas)

Prior to the collection of any soil sample a 10-second gamma measurement of the location will be made and recorded along with the sample number in the field notebook. A gamma measurement for each associated composite location also will be made and recorded.

Radionuclide soil samples will be obtained from the uppermost 15 centimeters of surface soil. The sample should be approximately cylindrical in cross section so that all horizontal components are equally represented in the sample. The soil at the selected sample location will be composited with four additional samples (equal volume) collected randomly within a radius of two meters. The five aliquots (about 500 cubic centimeters each) will be composited into a clean plastic container (preferably white or clear plastic) and homogenized. Cobbles, gravel, and organic material will be minimized in the samples. Because of the quantity of clay on site, screens or other methods may be required to produce an acceptable sample. After the samples have been homogenized, the soil will be placed in a 500-milliliter plastic jar filled to the top. The jar will be shaken, etc. to maximize the amount of soil in each jar. Samples will then be placed inside two resealable plastic bags. Laboratory samples also will include an additional 250 to 500 cubic centimeters of soil placed inside two resealable plastic bags. The additional material is necessary for alpha spectroscopy and/or metals analysis. A plastic bag will be used to keep the laboratory sample jars and bags together. Certified clean sample containers shall be used for all samples. Sampling equipment decontamination procedures are provided in section 2.5.1.

All relevant sampling data will be entered on an on site chain-of-custody form that will be kept with the samples to monitor the transfer of sample control (i.e., field technician to ISOCS personnel). A separate chain-of-custody form will be filled out for all samples submitted to the laboratory. No special preservatives are required for the radionuclide samples.

4.3.2.5 Verification Samples - Sample Locations, Numbering, and Documentation - Metals (Class 2 area material)

Verification samples also will be evaluated for metals after the remedial operations (excavation) have been completed. *The Superfund Lead-Contaminated Residential Sites Handbook* recommends that each quarter acre be sampled using a five point composite sample. Verification will require about 24 such samples. At least 10 percent of all samples will be split samples.

Sample numbering for the metals samples will be as follows. Samples will be sequentially numbered as follows: M101, M102, M103, etc. Split samples from the areas will be labeled with an S suffix (e.g., M102-S). Sample numbers will be legibly written on the sample containers (see section 3.2.3) and the chain-of-custody applicable (COC) form.

A general description of the sample material will be noted in the field notebook. Data required for all samples includes a description of soil type (e.g., silt, clay, sand) and the estimated percentages of the type. Soil color also shall be noted in the field notebook.

To determine the metals sample locations, the surveyors will divide the Site into one-quarter acre parcel and position a sample marker about in the center of each parcel. Each sample location will be recorded electronically and cross-referenced by sample number in a bound field notebook. Location markers labeled with the appropriate sample number will be placed at each sample location.

Additional metals samples may be required for areas that were not sufficiently characterized during the RI or if new areas are identified during the remediation operations.

4.3.2.6 Verification Samples - Sample Collection Methodology - Metals (Class 2 areas)

The Site will be divided into quarter-acre areas to determine the locations for metals samples. Five equal volume (500 cubic centimeters) samples will be collected at random within the quarter acre areas. As with the radionuclide samples, a cylindrical sample about 15 centimeters deep will be collected. The five samples will be homogenized in a five-gallon plastic bucket (preferably white or clear plastic) with minimal cobbles, gravel, or organic material introduced into the sample. After the sample has been homogenized, about 500-milliliter of material will be placed in double resealable plastic bags and marked with the appropriate sample number, date, and time of collection. Sample collection will be documented on a chain-of-custody form. Certified clean sample containers shall be used for all samples. Sampling equipment decontamination procedures are provided in section 2.5.1. All metal samples will be placed on ice (4°C) until delivered to the laboratory (requirement for mercury). In addition, all metals samples will be promptly delivered to the laboratory because of the 30-day holding time for mercury.

All relevant sampling data will be entered on an on site chain-of-custody form that will be kept with the samples to monitor the transfer of sample control (i.e., field technician to ISOCS personnel). A separate chain-of-custody form will be filled out for all samples submitted to the laboratory.

4.4 Previously Inaccessible or Unidentified Area Samples

The area around the previously active City of Golden water mains (near the former Building 101) will be characterized to determine if it falls into the Class 1 or Class 2 categories. The material is adjacent to material that has been identified as Class 1 material (some Class 1 material was found to overly the pipelines) and will be approached as a Class 1 excavation. If sufficient visual clues such as color coupled with portable radiation meter measurements indicate the material is Class 1, it will be placed directly into the Lift Liner™ bags. If obvious indications of activity are not available, samples will be collected to characterize the material. Sufficient samples must be collected to confidently disposition the material to the appropriate disposal site.

Excavation operations often reveal additional areas of material that were not identified during the characterization investigation. Color and portable radiation meter measurements will be used to make an initial determination of the material disposition. However, if obvious indications of activity are not available, samples will be collected to characterize the material. Sufficient samples must be collected to confidently disposition the material to the appropriate disposal site.

Because this material has not been previously characterized, a limited amount of TCLP samples may be required.

4.4.1 Previously Inaccessible or Unidentified Area Samples - Data Quality Objectives

The primary DQO that needs to be addressed is proper characterization of the material to ensure the appropriate landfill acceptance criteria are met. These areas will be evaluated to ensure sufficient material is removed in preparation for the final verification sampling.

All of the samples must be of sufficient quality to ensure that accurate Site data has been collected.

4.4.2 Previously Inaccessible or Unidentified Area Samples - Sample Locations, Numbering, and Documentation

Characterization samples will be primarily evaluated for radionuclides to determine if the area is Class 1 or Class 2 area material. Some metals samples may be collected at the discretion of the Project Manager or RSO. Actual sample collection locations will be selected after the area has been exposed and a preliminary evaluation (visual and instrument check) is complete.

Sample numbering for these areas will be as follows. Samples will be sequentially numbered as follows: PL101, PL102, PL103, etc. for the City of Golden pipeline area. Split samples from the areas will be labeled with an S suffix (e.g., PL102-S). Previously unidentified area sample areas will be numbered as Ux101, Ux102, Ux103, etc. where the "x" will be replaced with a letter (A, B, C) that designated the sequence in which the areas were discovered. The area and corresponding letter code must be noted in the field notebook. Split samples from the areas will be labeled with an S suffix (e.g., Ux102-S). Sample numbers will be legibly written on the sample containers (see section 3.2.3) and the chain-of-custody applicable (COC) form.

A general description of the sample material will be noted in the field notebook. Data required for all samples includes a description of soil type (e.g., silt, clay, sand) and the estimated percentages of the type. Soil color also shall be noted in the field notebook.

4.4.3 Previously Inaccessible or Unidentified Area Samples - Sample Collection Methodology

Prior to the collection of any soil sample a 10-second gamma measurement of the location will be made and recorded along with the sample number in the field notebook. A gamma measurement for each associated composite location also will be made and recorded.

Radionuclide soil samples will be obtained from the uppermost 15 centimeters of surface soil. The sample should be approximately cylindrical in cross section so that all horizontal components are equally represented in the sample. The soil at the selected sample location will be composited with four additional samples (equal volume) collected randomly within a radius of two meters. The five aliquots (about 500 cubic centimeters each) will be composited into a clean plastic container (preferably white or clear plastic) and homogenized. Cobbles, gravel, and organic material will be minimized in the samples. Because of the quantity of clay on site, screens or other methods may be required to produce an acceptable sample. After the samples have been homogenized, the soil will be placed in a 500-milliliter plastic jar filled to the top. The jar will be shaken, etc. to maximize the amount of soil in each jar. Samples will then be placed inside two resealable plastic bags. Laboratory samples also will include an additional 250 to 500 cubic centimeters of soil placed inside two resealable plastic bags. The additional material is necessary for alpha spectroscopy and/or metals analysis. A plastic bag will be used to keep the laboratory sample jars and bags together. Certified clean sample containers shall be used for all samples. Sampling equipment decontamination procedures are provided in section 2.5.1.

All relevant sampling data will be entered on an on site chain-of-custody form that will be kept with the samples to monitor the transfer of sample control (i.e., field technician to ISOCS personnel). A separate chain-of-custody form will be filled out for all samples submitted to the laboratory. No special preservatives are required for the radionuclide samples. Metals samples that are collected must be maintained on ice and promptly delivered to the laboratory.

4.5 Sample Storage and Shipment - All Samples

Samples will be placed in the on-site sample locker with the corresponding chain of custody. Samples requiring laboratory analysis can be stored up to one week prior to shipment. Metals samples will be stored in coolers on ice (4°C - requirement for mercury) and shipped to the laboratory within one day of collection. All samples requiring laboratory analysis will be couriered to the appropriate laboratory.

4.6 Sample Analytical Requirements

Samples for radiological analysis will be analyzed for following radioisotopes of the thorium and uranium decay chain: Ra-226, Ra-228, Th-228, Th-230, Th-232, U-234, U-235, and U-238. Sufficient samples also will be analyzed for Pb-210 and Po-210 to determine if a secular equilibrium has been achieved with a more easily detected radioisotope (e.g., Bi-214). Radionuclides will be analyzed using the ISOCS with at least 20-percent of all samples sent to a certified analytical laboratory for confirmation. If analytical values between the laboratory and ISOCS vary significantly, additional samples may be sent to the laboratory until a level of confidence is achieved. Samples with unspecified radioisotopes that are identified by the ISOCS analysis at a significant activity, will be brought to the attention of the project or data manager for evaluation. Radionuclide detection limits for the analytes are detailed in the QAPP.

Metals samples will be analyzed for arsenic, cadmium, lead, and mercury. These samples will be sent directly to a certified laboratory.

TCLP samples will primarily be analyzed for metals of concern on an as needed basis (previously inaccessible or unidentified areas). Additional TCLP requirements may be necessary if volatile compounds or other materials are discovered.

All analytes will be specified on the COC as required by the QAPP.

5.0 SAMPLING AND ANALYSIS SUPPORTING MATERIAL REMOVAL

Instrument surveys will be performed during material removal operations to ensure that fugitive radiologically impacted material is not dispersed beyond the Site during material removal operations. Other instrument surveys will be performed to ensure that waste shipped for disposal does not contain radionuclides above transportation requirements or landfill waste acceptance criteria.

5.1 Transportation Vehicle Survey and Documentation

The characterization data indicates on average that the TENORM and solid waste material identified on the Site are below activity levels regulated by the Department of Transportation. However, steps will be taken to ensure that the level of non-fixed (removable) radioactive contamination on the external surfaces of each package/vehicle is kept as low as reasonably achievable. Wipes will be collected from the Lift Liner^{TM} bags and compared to the requirements presented in 49 CFR 173.443, Table 11 (General transportation requirements, Part 173 Shippers - General Requirements for Shipments and Packaging). For the purpose of shipping, the material has been classified as transportation Class 9 (miscellaneous dangerous goods). The 49 CFR 173.443 requirements are for the actual shipment of radioactive material (transportation Class 7) and can be assumed as a worst case scenario for Site material.

Contaminant	Maximum permissible limits (decays per minute per square centimeter)
Beta and gamma emitters and low toxicity alpha emitters	22
All other alpha emitting radionuclides	2.2

From: 49 CFR 173.443, Table 11.

The dpm for these limits refers to the rate of emission by radioactive material as determined by correcting the counts per minute observed by the appropriate detector for background, efficiency, and geometric factors associated with the instrument. The measurement of average contamination should not be averaged over more than one square meter. For objects of less surface area, the average should be determined for each such object. The amount of removable radioactive material per 300 square centimeters of surface area should be determined by wiping that area with dry filter or soft absorbent paper (wipe samples), applying moderate pressure, and assessing the amount of radioactive material on the wipe with an appropriate instrument of known efficiency (NRC, Regulatory Guide 1.86). Sufficient measurements will be taken in the most appropriate locations to yield a representative assessment of the non-fixed contamination levels.

Determination of instrument background and efficiency is discussed in section 2.1.

Equipment, tools, and transportation vehicle surveys will involve the following specific activities (as necessary).

- Survey and document incoming equipment, tools, and transportation vehicles for total surface radioactivity,
- Survey and document outgoing equipment, tools, and transportation vehicles for total surface radioactivity,
- Survey and document outgoing equipment, tools, and transportation vehicles for removable surface radioactivity if necessary, and
- Survey and document outgoing loaded transportation vehicles for gamma radiation.

Each of these activities is further described in the following sections.

5.1.1 Incoming Equipment Surveys

All equipment entering the Site will be surveyed to determine the level of surface radioactivity that may be present. Equipment surfaces will be surveyed for alpha radioactivity. Each tire of wheeled equipment will be surveyed at one ground contact location. Selected locations on metal surfaces also will be surveyed (floor of operator cab).

Survey measurements will consist of instantaneous measurements of alpha activity. Alpha activity will be measured using a Ludlum model 43-5 large area scintillation detector (or equivalent) combined with a Ludlum model 2221 or 2350-1 counting instrument. These limits will be converted to equivalent instrument counts per minute by dividing the applicable disintegration rate by the instrument efficiency and active detector area.

Alternatively, timed counts may be obtained from survey locations for increased accuracy if instantaneous counts are near an acceptance limit.

Incoming instrument surveys will be recorded on an incoming equipment survey form. The survey form will include the following information:

- Equipment identification, including manufacturer, model number, serial number, owner's identification number, and/or license plate number as necessary to uniquely identify the item being surveyed.
- Model and serial numbers of the detectors and counters used to perform the survey.
- Name of the person performing the survey.
- A sketch of the equipment. Schematic drawings are sufficient if they permit accurate location of measurements.
- The numerical value of the instantaneous alpha count rates at each measurement location.
- Date and time of the survey.

A wipe sample will be obtained from any survey location that shows surface radioactivity in excess of the 49 CFR 173.443, Table 11 limits. Additional wipe samples may be collected randomly to ensure contamination is not moved off site.

5.1.2 Outgoing Equipment Survey

Equipment leaving the Site during the Class 1 excavation operations, including transportation vehicles for soil, will be surveyed before leaving the Site. Efforts will be made to limit transportation vehicle access during loading operations (see MHTP). The release survey will be conducted in the same manner as the incoming equipment survey. The release survey will be documented on an equipment release survey form. The equipment release survey and the matching incoming equipment survey will be compared. If the equipment item has acquired net fixed or removable radioactivity in excess of the Site release criteria, it must be decontaminated and resurveyed before leaving the Site.

Trucks that have entered the exclusion zone also may receive a gamma radiation survey using a Ludlum Model 19 MicroR dose rate meter or equivalent. Measurements will be made along the center of the load on both sides and the rear of the vehicle’s cargo bed at contact and at a distance of one meter. A separate measurement will be obtained in the driver’s cabin. Gamma radiation measurements will be recorded on the outgoing survey form.

One purpose of this gamma radiation survey is to ensure compliance with requirements for transportation of radioactive materials. The materials to be removed from the Site are unlikely to approach regulated transportation limits. A second purpose of this gamma survey is to ensure that none affected material will be summarily rejected by the receiving disposal facility. Any load of non-affected solid waste that exhibits detectable gamma radiation anomalies during this survey must not leave the Site. Any such load will be stockpiled in a designated staging area and be reassigned to disposal at the licensed radioactive material disposal facility.

Efforts will be made during the loading of the Class 2 area material to limit transportation vehicles to "clean" areas of the Site. Details of this process are provided in the MHTP.

6.0 EXPOSURE MONITORING

Exposure of employees to airborne and ionizing radiation will be monitored throughout the project. Specific measurements and procedures are identified in the following sections.

6.1 Dosimetry

Exposure to external ionizing radiation will be measured using thermoluminescent dosimeters. Each Site employee will be provided with a dosimeter that will be worn between the knees and shoulders whenever the employee is on site. Dosimeters will be analyzed on a quarterly basis. A designated secure storage location removed from sources of Site radiation will be used to store dosimeters when not in use.

Dosimetry results will presented to the Site employees, and posted in a prominent location on the Site for review. The Site RSO will be available to interpret the dosimetry results to the employees on request.

6.2 Personal Air Monitoring

Personal air monitoring will be performed throughout the Class 1 excavation operations. Once the Class 1 material has been removed from the Site, the daily monitoring will continue during the first

10 days of the Class 2 area work and periodically thereafter. Personal air samples will be collected on appropriate sampling media. Personal air samples will be monitored for total alpha radioactivity after a 72-hour holding time to allow for radon daughter decay. Total alpha radioactivity will be compared to the Derived Air Concentration (DAC) for thorium-230 (see table), the Site radionuclide with the most restrictive exposure limitation. The sample media will then be submitted to an accredited laboratory for isotopic analysis. The isotopic analyses will identify the isotope(s) of concern. The identified isotopes will be used for the remainder of project for anticipated air contaminants expected. All subsequent air samples will be counted on-site, air concentrations calculated, and compared to the appropriate standard. The derived air concentrations will be used to determine the appropriate level of respiratory protection.

Class	Derived Air Concentration (DAC) (microcuries per milliliter)
W, all materials except Class Y	$3x10^{-12}$
Y, oxides and hydroxides	$6x10^{-12}$

From 10CFR20, Appendix B to Part 20, Class W will be assumed for Site.

At the start of project activities, at least one employee in each work area will be provided with a personal sampling pump and dust collection cassette. The pump will be operated for the entire shift. If the measured alpha activity is less than the DAC for Thorium-230, no further action is necessary. If the measured alpha indicates that a potential exposure to Thorium-230 above the DAC may have occurred, the air sample filter will be submitted for laboratory analysis and a radionuclide-specific exposure will be determined.

This procedure will be repeated for each new work activity. During continuing work activities, at least one employee will be monitored each week to maintain a continuing record of potential employee exposure to airborne radioactivity.

6.3 Work Area Air Monitoring

Each work area will be monitored for airborne radioactivity on a weekly basis. Four 60 liters per minute air sampler will be located at the Site perimeters and operated throughout the shift. The air sampler will be provided with a dust collection cassette. A 10-day baseline area exposure assessment will be performed as detailed in Section 5.2.

After the holding time for radon daughter decay, each work area air monitor will be analyzed for total alpha activity. As with the personal air monitor, if the Site perimeter air monitor indicates that the DAC for thorium-230 (see table) may have been exceeded, the filter will be submitted for laboratory analysis and radionuclide-specific exposures will be calculated.

6.4 Work Area Dose Rate Monitoring

In addition to personal dosimetry measurements, a regular program of work area dose rate monitoring will be performed. Each day that work activities are carried out on the Site, work areas will be monitored for ionizing radiation. Monitoring will be performed using a pressurized ion chamber (PIC) or a gamma scintillation detector such as the Ludlum model 19 or equivalent that has been correlated to a PIC.

Any work area with an exposure rate equal to or greater than 5 millirads per hour will be designated as a radiation area. Radiation areas will be clearly marked with warning signs and flagging tape. Entry into the radiation area and duration of work in the radiation area will be controlled by and documented by the RSO. Based on previous experience with the Site, no radiation areas are anticipated.

A written record of work area dose rate monitoring will be prepared and maintained to calculate potential employee exposure to ionizing radiation.

6.5 Dose Calculation and Recording

Total employee exposure to ionizing radiation will be calculated on a quarterly basis. Employee exposure will consist of external ionizing radiation exposure as measured by the dosimetry program and internal exposures. Internal exposure will be determined on the basis of the air monitoring results and radon exposure monitoring results. The internal and external exposure will be combined to yield a total radiation dose exposure value for each employee.

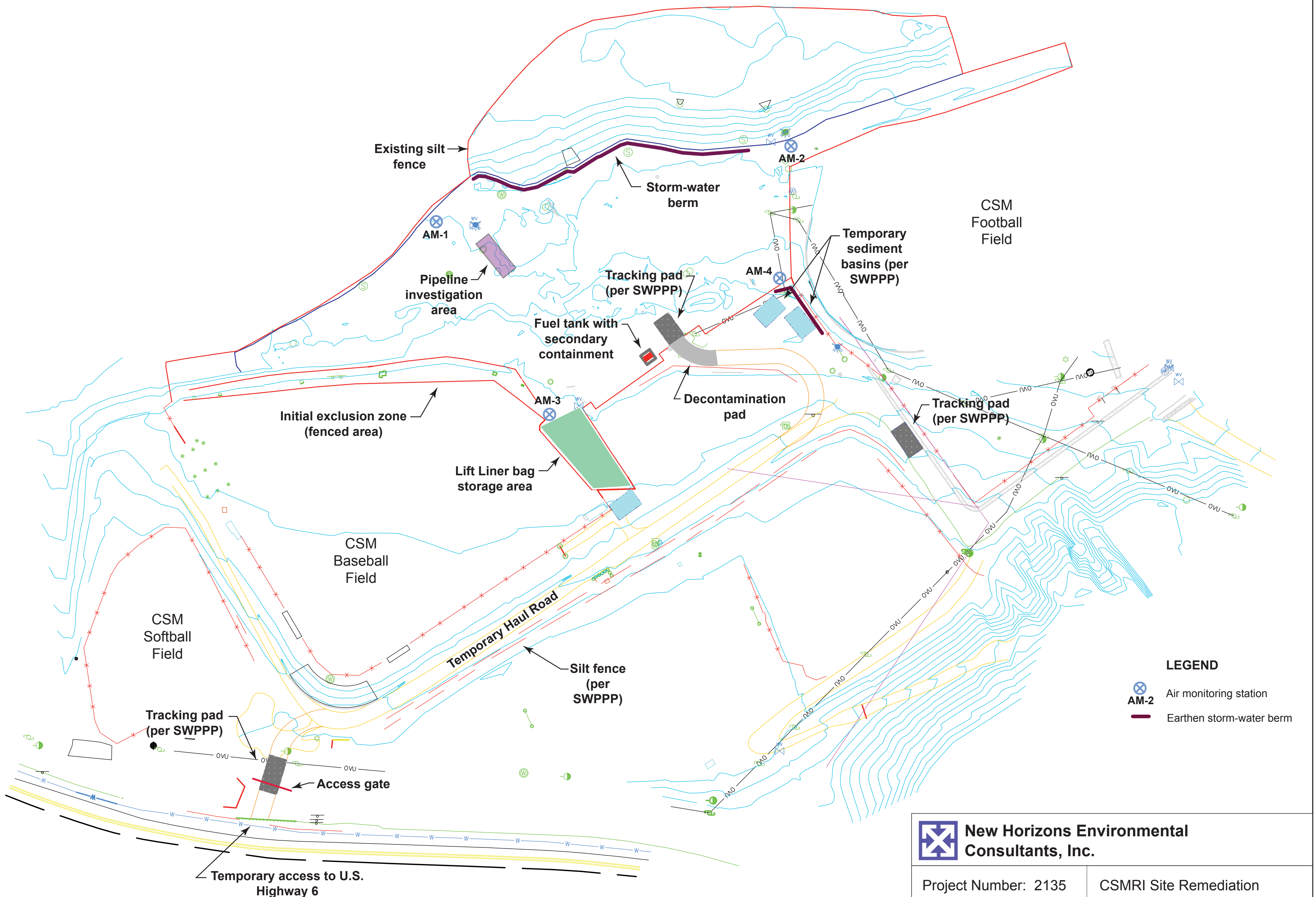
6.6 Dose Reporting

Employees will be informed of their dose exposure record as the values are obtained. Employee dose exposure records will be generated and maintained indefinitely for communication to future employers or the employee.

7.0 FINAL REPORT

A final data report will be submitted at the end of the project that documents the decision processes and summarizes the excavation and sampling activities. The report will contain copies of all applicable documentation relating to ISOCS measurements, laboratory analyses, and transport and disposal of soils. Exposure records for Site personnel, air monitoring data, photographs, and other documentation relating to the conduct and progress of the project will be included as Appendices.

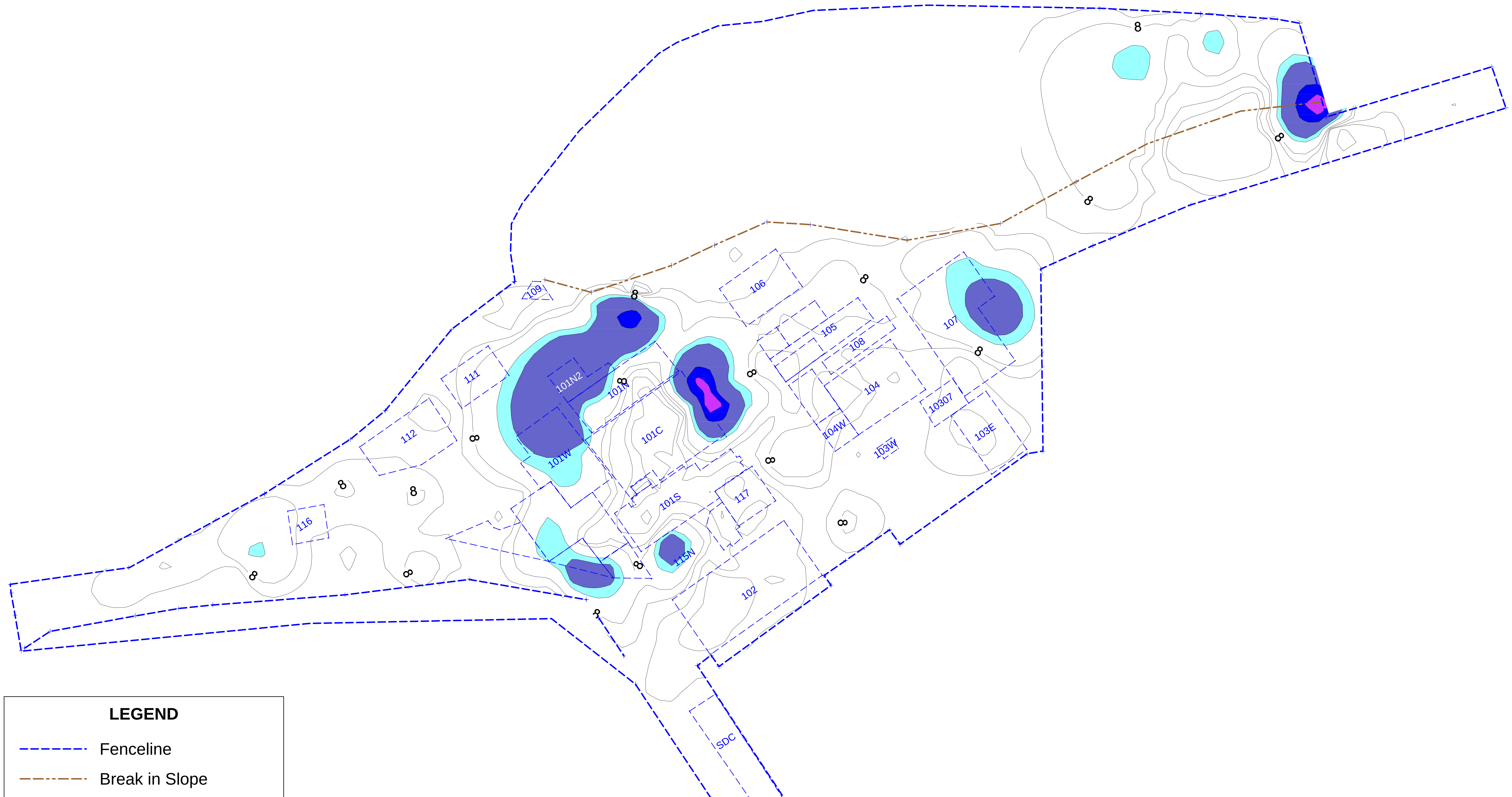
FIGURES



New Horizons Environmental Consultants, Inc.

Project Number: 2135	CSMRI Site Remediation
Date: April 14, 2004	Figure 1 CSMRI Site

Figure 1 CSMRI Site - Predicted Class 1 Areas
(Kriging Performed on Characterization Samples)



LEGEND

- Fenceline
- Break in Slope
- Building Outline

N

0 10 20 30 40
Meters

New Horizons Environmental Consultants, Inc.
6585 South Wright Street
Littleton, CO 80127-4806

Project: CSMRI Site Remediation	Date: April 13, 2004
Project Number: 2135	Figure 1 Class 1 Areas

APPENDIX A

CSMRI SITE REMEDIATION

STATEMENT OF WORK
FOR
ON-SITE RADIOLOGICAL MEASUREMENTS
WITH
IN SITU OBJECT COUNTING SYSTEM - CANBERRA INDUSTRIES
REVISION 2

March 24, 2004

New Horizons Environmental Consultants, Inc.
6585 S. Wright Street
Littleton, CO 80127

Table of Contents

1.0 GENERAL INFORMATION AND SCOPE

This Statement of Work (SOW) documents the technical, quality control, and deliverable requirements for on-site analysis of soils containing radionuclides at the CSMRI Remediation Site (Site) in Golden, Colorado. Canberra (Subcontractor) shall provide New Horizons Environmental Consultants, Inc. (Contractor) with the necessary labor, supervision, equipment, materials, analytical reports, and sample documentation to support the on-site radionuclide analytical portion of the Site remediation using an In Situ Object Counting System (ISOCS).

1.1 Location of the Required Services

The services shall be performed at the on-site sample trailer located south of the main entrance of the fenced portion of the CSMRI Remediation Site. The trailer is equipped with furniture, electricity, lighting, and air conditioning but phone service is not available on site. Cell phones and Site radios are used to maintain Site communications. The Subcontractor shall plan accordingly for communication. The Subcontractor will be provided with a key(s) to the trailer and the trailer shall be locked when not occupied.

Additional services required by the Subcontractor may include a limited amount of on site in situ measurements.

1.2 Project Schedule and Hours

The Subcontractor shall provide the services described in this contract during normal workdays, that is, Monday through Friday with the exception of specific holidays. The Subcontractor shall provide routine services between the hours of 7:30 a.m. and 4:00 p.m., however, hours may be adjusted because of weather conditions or to meet off-site transportation requirements. Overtime hours are not anticipated but may be required for specific tasks. Weather conditions, equipment failure, etc. may result in limited downtime during the project, which may result in all personnel being dismissed from the Site for all or part of a day. The anticipated work schedule is from April 1, 2004 through June 30, 2004 but the schedule may change because of delays or accelerated production rates.

2.0 REGULATORY COMPLIANCE, PERMITS, LICENSES

The Colorado Department of Public Health and Environment (CDPHE) issued a Radioactive Materials License for the Site (License 617-01). The license authorizes storage of NORM, source, and byproduct materials. Sources used for portable field instrument calibration are documented in the New Horizons' *Radioactive Materials License Application for Waste Brokers and Consultants Handling Radioactive Materials.* The Subcontractor shall provide the appropriate documentation associated with all calibration sources used on the Site. A copy of all calibration source documentation shall be maintained on site.

The Subcontractor shall perform all operations associated with this contract in accordance with all current public laws and occupational health, safety and environmental protection regulations applicable to the management of all regulated and non-regulated waste chemicals, chemically contaminated equipment, and samples submitted for laboratory analysis. All Subcontractor operations shall comply with applicable Federal, State, and local regulations and/or all changes in these regulations and/or permit conditions that govern the handling, packing, transportation, treatment and disposal of all regulated and non-regulated chemicals, chemically contaminated equipment, and samples for laboratory analysis.

The Contractor will provide disposal services for all materials generated from the Site. If additional chemicals are required for the operation of the ISOCS, the Subcontractor shall inform the Contractor and may be responsible for final disposal of any generated waste.

Equipment transported to an from the Site shall have the appropriate packing, containers, labels, packing slips, and Material Safety Data Sheets to meet the requirements of all United States (U.S.) Department of Transportation (DOT), U.S. Environmental Protection Agency (EPA), and State and local regulations. In addition, shipment of unspecified equipment also shall comply with U.S. Postal Service (USPS) or any other applicable shipping requirements.

3.0 ANALYTICAL EQUIPMENT

The Subcontractor shall provide all necessary equipment for the proper operation of the ISOCS instrument.

4.0 SPECIFIC REQUIREMENTS - SAMPLING, TESTING, AND ANALYSIS

The Contractor personnel will provide all labor, supervision, materials, equipment, and facilities for the sample collection. The Subcontractor may be requested to perform a limited amount of in situ sampling and will control the operation of the ISOCS equipment. Contractor personnel will provide assistance on an as needed basis.

Contractor supplied soil samples will be composited (five point composite), homogenized, placed in 500 milliliter plastic jars (jars will be double bagged - resealable plastic), properly labeled and documented, and placed in an on-site sample locker (located near the laboratory trailer). All samples will be documented with an on-site chain-of-custody (COC) form that will identify the sampler, sample number, analytes, sample collection time and date, and track the transfer of the samples. COC information will be neatly printed - handwriting must be legible. The COC shall be maintained with the samples at all times. The COC also will be used to track sample weight (using an on site scale).

Two levels of samples will be collected from the Site, screening samples and Site verification samples. The screening samples will be used to determine if sufficient material has been removed from the Site (excavation activities). Verification samples are legally defensible samples that provide documentation of the final condition of the Site and the average activities of material transported off site for disposal.

A percentage of the soil samples will be transferred to a certified analytical laboratory after ISOCS analysis has been completed. Samples for laboratory analysis will be selected at random, however, specific samples may be selected if necessary. At least 10-percent of the samples sent to the analytical laboratory will be split samples. A laboratory specific COC form will document all samples sent to the analytical laboratory. All relevant data (e.g., sample collection date and time, matrix, analytical requirements, etc.) shall be properly documented on the laboratory COC.

All samples (except those submitted to the laboratory) shall be archieved on site until a determination has been made that the material disposition has been correctly identified. The Contractor will dispose of all samples at the appropriate disposal facility.

The average number of samples generated during a standard workday is estimated to be between eight and ten. The majority of these samples will be screening samples. If extra samples are collected during a single day they shall be stored in the on-site sample locker for the following day. Up to five days of laboratory samples may be stored in the sample locker if necessary. At the end of the five-day period the laboratory COC will be completed and the samples shall be couriered to the laboratory (Contractor responsibility).

The following table indicates the required analytes and minimum detection limits (MDL) required for Site verification. If the ISOCS cannot attain these MDLs, a relationship between the radionuclide in question and another detectable radionuclide in the decay chain will be established for the Site material. In order to determine these relationships sample submittal to the laboratory may be increased during the initial phases of the project. The Contractor recognizes that some of the MDLs will be problematic for the ISOCS instrumentation and will work with the Subcontractor to determine Site specific detection limits.

Radionuclide	Minimum Detection Limits (picocuries per gram)
Lead-210	0.7
Polonium-210	0.7
Radium-226	1.0
Radium-228	1.0
Thorium-228	1.0
Thorium-230	1.0
Thorium-232	1.0
Uranium-234*	1.7
Uranium-235*	0.17
Uranium-238*	1.7

*Site ratios for uranium have been established.

If the ISOCS identifies additional radionuclides at elevated activities during the sample analytical process, the information shall be brought to the attention of the Contractor as soon as possible.

Analytical protocols shall be in accordance with established Subcontractor methods. A copy of these protocols shall be available on site for review by the Contractor, if necessary, and any deviations from these protocols shall be noted (see section 5.0).

5.0 DELIVERABLES

ISOCS data will be maintained and transferred electronically. Sample data shall be reviewed and submitted to the Contractor within 72-hours (email or CD) or at the direction of Contractor project or data manager. Analytical results for the screening samples shall be verbally communicated to the Contractor as soon as possible (screening data will be the primary guide for excavation and needs to be promptly communicated). The electronic submission to the Contractor data manager shall be in an accessible format (e.g., ASCII format, Microsoft Word, or Microsoft Excel). Files may be in pdf format for data control, but data access must be provided to the Contractor data manager. The format of the electronic submission shall be similar to the long and short form examples submitted to the Contractor. If additional elevated radionuclides are discovered during the analytical process, quantitative data about these radionuclides shall be documented in the analytical reports. Unidentified peaks shall be brought to the attention of project management and documented.

Short form reports are required for the screening samples; however, about 10-percent of these samples should be documented with the long form (random selection). The verification samples shall all be documented with the long form. The Contractor data manager may request additional long form reports for specific sample areas.

In addition to all analytical data the Subcontractor shall document all calibration procedures, instrumentation modifications, and deviations from the Subcontractors internal procedures. A summary of this information shall be provided to the Contractor in electronic format (pdf file or equivalent). The Subcontractor shall collect sufficient information to allow data validation by a third party, if necessary. The Subcontractor shall perform an internal data validation process at least monthly and electronically submit the findings to the Contractor.

APPENDIX B

C-2 Preacceptance Protocol

C-2a Hazardous Waste Preacceptance Review

The preacceptance protocol has been designed to ensure that only hazardous waste streams that can be properly and safely stored, treated and/or disposed of by USEI are approved for receipt at the facility. A two-step approach is taken by USEI. The first step is the chemical and physical characterization of the candidate waste stream by the generator. The second step is the preacceptance evaluation preformed by USEI to determine the acceptability of the waste for receipt at the facility. Figure C-2 presents a logic diagram of the preacceptance protocol that is utilized at the facility.

C-2a(1) Radioactive Material Waste Acceptance Criteria

The following waste acceptance criteria are established for accepting radiological contaminated waste material that is not regulated by the Nuclear Regulatory Commission (NRC) under the Atomic Energy Act of 1954, as amended. These criteria are set forth in the following four tables establishing types and concentrations of radioactive materials that may be accepted.

The tables are based on categories and types of radioactive material not regulated by the NRC based on statute or regulation. The criteria are consistent with these restrictions and detailed analyses set forth in *Waste Acceptance Criteria and Justification for FUSRAP Material*, prepared by Radiation Safety Associates, Inc. (RSA) as subsequently refined, expanded and updated in *Waste Acceptance Criteria and Justification for Radioactive Material*, prepared by USEI certified Health Physicists in consultation with RSA.

Based on the categories of waste described in the waste acceptance criteria, the concentration of the various radionuclides in the conveyance (e.g., rail car gondola, other container etc.) shall not exceed the concentration limits established in the WAC. If individual “pockets” of activity are detected indicating the limits may be exceeded, the Facility Radiation Safety Officer or Facility Safety Officer shall investigate the discrepancy and estimate the extent or volume of the material with the potentially elevated radiation levels. The Radiation Safety Officer shall then make a determination on the compliance of the entire conveyance load with the appropriate WAC limits. If the conveyance is determined to meet the limits, the material may be disposed. If an exceedance is determined to exist, USEI will contact the IDEQ’s Radiation Control Program (Radiation Control Officer) to evaluate and discuss management options. The findings and resolution actions shall then be documented and submitted to the IDEQ.

The radioactive material waste acceptance criteria, when used in conjunction with an effective radiation monitoring and protection program as defined in the USEI *Radioactive Material Health and Safety Manual* and *Radioactive Material Receipt Procedures* provides adequate protection of human health and the environment. Included within this manual are requirements for USEI to submit a written summary report of waste receipts showing volumes and radionuclide concentrations disposed at the USEI site on quarterly basis.

These criteria and procedures are designed to assure that the highest potential dose to a worker handling radioactive material at USEI shall not exceed 400 mrem/year TEDE dose, and that no member of the public is calculated to receive a potential dose exceeding 15 mrem/year TEDE dose, from the USEI program. TEDE is defined as the “Total Effective Dose Equivalent”, which equals the sum of external and internal exposures. The public dose limit during operational activities will be limited to 100 mrem/yr TEDE dose.

Table 1: Unimportant Quantities of Source Material Uniformly Dispersed* in Soil or Other Media**

Status of Equilibrium	Maximum Concentration of Source Material	Sum of Concentrations Parent(s) and all progeny present***
Natural uranium in equilibrium with progeny	211 ppm / 141 pCi/g	≤ 2000 pCi/g
Refined natural uranium (U-238,235,234; Th-234; Pa-234m)	500 ppm / 333 pCi/g	
Depleted Uranium,DU(Th-234 & Pa-234m)	500 ppm / 169 pCi/g	
Natural thorium (Th-232 + Th-228)	500 ppm / 110 pCi/g	
Thorium-230 in equilibrium with progeny	0.01 ppm / 200 pCi/g	≤2000 pCi/g
Thorium-230 (with no progeny)	0.1 ppm / ≤2000 pCi/g	
Any mixture of Thorium and Uranium	Sum of ratios ≤ 1****	≤2000 pCi/g

Table 2: Naturally Occurring Radioactive Material Other Than Source Material Uniformly Dispersed* in Soil or Other Media**

Status of Equilibrium	Maximum Concentration of Parent Nuclide	Sum of Concentrations of Parent and All Progeny Present***
Radium-226 or 228 with progeny	222 pCi/g	≤2000 pCi/g
Lead-210 with progeny(Bi & Po-210)	666 pCi/g	≤2000 pCi/g
Any other NORM		≤2000 pCi/g

Table 3: Accelerator Produced Radioactive Material

Acceptable Material	Activity or Concentration
Any accelerator produced radionuclide the half-life of which is ≤ 3 years. Longer half-life materials may only be accepted based on IDEQ review and approval of a specific proposal.	All materials shall be packaged in metal packages, metal drums or metal boxes meeting the USDOT Type A package requirements. Any packages containing iodines or volatile radionuclides will have lids or covers sealed to the container with gaskets. Contamination levels on the surface of the packages shall not exceed those allowed at point of receipt by USDOT rules. Gamma or x-ray radiation levels may not exceed 10 millirem per hour anywhere on the surface of the package. All packages received shall be directly disposed in the active cell. All containers shall be certified to be 90% full.

*Average over conveyance or container. The use of the phrase "over the conveyance or container is meant to reflect the variability on the generator side. The concentration limit is the primary acceptance criteria.

**Other Media does not include radioactively contaminated liquid (except for incidental liquids in soils or other materials).

*** Defuse waste with a total concentration (sum of concentrations of all radionuclides present) which is 2000 pCi/g or less may be accepted at the site (i.e, the controlling limits is 2000 pCi/g).

**** $$\frac{\text{Conc. of U in sample}}{\text{Allowable conc. of U}} + \frac{\text{Conc. of Th in Sample}}{\text{Allowable conc. of Th}} \leq 1$$

Table 4: NRC Exempted Products, Devices or Items

Exemption 10 CFR Part	Product, Device or Item	Isotope, Activity or Concentration
30.15	Timepieces, lock illuminators, balances, auto shift quadrants, marine compasses, thermostat dials & pointers, internal and external calibration sources for radiation measurement devices, spark gap irradiators.	Various isotopes and activities as set forth in 30.15
30.16	Resins containing Sc-46 for sand consolidation in oil wells	Activity by Manufacuring License. Surface radiation level must not exceed 10 millirem/hr.
30.19	Self-luminous products containing tritium, Kr-85, H-3 or Pm-147	Activity by Manufacturing license
30.20	Gas and aerosol detectors for protection of life and property from fire	Isotope and activity by Manufacturing license
30.21	Capsules containing C-14 urea for *in vivo* diagnosis of humans	Carbon-14, one microcurie per capsule
40.13(a)	Unimportant quantity of source material: see table above	≤0.05% by weight source material
40.13(b)	Unrefined and unprocessed ore containing source material	2,000 pCi/gm (source material plus progeny)
40.13(c)(1)	Source material in incandescent gas mantles, vacuum tubes, welding rods, electric lamps for illumination	Thorium and uranium, various amounts or concentrations, see rules
40.13(c)(2)	(i)Source material in glazed ceramic tableware	≤20% by weight
	(ii)Piezoelectric ceramic	≤2% by weight
	(iii)glassware not including glass brick, pane glass, ceramic tile, or other glass or ceramic used in construction	≤10% by weight
40.13(c)(3)	Photographic film, negatives or prints	Uranium or Thorium
40.13(c)(4)	Finished product or part fabricated of or containing tungsten or magnesium-thorium alloys. Cannot treat or process chemically, metallurgically, or physically.	≤4% by weight thorium content.
40.13(c)(5)	Uranium contained in counterweights installed in aircraft, rockets, projectiles and missiles or stored or handled in connection with installation or removal of such counterweights.	Per stated conditions in rule.
40.13(c)(6)	Uranium used as shielding in shipping containers if conspicuously and legibly impressed with legend "CAUTION RADIOACTIVE SHIELDING – URANIUM" and uranium incased in at least 1/8 inch thick steel or fire resistant metal.	Depleted Uranium
40.13(c)(7)	Thorium contained in finished optical lenses	≤30% by weight thorium, per conditions in rule.
40.13(c)(8)	Thorium contained in any finished aircraft engine part containing nickel-thoria alloy.	≤4% by weight thorium, per conditions in rule.
32.11, 32.18, 40.41	Other materials, products or devices exempted from NRC regulation by rule, order, license, license condition or letter of interpretation may only be accepted based on IDEQ review and approval of a specific proposal.	IDEQ will review for approval any other materials, products, or devices exempted from the NRC not already specified in this modification. Approval of this material will not require a formal modification.

APPENDIX C

On Site Chain-of-Custody

CSMRI Site Remediation

New Horizons Environmental Consultants, Inc.

Date ________________ Page ___ of ____

*COC Number CSMRI-*______________________________

6585 South Wright Street, Littleton, CO 80127
Phone: (303) 932-2220 Fax: (303) 932-2221

Project Number: 2135 **Sampler(s):**

Sample ID	Date	Sample Collection Time (military time)	ISOCS ID	Matrix (S,Soil; W, Water)	Number of Containers	Sample Weight (grams)	Laboratory Sample? (Y/N)	Sample Dried? (Y/N)

Comments:

Relinquished By:
Signature ______________________
Printed Name ____________________
Date ___________ Time _________
Company _______________________

Received By:
Signature ______________________
Printed Name ____________________
Date ___________ Time _________
Company _______________________

225 Commerce Drive Fort Collins, CO 80524
800-443-1511 or (970) 490-1511 (970) 490-1522 Fax

Accession Number (LAB ID) ______________________

Paragon Analytics, Inc.

Chain-of-Custody

Date ______________ Page ___ of ____

Project Name / No.: ______________________ **Sampler(s):** ______________________ (circle one) **Turnaround: Standard or Rush (Due ___________) Dispose or Return to Client**

Report To:
Phone: **Fax:**
Company:
Address:

circle method or specify under comments

Sample ID	Date	Time *	Lab ID	Matrix	No. of Containers	VOCs (SW8260B E624 E524.2 OLMO___)	BTEX (only) (SW8021B)	SVOCs (SW8270C E625 E525 OLMO___)	OC Pesticides (SW8081A E608 E508 OLMO___)	PCBs (SW8082 E608 E508 OLMO___)	OP Pesticides (SW8141A E614)	Herbicides (SW8151A E615)	TCLP Organics (SW1311 8260B 8270C 8081A 8151A)	TCLP Metals (SW 1311 6010B 7471)	Total Metals (SW6010B 7470 7471 E200 ILMO___)	Dissolved Metals (SW6010B 7470 E200 ILMO___)	Reactive CN / S (SW846 Chapter 7)	Hexavalent Chromium (SW7196A Alkaline Digest? Y / N)	Inorganic Anions ** (SW9056 E300.0)	pH (SW9040B 9045C)	Oil & Grease (SW9071A E413.2)	TPH (GRO DRO SW8015B (both))	TOX (SW9020B)	Gross Alpha / Beta (SW9310 E900.0)	Actinides by PAI SOP (circle): Pu / U / Am / Th / Cm	Total Uranium by KPA (D5174-91)	Tritium (E906.0)	Total Alpha-Emitting Radium (SW9315 E903.0)	Radium 226 SW9315 E903.0 / Radium 228 SW9320 E904.0	Strontium 89 D5811-95 / Strontium 90 D5811-95	Gamma Isotopes ** (E901.1)		

Comments:

Form 202r4.xls (1/3/01)

Relinquished By: (1)	*Relinquished By:* (2)
Signature ______________	Signature ______________
Printed Name ______________	Printed Name ______________
Date ________ Time ________	Date ________ Time ________
Company ______________	Company ______________
Received By: (1)	*Received By:* (2)
Signature ______________	Signature ______________
Printed Name ______________	Printed Name ______________
Date ________ Time ________	Date ________ Time ________
Company ______________	Company ______________

*** Time Zone** (circle one) : EST CST MST PST

**** Indicate specific analytes under comments.**

Distribution: white / yellow (Paragon); pink retained by originator.

APPENDIX D

Class 1 Areas - Excavation Verification Samples

0.05 Alpha and 0.10 Beta - 20% Samples to Laboratory

Systematic sampling locations for detecting an area of elevated values (hot spot)

This report summarizes the sampling design used, associated statistical assumptions, as well as general guidelines for conducting post-sampling data analysis. Sampling plan components presented here include how many sampling locations to choose and where within the sampling area to collect those samples. The type of medium to sample (i.e., soil, groundwater, etc.) and how to analyze the samples (in-situ, fixed laboratory, etc.) are addressed in other sections of the sampling plan.

The following table summarizes the sampling design developed. A figure that shows sampling locations in the field and a table that lists sampling location coordinates are also provided below.

SUMMARY OF SAMPLING DESIGN	
Primary Objective of Design	Detect the presence of a hot spot that has a specified size and shape
Type of Sampling Design	Hot spot
Sample Placement (Location) in the Field	Systematic (Hot Spot) with a random start location
Formula for calculating number of sampling locations	Singer and Wickman algorithm
Calculated total number of samples	66
Number of samples on map [a]	68
Number of selected sample areas [b]	8
Specified sampling area [c]	2046.44 ft^2
Grid pattern	Triangular
Size of grid / Area of grid cell [d]	6 feet / 31.1769 ft^2
Total cost of sampling [e]	$31880.00

[a] This number may differ from the calculated number because of 1) grid edge effects, 2) adding judgment samples, or 3) selecting or unselecting sample areas.
[b] The number of selected sample areas is the number of colored areas on the map of the site. These sample areas contain the locations where samples are collected.
[c] The sampling area is the total surface area of the selected colored sample areas on the map of the site.
[d] Size of grid / Area of grid cell gives the linear and square dimensions of the grid used to systematically place samples.
[e] Including measurement analyses and fixed overhead costs. See the Cost of Sampling section for an explanation of the costs presented here.

Area 1					
X Coord	Y Coord	Label	Value	Type	Historical
480300.9314	4400393.8918		0	Hotspot	
480306.9314	4400393.8918		0	Hotspot	
480291.9314	4400388.6957		0	Hotspot	
480297.9314	4400388.6957		0	Hotspot	
480303.9314	4400388.6957		0	Hotspot	
480309.9314	4400388.6957		0	Hotspot	
480282.9314	4400383.4995		0	Hotspot	
480288.9314	4400383.4995		0	Hotspot	
480294.9314	4400383.4995		0	Hotspot	
480300.9314	4400383.4995		0	Hotspot	
480306.9314	4400383.4995		0	Hotspot	
480279.9314	4400378.3033		0	Hotspot	
480285.9314	4400378.3033		0	Hotspot	
480291.9314	4400378.3033		0	Hotspot	
480297.9314	4400378.3033		0	Hotspot	
480276.9314	4400373.1072		0	Hotspot	
480282.9314	4400373.1072		0	Hotspot	
480288.9314	4400373.1072		0	Hotspot	
480294.9314	4400373.1072		0	Hotspot	
480279.9314	4400367.9110		0	Hotspot	
480285.9314	4400367.9110		0	Hotspot	
480291.9314	4400367.9110		0	Hotspot	
480282.9314	4400362.7149		0	Hotspot	
480288.9314	4400362.7149		0	Hotspot	
480294.9314	4400362.7149		0	Hotspot	
480285.9314	4400357.5187		0	Hotspot	
480291.9314	4400357.5187		0	Hotspot	

Area 2					
X Coord	Y Coord	Label	Value	Type	Historical
480325.9015	4400386.6108		0	Hotspot	
480322.9015	4400381.4147		0	Hotspot	
480328.9015	4400381.4147		0	Hotspot	
480319.9015	4400376.2185		0	Hotspot	
480325.9015	4400376.2185		0	Hotspot	
480331.9015	4400376.2185		0	Hotspot	
480322.9015	4400371.0224		0	Hotspot	
480328.9015	4400371.0224		0	Hotspot	
480334.9015	4400371.0224		0	Hotspot	
480325.9015	4400365.8262		0	Hotspot	

480331.9015	4400365.8262		0	Hotspot	

Area 3					
X Coord	**Y Coord**	**Label**	**Value**	**Type**	**Historical**
480395.5905	4400400.8964		0	Hotspot	
480392.5905	4400395.7002		0	Hotspot	
480398.5905	4400395.7002		0	Hotspot	
480404.5905	4400395.7002		0	Hotspot	
480395.5905	4400390.5041		0	Hotspot	
480401.5905	4400390.5041		0	Hotspot	

Area 4					
X Coord	**Y Coord**	**Label**	**Value**	**Type**	**Historical**
480473.2927	4400462.1429		0	Hotspot	
480479.2927	4400462.1429		0	Hotspot	
480470.2927	4400456.9468		0	Hotspot	
480476.2927	4400456.9468		0	Hotspot	
480482.2927	4400456.9468		0	Hotspot	
480488.2927	4400456.9468		0	Hotspot	
480467.2927	4400451.7506		0	Hotspot	
480473.2927	4400451.7506		0	Hotspot	
480479.2927	4400451.7506		0	Hotspot	
480485.2927	4400451.7506		0	Hotspot	
480491.2927	4400451.7506		0	Hotspot	
480470.2927	4400446.5544		0	Hotspot	
480476.2927	4400446.5544		0	Hotspot	
480482.2927	4400446.5544		0	Hotspot	
480488.2927	4400446.5544		0	Hotspot	
480473.2927	4400441.3583		0	Hotspot	
480479.2927	4400441.3583		0	Hotspot	

Area 5					
X Coord	**Y Coord**	**Label**	**Value**	**Type**	**Historical**
480426.6676	4400456.7012		0	Hotspot	
480423.6676	4400451.5050		0	Hotspot	

Area 6					
X Coord	**Y Coord**	**Label**	**Value**	**Type**	**Historical**

Area 7					
X Coord	**Y Coord**	**Label**	**Value**	**Type**	**Historical**

480290.4067	4400335.7605		0	Hotspot	
480293.4067	4400330.5643		0	Hotspot	
480299.4067	4400330.5643		0	Hotspot	
480296.4067	4400325.3682		0	Hotspot	
480302.4067	4400325.3682		0	Hotspot	

Area 8					
X Coord	**Y Coord**	**Label**	**Value**	**Type**	**Historical**

Primary Sampling Objective
The primary purpose of sampling at this site is to detect "hot spots" (local areas of elevated concentration) of a given size and shape with a specified probability, 1-β.

Selected Sampling Approach
This sampling approach requires systematic grid sampling with a random start. If a systematic grid is not used, the probability of detecting a hot spot of a given size and shape will be different than desired or calculated.

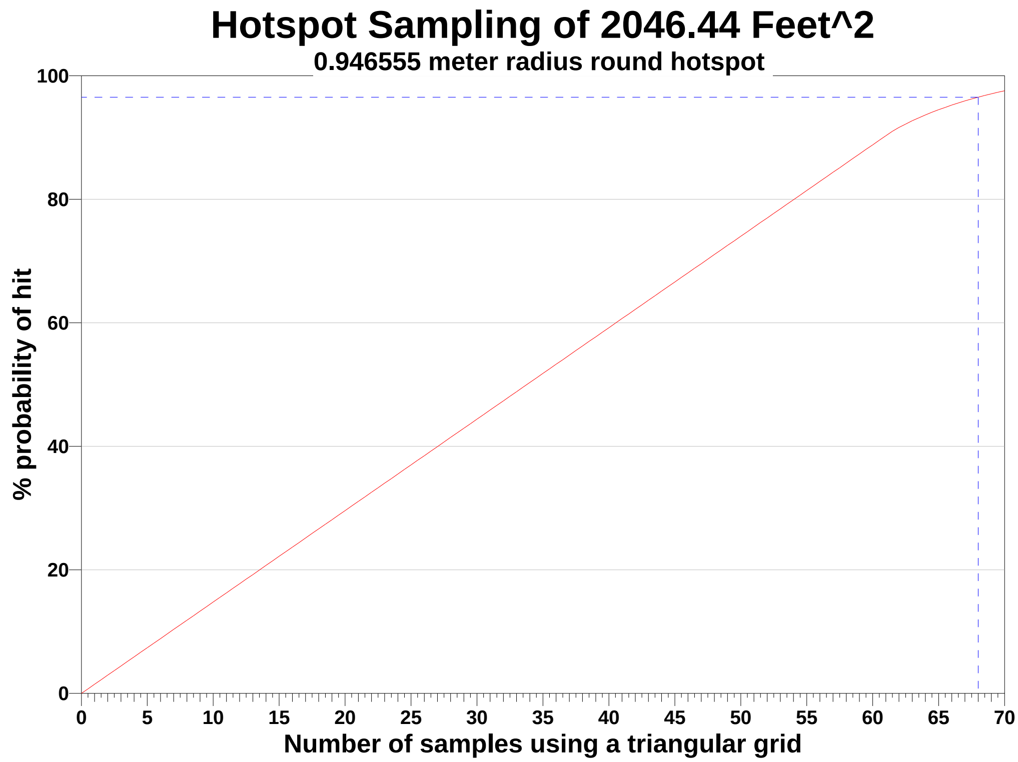
Number of Total Samples: Calculation Equation and Inputs
The algorithm used to calculate the grid size (and hence, the number of samples) is based on work by Singer for locating geologic deposits [see Singer (1972, 1975) and PNNL-13450 for details]. Inputs to the algorithm include the size, shape, and orientation of a hot spot of interest, an acceptable probability of not finding a hot spot, the desired type of sampling grid, and the sampling budget. For this design, the smallest hot spot that could be detected was calculated based on a given grid size and other parameters.

The inputs to the algorithm that result in the smallest hot spot that could be detected are:

Parameter	Description	Value
Inputs		
1-β	Probability of detection	95%
Grid Type	Grid pattern (Square, Triangular or Rectangular)	Triangular
Grid Size	Length of side of grid	6 feet
Grid Area	Area covered by one grid cell	31.1769 ft^2
Hot Spot Shape	Hot spot height to width ratio	1
Angle	Angle of orientation between hot spot and grid	Random
Sampling Area	Total area to sample	2046.44 ft^2
Outputs		
Hot Spot Size	Length of hot spot semi-major axis	0.946555 meters
Hot Spot Area [a]	Area of hot spot ($Length^2$ * Shape * π)	30.2976 ft^2
Samples [b]	Optimum number of samples	65.6397

[a] Length of semi-major axis is used by algorithm. Hot spot area is provided for informational purposes.
[b] The optimum number of samples is calculated by dividing the sampling area by the grid area.

The following graph shows the relationship between number of samples and the probability of finding the hot spot. The dashed blue line shows the actual number of samples for this design (which may differ from the optimum number of samples because of edge effects).



Statistical Assumptions
The assumptions associated with the sample spacing algorithm are that:
1. the target hot spot (its projection onto the coordinate plane) is circular or elliptical,
2. samples are taken on a square, rectangular, or triangular grid,
3. a very small proportion of the area being studied will be sampled (the sample is much smaller than the hot spot of interest),
4. the level of contamination that classifies a hot spot is well defined, and
5. there are no misclassification errors (a hot spot is not mistakenly overlooked or an area is not mistakenly identified as a hot spot).

These assumptions cannot be validated through data collection. The size and shape of a hot spot of interest are well defined prior to determining the number of samples and the measured value that defines a hot spot is well above the detection limit for the analytical methods that will be used. Grid sampling will be carried out to the level achievable; topographic, vegetative, and other features that prevent sampling at the specified coordinates will be noted and their influence recognized.

Sensitivity Analysis
The sensitivity of the calculation of number of samples was explored by varying Area and Side and examining the resulting changes in the number of samples. The following table shows the results of this analysis.

Number of Samples			
	Side=3	**Side=6**	**Side=9**
Area=1023.22	132	33	15
Area=2046.44	263	66	30
Area=3069.66	394	99	44

Area = Total Sampling Area
Side = Length of Grid Side

Cost of Sampling
The total cost of the completed sampling program depends on several cost inputs, some of which are fixed, and others that are based on the number of samples collected and measured. Based on the numbers of samples determined above, the estimated total cost of sampling and analysis at this site is $31880.00, which averages out to a per sample cost of $483.03. The following table summarizes the inputs and resulting cost estimates.

COST INFORMATION

Cost Details	Per Analysis	Per Sample	66 Samples
Field collection costs		$100.00	$6600.00
Analytical costs	$80.00	$80.00	$5280.00
Sum of Field & Analytical costs		**$180.00**	**$11880.00**
Fixed planning and validation costs			$20000.00
Total cost			**$31880.00**

Recommended Data Analysis Activities

Post data collection activities generally follow those outlined in EPA's Guidance for Data Quality Assessment (EPA, 2000). The data analysts will become familiar with the context of the problem and goals for data collection and assessment. The data will be verified and validated before being subjected to statistical or other analyses. Graphical and analytical tools will be used to verify to the extent possible the assumptions of any statistical analyses that are performed as well as to achieve a general understanding of the data. The data will be assessed to determine whether they are adequate in both quality and quantity to support the primary objective of sampling.

A map of the actual sample locations will be generated so that the sampling plan and the field implementation may be compared. Deviations from planned sample locations due to topographic, vegetative, or other features will be noted. Their impacts will be qualitatively assessed. If a hot spot is discovered, additional sampling may be performed to determine its size and shape, in which case, the initial assumptions of the sampling design may then be assessed and/or reconsidered.

Area 1

X Coord	Y Coord	Label	Value	Type	Historical
480300.93	4400393.89		0	Hotspot	False
480306.93	4400393.89		0	Hotspot	False
480291.93	4400388.70		0	Hotspot	False
480297.93	4400388.70		0	Hotspot	False
480303.93	4400388.70		0	Hotspot	False
480309.93	4400388.70		0	Hotspot	False
480282.93	4400383.50		0	Hotspot	False
480288.93	4400383.50		0	Hotspot	False
480294.93	4400383.50		0	Hotspot	False
480300.93	4400383.50		0	Hotspot	False
480306.93	4400383.50		0	Hotspot	False
480279.93	4400378.30		0	Hotspot	False
480285.93	4400378.30		0	Hotspot	False
480291.93	4400378.30		0	Hotspot	False
480297.93	4400378.30		0	Hotspot	False
480276.93	4400373.11		0	Hotspot	False
480282.93	4400373.11		0	Hotspot	False
480288.93	4400373.11		0	Hotspot	False
480294.93	4400373.11		0	Hotspot	False
480279.93	4400367.91		0	Hotspot	False
480285.93	4400367.91		0	Hotspot	False
480291.93	4400367.91		0	Hotspot	False
480282.93	4400362.71		0	Hotspot	False
480288.93	4400362.71		0	Hotspot	False
480294.93	4400362.71		0	Hotspot	False
480285.93	4400357.52		0	Hotspot	False
480291.93	4400357.52		0	Hotspot	False

Area 2

X Coord	Y Coord	Label	Value	Type	Historical
480325.90	4400386.61		0	Hotspot	False
480322.90	4400381.41		0	Hotspot	False
480328.90	4400381.41		0	Hotspot	False
480319.90	4400376.22		0	Hotspot	False
480325.90	4400376.22		0	Hotspot	False
480331.90	4400376.22		0	Hotspot	False
480322.90	4400371.02		0	Hotspot	False
480328.90	4400371.02		0	Hotspot	False
480334.90	4400371.02		0	Hotspot	False
480325.90	4400365.83		0	Hotspot	False
480331.90	4400365.83		0	Hotspot	False

Area 3

X Coord	Y Coord	Label	Value	Type	Historical
480395.59	4400400.90		0	Hotspot	False
480392.59	4400395.70		0	Hotspot	False
480398.59	4400395.70		0	Hotspot	False
480404.59	4400395.70		0	Hotspot	False
480395.59	4400390.50		0	Hotspot	False
480401.59	4400390.50		0	Hotspot	False

Area 4

X Coord	Y Coord	Label	Value	Type	Historical
480473.29	4400462.14		0	Hotspot	False
480479.29	4400462.14		0	Hotspot	False
480470.29	4400456.95		0	Hotspot	False
480476.29	4400456.95		0	Hotspot	False
480482.29	4400456.95		0	Hotspot	False
480488.29	4400456.95		0	Hotspot	False
480467.29	4400451.75		0	Hotspot	False
480473.29	4400451.75		0	Hotspot	False
480479.29	4400451.75		0	Hotspot	False

Area 4 (cont.)

X Coord	Y Coord	Label	Value	Type	Historical
480485.29	4400451.75		0	Hotspot	False
480491.29	4400451.75		0	Hotspot	False
480470.29	4400446.55		0	Hotspot	False
480476.29	4400446.55		0	Hotspot	False
480482.29	4400446.55		0	Hotspot	False
480488.29	4400446.55		0	Hotspot	False
480473.29	4400441.36		0	Hotspot	False
480479.29	4400441.36		0	Hotspot	False

Area 5

X Coord	Y Coord	Label	Value	Type	Historical
480426.67	4400456.70		0	Hotspot	False
480423.67	4400451.51		0	Hotspot	False

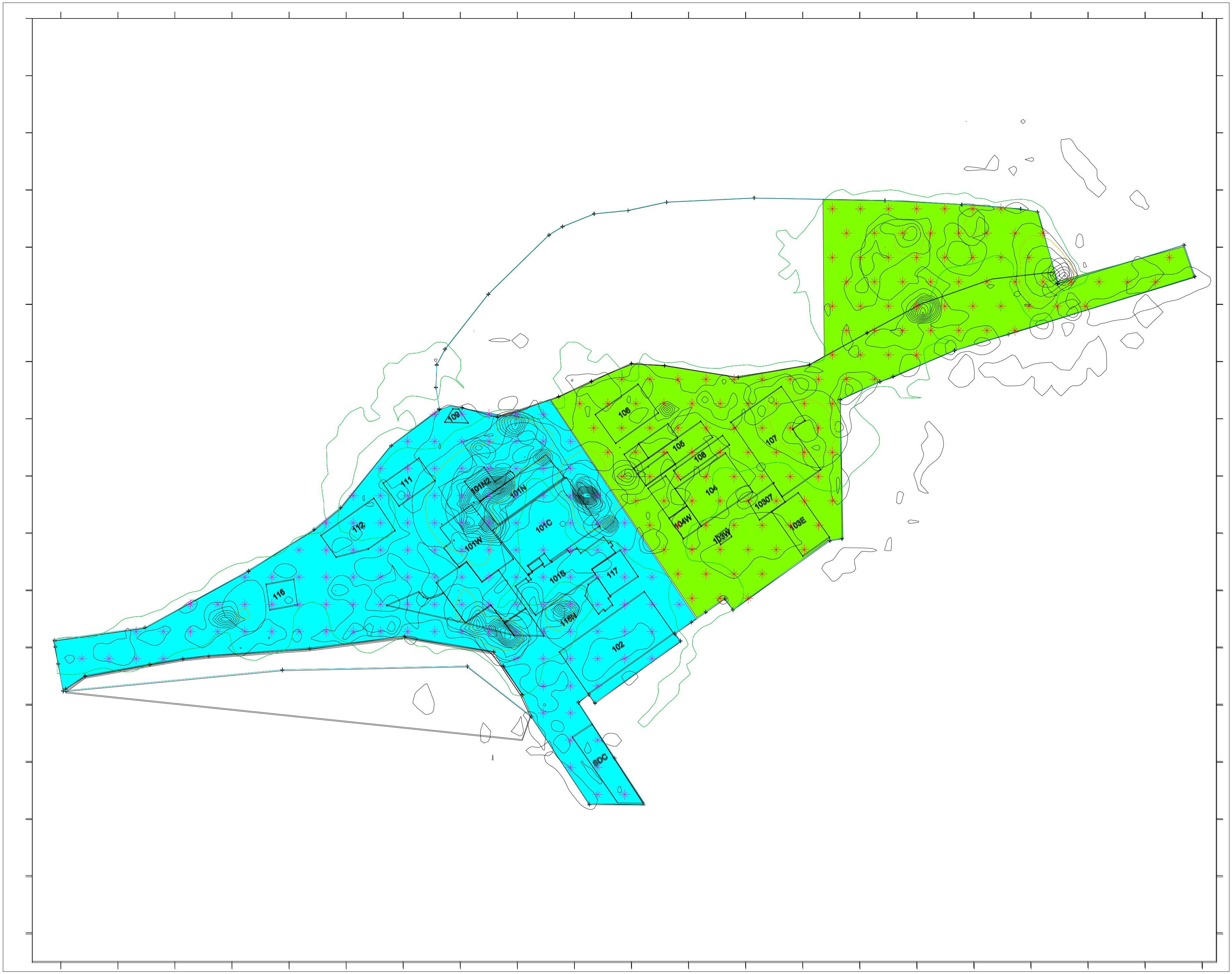
Area 7

X Coord	Y Coord	Label	Value	Type	Historical
480290.41	4400335.76		0	Hotspot	False
480293.41	4400330.56		0	Hotspot	False
480299.41	4400330.56		0	Hotspot	False
480296.41	4400325.37		0	Hotspot	False
480302.41	4400325.37		0	Hotspot	False

APPENDIX E

Class 2 Areas - Final Verification Samples

0.05 Alpha and 0.10 Beta - 20%



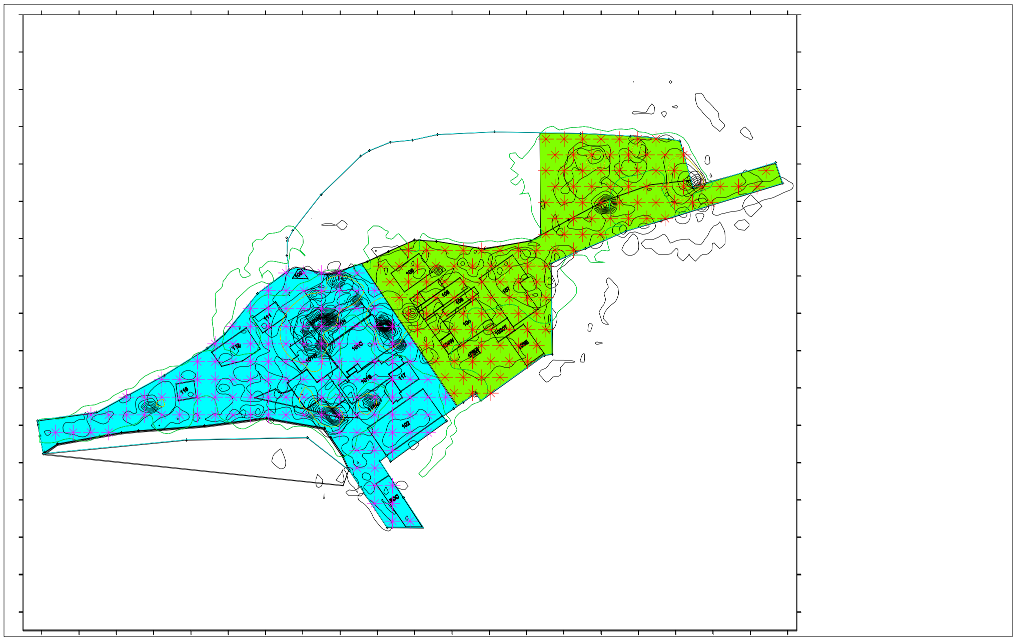
Systematic sampling locations for comparing a mean with a fixed threshold (nonparametric)

Summary
This report summarizes the sampling design used, associated statistical assumptions, as well as general guidelines for conducting post-sampling data analysis. Sampling plan components presented here include how many sampling locations to choose and where within the sampling area to collect those samples. The type of medium to sample (i.e., soil, groundwater, etc.) and how to analyze the samples (in-situ, fixed laboratory, etc.) are addressed in other sections of the sampling plan.

The following table summarizes the sampling design developed. A figure that shows sampling locations in the field is also provided below.

SUMMARY OF SAMPLING DESIGN	
Primary Objective of Design	Compare a site mean or median to a fixed threshold
Type of Sampling Design	Nonparametric
Sample Placement (Location) in the Field	Systematic with a random start location
Working (Null) Hypothesis	The median(mean) value at the site exceeds the threshold
Formula for calculating number of sampling locations	Wilcoxon signed ranks test
Calculated total number of samples	131
Number of samples on map [a]	262
Number of selected sample areas [b]	2
Specified sampling area [c]	19221.76 ft^2
Size of grid / Area of grid cell [d]	8.72555 feet / 76.1353 ft^2
Grid pattern	Square
Total cost of sampling [e]	$66500.00

[a] This number may differ from the calculated number because of 1) grid edge effects, 2) adding judgment samples, or 3) selecting or unselecting sample areas.
[b] The number of selected sample areas is the number of colored areas on the map of the site. These sample areas contain the locations where samples are collected.
[c] The sampling area is the total surface area of the selected colored sample areas on the map of the site.
[d] Size of grid / Area of grid cell gives the linear and square dimensions of the grid used to systematically place samples.
[e] Including measurement analyses and fixed overhead costs. See the Cost of Sampling section for an explanation of the costs presented here.



Primary Sampling Objective
The primary purpose of sampling at this site is to compare a median or mean value with a fixed threshold. The working hypothesis (or 'null' hypothesis) is that the median(mean) value at the site is equal to or exceeds the threshold. The alternative hypothesis is that the median(mean) value is less than the threshold. VSP calculates the number of samples required to reject the null hypothesis in favor of the alternative one, given a selected sampling approach and inputs to the associated equation.

Selected Sampling Approach
A nonparametric systematic sampling approach with a random start was used to determine the number of samples and to specify sampling locations. A nonparametric formula was chosen because the conceptual model and historical information (e.g., historical data from this site or a very similar site) indicate that typical parametric assumptions may not be true.

Both parametric and non-parametric equations rely on assumptions about the population. Typically, however, non-parametric equations require fewer assumptions and allow for more uncertainty about the statistical distribution of values at the site. The trade-off is that if the parametric assumptions are valid, the required number of samples is usually less than if a non-parametric equation was used.

Locating the sample points over a systematic grid with a random start ensures spatial coverage of the site. Statistical analyses of systematically collected data are valid if a random start to the grid is used. One disadvantage of systematically collected samples is that spatial variability or patterns may not be discovered if the grid spacing is large relative to the spatial patterns.

Number of Total Samples: Calculation Equation and Inputs
The equation used to calculate the number of samples is based on a Wilcoxon Signed Ranks test. For this site, the null hypothesis is rejected in favor of the alternative one if the sample median(mean) is sufficiently smaller than the threshold. The number of samples to collect is calculated so that if the inputs to the equation are true, the calculated number of samples will cause the null hypothesis to be rejected.

The formula used to calculate the number of samples is:

$$n = 1.16\left[\frac{\left(S_{sample}^{2} + \frac{S_{analytical}^{2}}{r}\right)}{\Delta^{2}}\left(Z_{1-\alpha} + Z_{1-\beta}\right)^{2} + 0.5 Z_{1-\alpha}^{2}\right]$$

where

n	is the number of samples,
S	is the estimated standard deviation of the measured values including analytical error,
Δ	is the width of the gray region,
α	is the acceptable probability of incorrectly concluding the site median(mean) is less than the threshold,
β	is the acceptable probability of incorrectly concluding the site median(mean) exceeds the threshold,
$Z_{1-\alpha}$	is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\alpha}$ is $1-\alpha$,
$Z_{1-\beta}$	is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\beta}$ is $1-\beta$.

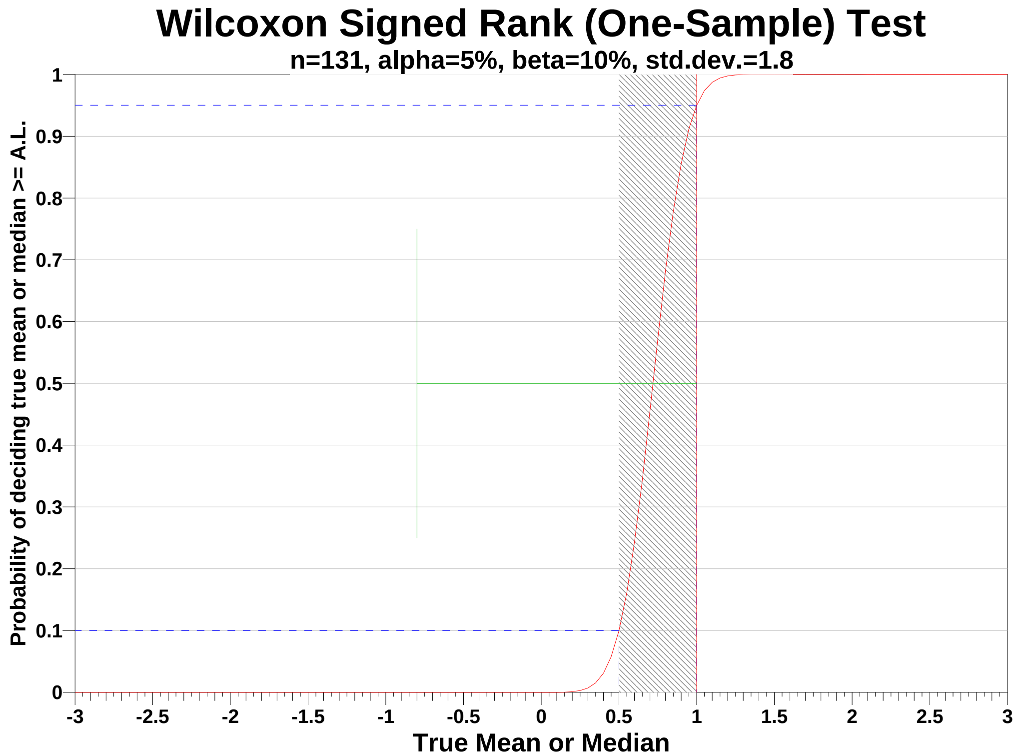
The values of these inputs that result in the calculated number of sampling locations are:

Parameter	**Value**
S	1.8
Δ	0.5
α	5%
β	10%
$Z_{1-\alpha}$	1.64485 [a]
$Z_{1-\beta}$	1.28155 [b]

[a] This value is automatically calculated by VSP based upon the user defined value of α.
[b] This value is automatically calculated by VSP based upon the user defined value of β.

The following figure is a performance goal diagram, described in EPA's QA/G-4 guidance (EPA, 2000). It shows the probability of concluding the sample area is dirty on the vertical axis versus a range of possible true median(mean) values for the site on the horizontal axis. This graph contains all of the inputs to the number of samples equation and pictorially represents the calculation.

The red vertical line is shown at the threshold (action limit) on the horizontal axis. The width of the gray shaded area is equal to Δ; the upper horizontal dashed blue line is positioned at $1-\alpha$ on the vertical axis; the lower horizontal dashed blue line is positioned at β on the vertical axis. The vertical green line is positioned at one standard deviation below the threshold. The shape of the red curve corresponds to the estimates of variability. The calculated number of samples results in the curve that passes through the lower bound of Δ at β and the upper bound of Δ at $1-\alpha$. If any of the inputs change, the number of samples that result in the correct curve changes.



Statistical Assumptions
The assumptions associated with the formulas for computing the number of samples are:
1. the data originate from a symmetric (but not necessarily normal) population,
2. the variance estimate, S^2, is reasonable and representative of the population being sampled,
3. the population values are not spatially or temporally correlated, and
4. the sampling locations will be selected probabilistically.

The first three assumptions will be assessed in a post data collection analysis. The last assumption is valid because the gridded sample locations were selected based on a random start.

Sensitivity Analysis
The sensitivity of the calculation of number of samples was explored by varying LBGR and β and examining the resulting changes in the number of samples. The following table shows the results of this analysis.

Number of Samples			
AL=1	**β=5**	**β=10**	**β=15**
LBGR=90	4069	3221	2704
LBGR=80	1019	807	678
LBGR=70	454	360	302

LBGR = Lower Bound of Gray Region (% of Action Level)
β = Beta (%), Probability of mistakenly concluding that μ > action level
AL = Action Level (Threshold)

Cost of Sampling
The total cost of the completed sampling program depends on several cost inputs, some of which are fixed, and others that are based on the number of samples collected and measured. Based on the numbers of samples determined above, the estimated total cost of sampling and analysis at this site is $66500.00, which averages out to a per sample cost of $507.63. The following table summarizes the inputs and resulting cost estimates.

COST INFORMATION			
Cost Details	**Per Analysis**	**Per Sample**	**131 Samples**
Field collection costs		$100.00	$13100.00

Analytical costs	$400.00	$400.00	$52400.00
Sum of Field & Analytical costs		**$500.00**	**$65500.00**
Fixed planning and validation costs			$1000.00
Total cost			**$66500.00**

Recommended Data Analysis Activities
Post data collection activities generally follow those outlined in EPA's Guidance for Data Quality Assessment (EPA, 2000). The data analysts will become familiar with the context of the problem and goals for data collection and assessment. The data will be verified and validated before being subjected to statistical or other analyses. Graphical and analytical tools will be used to verify to the extent possible the assumptions of any statistical analyses that are performed as well as to achieve a general understanding of the data. The data will be assessed to determine whether they are adequate in both quality and quantity to support the primary objective of sampling.

Because the primary objective for sampling for this site is to compare the site median(mean) value with a threshold value, the data will be assessed in this context. Assuming the data are adequate, at least one statistical test will be done to perform a comparison between the data and the threshold of interest. Results of the exploratory and quantitative assessments of the data will be reported, along with conclusions that may be supported by them.

Area 12

X Coord	Y Coord	Label	Value	Type	Historical
480405.74	4400466.36		0	Systematic	False
480414.77	4400466.36		0	Systematic	False
480423.80	4400466.36		0	Systematic	False
480432.82	4400466.36		0	Systematic	False
480441.85	4400466.36		0	Systematic	False
480450.88	4400466.36		0	Systematic	False
480459.91	4400466.36		0	Systematic	False
480410.25	4400458.54		0	Systematic	False
480419.28	4400458.54		0	Systematic	False
480428.31	4400458.54		0	Systematic	False
480437.34	4400458.54		0	Systematic	False
480446.37	4400458.54		0	Systematic	False
480455.40	4400458.54		0	Systematic	False
480464.42	4400458.54		0	Systematic	False
480473.45	4400458.54		0	Systematic	False
480405.74	4400450.72		0	Systematic	False
480414.77	4400450.72		0	Systematic	False
480423.80	4400450.72		0	Systematic	False
480432.82	4400450.72		0	Systematic	False
480441.85	4400450.72		0	Systematic	False
480450.88	4400450.72		0	Systematic	False
480459.91	4400450.72		0	Systematic	False
480468.94	4400450.72		0	Systematic	False
480514.08	4400450.72		0	Systematic	False
480410.25	4400442.90		0	Systematic	False
480419.28	4400442.90		0	Systematic	False
480428.31	4400442.90		0	Systematic	False
480437.34	4400442.90		0	Systematic	False
480446.37	4400442.90		0	Systematic	False
480455.40	4400442.90		0	Systematic	False
480464.42	4400442.90		0	Systematic	False
480473.45	4400442.90		0	Systematic	False
480482.48	4400442.90		0	Systematic	False
480491.51	4400442.90		0	Systematic	False
480500.54	4400442.90		0	Systematic	False
480509.57	4400442.90		0	Systematic	False
480405.74	4400435.08		0	Systematic	False
480414.77	4400435.08		0	Systematic	False
480423.80	4400435.08		0	Systematic	False
480432.82	4400435.08		0	Systematic	False
480441.85	4400435.08		0	Systematic	False
480450.88	4400435.08		0	Systematic	False
480459.91	4400435.08		0	Systematic	False
480468.94	4400435.08		0	Systematic	False
480477.97	4400435.08		0	Systematic	False
480487.00	4400435.08		0	Systematic	False
480410.25	4400427.27		0	Systematic	False
480419.28	4400427.27		0	Systematic	False
480428.31	4400427.27		0	Systematic	False
480437.34	4400427.27		0	Systematic	False
480446.37	4400427.27		0	Systematic	False
480455.40	4400427.27		0	Systematic	False
480464.42	4400427.27		0	Systematic	False
480405.74	4400419.45		0	Systematic	False
480414.77	4400419.45		0	Systematic	False
480423.80	4400419.45		0	Systematic	False
480432.82	4400419.45		0	Systematic	False
480338.02	4400411.63		0	Systematic	False
480347.05	4400411.63		0	Systematic	False
480356.08	4400411.63		0	Systematic	False
480365.11	4400411.63		0	Systematic	False
480374.14	4400411.63		0	Systematic	False
480383.17	4400411.63		0	Systematic	False
480392.20	4400411.63		0	Systematic	False
480401.22	4400411.63		0	Systematic	False

Area 12 (cont.)

X Coord	Y Coord	Label	Value	Type	Historical
480410.25	4400411.63		0	Systematic	False
480419.28	4400411.63		0	Systematic	False
480324.48	4400403.81		0	Systematic	False
480333.51	4400403.81		0	Systematic	False
480342.54	4400403.81		0	Systematic	False
480351.57	4400403.81		0	Systematic	False
480360.60	4400403.81		0	Systematic	False
480369.62	4400403.81		0	Systematic	False
480378.65	4400403.81		0	Systematic	False
480387.68	4400403.81		0	Systematic	False
480396.71	4400403.81		0	Systematic	False
480405.74	4400403.81		0	Systematic	False
480328.99	4400395.99		0	Systematic	False
480338.02	4400395.99		0	Systematic	False
480347.05	4400395.99		0	Systematic	False
480356.08	4400395.99		0	Systematic	False
480365.11	4400395.99		0	Systematic	False
480374.14	4400395.99		0	Systematic	False
480383.17	4400395.99		0	Systematic	False
480392.20	4400395.99		0	Systematic	False
480401.22	4400395.99		0	Systematic	False
480333.51	4400388.17		0	Systematic	False
480342.54	4400388.17		0	Systematic	False
480351.57	4400388.17		0	Systematic	False
480360.60	4400388.17		0	Systematic	False
480369.62	4400388.17		0	Systematic	False
480378.65	4400388.17		0	Systematic	False
480387.68	4400388.17		0	Systematic	False
480396.71	4400388.17		0	Systematic	False
480405.74	4400388.17		0	Systematic	False
480338.02	4400380.35		0	Systematic	False
480347.05	4400380.35		0	Systematic	False
480356.08	4400380.35		0	Systematic	False
480365.11	4400380.35		0	Systematic	False
480374.14	4400380.35		0	Systematic	False
480383.17	4400380.35		0	Systematic	False
480392.20	4400380.35		0	Systematic	False
480401.22	4400380.35		0	Systematic	False
480342.54	4400372.53		0	Systematic	False
480351.57	4400372.53		0	Systematic	False
480360.60	4400372.53		0	Systematic	False
480369.62	4400372.53		0	Systematic	False
480378.65	4400372.53		0	Systematic	False
480387.68	4400372.53		0	Systematic	False
480396.71	4400372.53		0	Systematic	False
480405.74	4400372.53		0	Systematic	False
480347.05	4400364.71		0	Systematic	False
480356.08	4400364.71		0	Systematic	False
480365.11	4400364.71		0	Systematic	False
480374.14	4400364.71		0	Systematic	False
480383.17	4400364.71		0	Systematic	False
480392.20	4400364.71		0	Systematic	False
480401.22	4400364.71		0	Systematic	False
480351.57	4400356.89		0	Systematic	False
480360.60	4400356.89		0	Systematic	False
480369.62	4400356.89		0	Systematic	False
480378.65	4400356.89		0	Systematic	False
480387.68	4400356.89		0	Systematic	False
480396.71	4400356.89		0	Systematic	False
480356.08	4400349.08		0	Systematic	False
480365.11	4400349.08		0	Systematic	False
480374.14	4400349.08		0	Systematic	False
480383.17	4400349.08		0	Systematic	False
480360.60	4400341.26		0	Systematic	False
480369.62	4400341.26		0	Systematic	False

Area 12 (cont.)

X Coord	Y Coord	Label	Value	Type	Historical
480378.65	4400341.26		0	Systematic	False

Area 13

X Coord	Y Coord	Label	Value	Type	Historical
480277.88	4400400.39		0	Systematic	False
480286.61	4400400.39		0	Systematic	False
480295.33	4400400.39		0	Systematic	False
480304.06	4400400.39		0	Systematic	False
480312.78	4400400.39		0	Systematic	False
480269.16	4400391.66		0	Systematic	False
480277.88	4400391.66		0	Systematic	False
480286.61	4400391.66		0	Systematic	False
480295.33	4400391.66		0	Systematic	False
480304.06	4400391.66		0	Systematic	False
480312.78	4400391.66		0	Systematic	False
480321.51	4400391.66		0	Systematic	False
480260.43	4400382.94		0	Systematic	False
480269.16	4400382.94		0	Systematic	False
480277.88	4400382.94		0	Systematic	False
480286.61	4400382.94		0	Systematic	False
480295.33	4400382.94		0	Systematic	False
480304.06	4400382.94		0	Systematic	False
480312.78	4400382.94		0	Systematic	False
480321.51	4400382.94		0	Systematic	False
480251.71	4400374.21		0	Systematic	False
480260.43	4400374.21		0	Systematic	False
480269.16	4400374.21		0	Systematic	False
480277.88	4400374.21		0	Systematic	False
480286.61	4400374.21		0	Systematic	False
480295.33	4400374.21		0	Systematic	False
480304.06	4400374.21		0	Systematic	False
480312.78	4400374.21		0	Systematic	False
480321.51	4400374.21		0	Systematic	False
480330.24	4400374.21		0	Systematic	False
480242.98	4400365.48		0	Systematic	False
480251.71	4400365.48		0	Systematic	False
480260.43	4400365.48		0	Systematic	False
480269.16	4400365.48		0	Systematic	False
480277.88	4400365.48		0	Systematic	False
480286.61	4400365.48		0	Systematic	False
480295.33	4400365.48		0	Systematic	False
480304.06	4400365.48		0	Systematic	False
480312.78	4400365.48		0	Systematic	False
480321.51	4400365.48		0	Systematic	False
480330.24	4400365.48		0	Systematic	False
480338.96	4400365.48		0	Systematic	False
480234.25	4400356.76		0	Systematic	False
480242.98	4400356.76		0	Systematic	False
480251.71	4400356.76		0	Systematic	False
480260.43	4400356.76		0	Systematic	False
480269.16	4400356.76		0	Systematic	False
480277.88	4400356.76		0	Systematic	False
480286.61	4400356.76		0	Systematic	False
480295.33	4400356.76		0	Systematic	False
480304.06	4400356.76		0	Systematic	False
480312.78	4400356.76		0	Systematic	False
480321.51	4400356.76		0	Systematic	False
480330.24	4400356.76		0	Systematic	False
480338.96	4400356.76		0	Systematic	False
480216.80	4400348.03		0	Systematic	False
480225.53	4400348.03		0	Systematic	False
480234.25	4400348.03		0	Systematic	False
480242.98	4400348.03		0	Systematic	False
480251.71	4400348.03		0	Systematic	False

Area 13 (cont.)

X Coord	Y Coord	Label	Value	Type	Historical
480260.43	4400348.03		0	Systematic	False
480269.16	4400348.03		0	Systematic	False
480277.88	4400348.03		0	Systematic	False
480286.61	4400348.03		0	Systematic	False
480295.33	4400348.03		0	Systematic	False
480304.06	4400348.03		0	Systematic	False
480312.78	4400348.03		0	Systematic	False
480321.51	4400348.03		0	Systematic	False
480330.24	4400348.03		0	Systematic	False
480338.96	4400348.03		0	Systematic	False
480347.69	4400348.03		0	Systematic	False
480199.35	4400339.31		0	Systematic	False
480208.08	4400339.31		0	Systematic	False
480216.80	4400339.31		0	Systematic	False
480225.53	4400339.31		0	Systematic	False
480234.25	4400339.31		0	Systematic	False
480242.98	4400339.31		0	Systematic	False
480251.71	4400339.31		0	Systematic	False
480260.43	4400339.31		0	Systematic	False
480269.16	4400339.31		0	Systematic	False
480277.88	4400339.31		0	Systematic	False
480286.61	4400339.31		0	Systematic	False
480295.33	4400339.31		0	Systematic	False
480304.06	4400339.31		0	Systematic	False
480312.78	4400339.31		0	Systematic	False
480321.51	4400339.31		0	Systematic	False
480330.24	4400339.31		0	Systematic	False
480338.96	4400339.31		0	Systematic	False
480347.69	4400339.31		0	Systematic	False
480356.41	4400339.31		0	Systematic	False
480181.90	4400330.58		0	Systematic	False
480190.63	4400330.58		0	Systematic	False
480199.35	4400330.58		0	Systematic	False
480208.08	4400330.58		0	Systematic	False
480216.80	4400330.58		0	Systematic	False
480225.53	4400330.58		0	Systematic	False
480234.25	4400330.58		0	Systematic	False
480242.98	4400330.58		0	Systematic	False
480251.71	4400330.58		0	Systematic	False
480260.43	4400330.58		0	Systematic	False
480269.16	4400330.58		0	Systematic	False
480277.88	4400330.58		0	Systematic	False
480286.61	4400330.58		0	Systematic	False
480295.33	4400330.58		0	Systematic	False
480304.06	4400330.58		0	Systematic	False
480312.78	4400330.58		0	Systematic	False
480321.51	4400330.58		0	Systematic	False
480330.24	4400330.58		0	Systematic	False
480338.96	4400330.58		0	Systematic	False
480347.69	4400330.58		0	Systematic	False
480164.45	4400321.86		0	Systematic	False
480173.18	4400321.86		0	Systematic	False
480181.90	4400321.86		0	Systematic	False
480190.63	4400321.86		0	Systematic	False
480304.06	4400321.86		0	Systematic	False
480312.78	4400321.86		0	Systematic	False
480321.51	4400321.86		0	Systematic	False
480330.24	4400321.86		0	Systematic	False
480338.96	4400321.86		0	Systematic	False
480347.69	4400321.86		0	Systematic	False
480312.78	4400313.13		0	Systematic	False
480321.51	4400313.13		0	Systematic	False
480330.24	4400313.13		0	Systematic	False
480312.78	4400304.41		0	Systematic	False
480321.51	4400304.41		0	Systematic	False

Area 13 (cont.)

X Coord	Y Coord	Label	Value	Type	Historical
480321.51	4400295.68		0	Systematic	False
480330.24	4400295.68		0	Systematic	False
480321.51	4400286.95		0	Systematic	False
480330.24	4400286.95		0	Systematic	False
480330.24	4400278.23		0	Systematic	False
480338.96	4400278.23		0	Systematic	False