SUA-1341 License Amendment
Ludeman Project
Converse County, Wyoming

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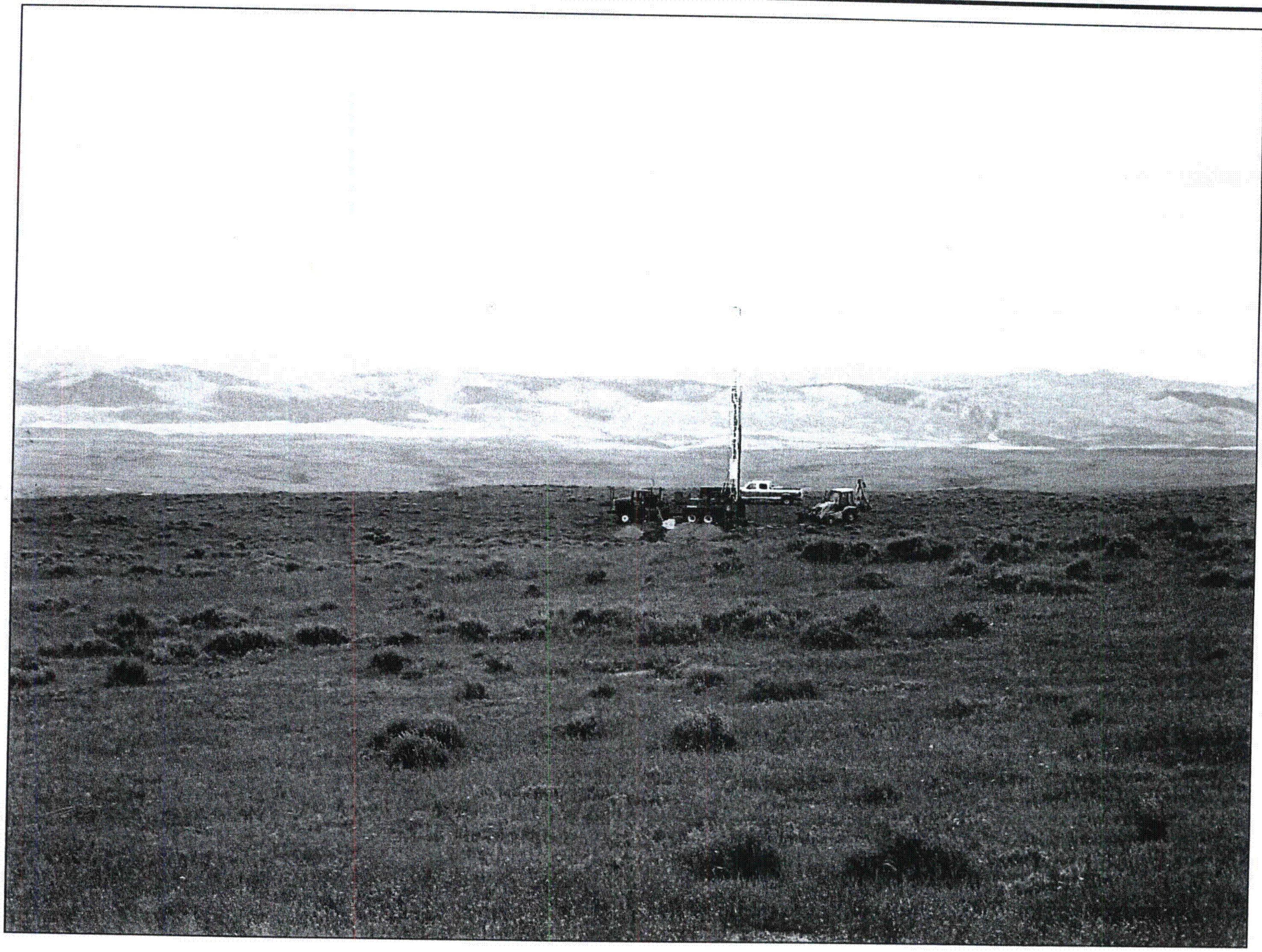

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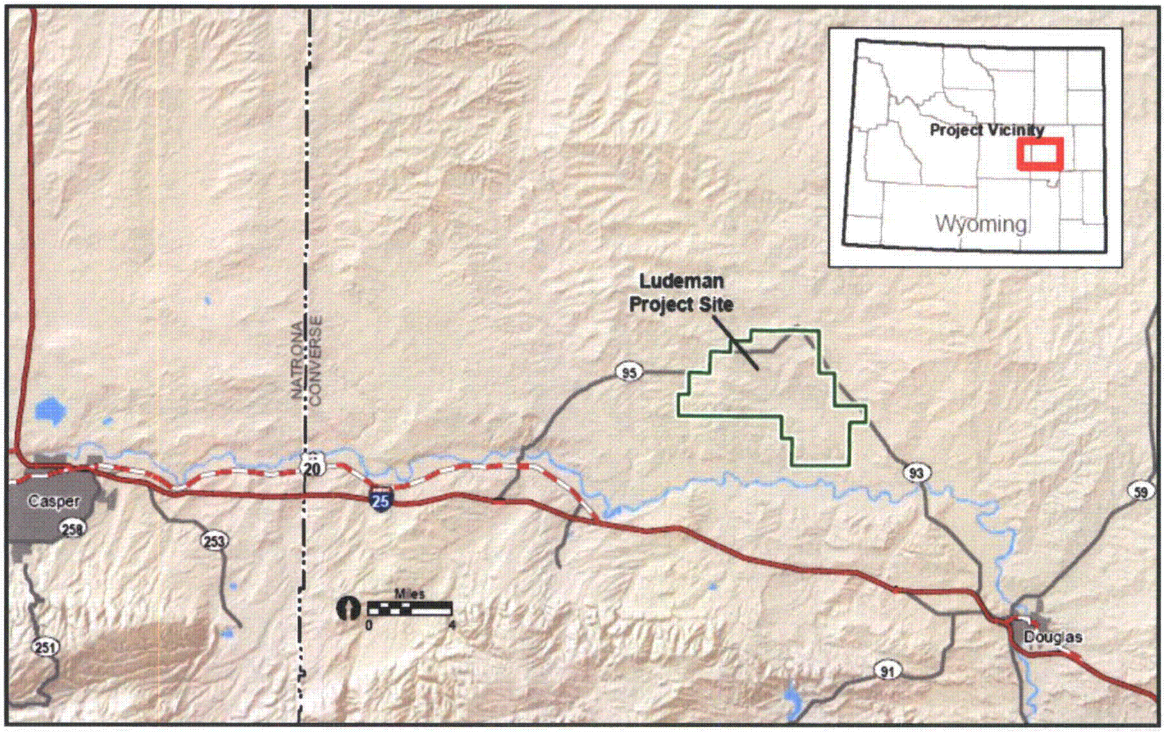
2.9 BASELINE RADIOLOGICAL SURVEY CHARACTERISTICS

2.9.1 Introduction

Radiological baseline studies and monitoring results for the proposed Ludeman Project (proposed project) area in Converse County, Wyoming are provided in this Section. The baseline studies were conducted by Tetra Tech. Various radiological parameters in different environmental media have been surveyed according to applicable regulatory guidance. The site is situated on approximately 20,000 acres of private lands (Figure 2.9-1). Because the deposits are distributed across considerable distances within the proposed project area boundaries, three Satellite recovery facility locations are proposed and baseline radiological surveys were designed accordingly.

Figure 2.9-1: Location of the Proposed Ludeman Project Area and vicinity locations.



Basic guidance for radiological surveys at uranium recovery sites can be found in the U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide 4.14 (NRC, 1980). Although Regulatory Guide 4.14 does not address special considerations associated with ISR uranium recovery sites, the NRC and the Wyoming Department of Environmental Quality / Land Quality Division (WDEQ/LQD), both currently recommend following

Regulatory Guide 4.14 for conducting radiological baseline surveys of ISR sites (NRC, 1982; WDEQ/LQD, 2007).

Radiological baseline surveys of the proposed project site were initiated by Uranium One and Tetra Tech in 2008. Relevant planning was developed under the assumption that all phases of the uranium extraction and processing cycle could potentially be performed at any of the three recovery facility sites.

Topography at the site is comprised primarily of low rolling hills, relatively flat areas, and small ephemeral drainages (Figure 2.9-2). Vegetation includes a mixture of short grass prairie varieties including occasional copse of sagebrush. The predominant land uses are livestock grazing and wildlife habitat. There is currently one residential ranch site within the project area and a number of residential dwellings near the northern boundaries of the site along Highway 95.

Figure 2.9-2: Select photos of portions of the Proposed Ludeman Project Area.

Although these radiological baseline surveys were conducted primarily based on Regulatory Guide 4.14 protocols (NRC, 1980), some aspects of survey approaches were enhanced or modified to address site- and project-specific issues along with more recent ISR specific regulatory guidance as referenced in the applicable sections of this report. Data from these baseline studies are presented in this report for consideration by the U.S. Nuclear Regulatory Commission (NRC) and the Wyoming Department of Environmental Quality / Land Quality Division (WDEQ/LQD) with respect to licensing/permitting applications. The following sections describe methods, activities, and results to date of radiological baseline surveys for the proposed project area.

2.9.2 Gamma Survey

A survey of baseline gamma exposure rates and respectively estimated soil radionuclide concentrations at the proposed project area was conducted by Tetra Tech (Fort Collins, Colorado) on September 16 through 22, 2008 on behalf of Uranium One (Casper, Wyoming). The purpose of the survey was to establish baseline levels and spatial distributions of these radiological parameters prior to proposed in-situ recovery (ISR) operations at the site. This information is an important component of overall radiological baseline characterizations as required for licensing/permitting applications by the NRC and WDEQ/LQD.

NRC Regulatory Guide 4.14 calls for a pre-operational gamma survey with up to 80 individual radial grid-based gamma exposure rate measurements for each processing facility location (NRC, 1980). Consistent with ISR license application guidelines described in Regulatory Guide 3.46 (NRC, 1982) and NUREG-1569 (NRC, 2003), as well as with radiological survey guidelines outlined in MARSSIM, the Multi-Agency Radiation Survey and Site Investigation Manual (NRC, 2000), Tetra Tech used modern GPS-based scanning system technologies for this project.

Unlike discrete grid-based measurements as recommended in NRC Regulatory Guide 4.14, these scanning systems are able to quickly and efficiently provide a more thorough characterization of the spatial distribution of gamma exposure rates across very large areas (Whicker et al., 2008). The basic gamma scanning system developed by Tetra Tech can be mounted in various configurations including backpacks, off-highway vehicles (OHVs), or trucks, and has been used for remedial support at a number of uranium mill site decommissioning projects, as well as for numerous radiological baseline surveys of proposed uranium recovery sites (Whicker et al., 2008 & 2006; Johnson et al., 2006).

Tetra Tech has used OHV-mounted versions of this scanning system for previous ISR baseline surveys at many sites in Wyoming, with results from several of these studies presented in licensing/permitting applications to the NRC and the WDEQ/LQD (Uranium One, 2008; EMC, 2007; Lost Creek ISR, LLC, 2007). The method should meet or exceed minimum guidelines outlined in NRC Regulatory Guide 4.14 and other applicable regulatory guidance documents. This system is considered current state-of-the-art technology for conducting gamma surveys. Associated analysis methods, including gamma-based estimation of certain soil radionuclide concentrations, have been further developed in recent years (Whicker et al., 2008).

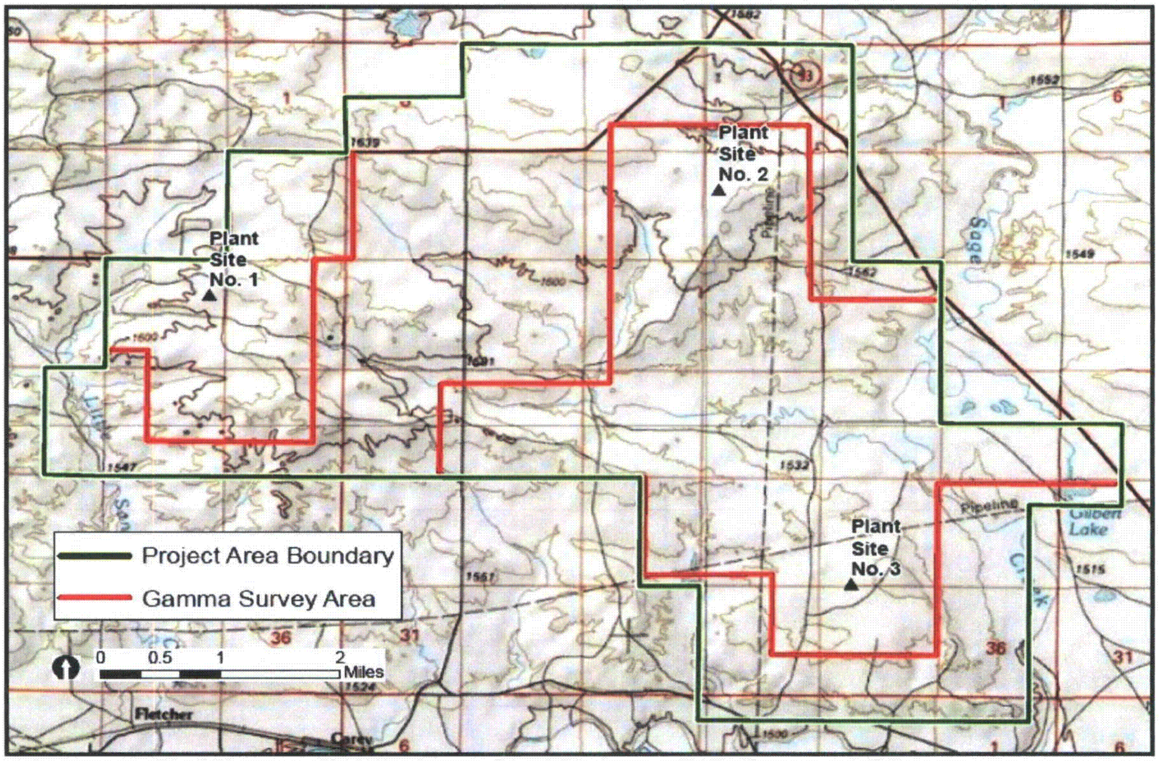
The objectives of this survey were to characterize the spatial distribution of gamma exposure rates across areas scanned (corrected for the energy dependence of sodium iodide (NaI) gamma detectors) and if possible, to estimate approximate Ra-226 and natural uranium (U-nat) concentrations in surface soils using statistical correlations between NaI-based gamma readings and concentrations of these radionuclides in surface soils. Data and analyses from this study are presented in this report for consideration by the NRC and WDEQ/LQD with respect to licensing/permitting applications.

2.9.2.1 Methods

2.9.2.1.1 Gamma Scanning

This survey consisted of gamma scans of select areas of the site along with targeted composite sampling of surface soils and static exposure rate measurements using a high-pressure ionization chamber (HPIC). The site layout and general survey areas are shown in Figure 2.9-3. The planned survey areas, comprising about 11,000 acres, were selected to establish baseline conditions in probable ISR wellfield areas, and to provide about 1.5 kilometers of survey coverage in any direction from proposed facility locations. Portions of Sections 35/36, T34N R73W were later determined to be wellfield areas and will be surveyed prior to development.

Figure 2.9-3: Site layout and gamma survey areas



For the proposed project survey, the most recently developed Yamaha Rhino-mounted scanning system configuration was used (Figure 2.9-4). Given the large size of the site, along with occasional rugged terrain and sagebrush vegetation, these two-seater Rhino OHVs with roll bar cages and conventional driver control systems (steering wheel, foot-controlled gas and brake pedals) were well suited for the project. Equipped with special extra-wide tires, these vehicles are well suited to safely negotiating sites like Ludeman while minimizing environmental impact.

Figure 2.9-4: 3-detector GPS-based scanning systems mounted on Rhino OHVs

In addition to addressing safety considerations, roll bar cages on Rhino OHVs provide a support system for adjustable outriggers designed to mount three Ludlum 44-10 NaI gamma detectors and paired GPS receivers. The detectors are coupled to Ludlum 2350 rate meters housed in a cooler carried in the OHV cargo bed. Simultaneous GPS and gamma exposure rate data are recorded every 1 to 2 seconds using an onboard PC with data acquisition software developed by Tetra Tech (Tetra Tech, 2007).

System configuration involves about 8-foot spacing between detectors (measured perpendicular to direction of travel), with each detector positioned at 4.5 feet above the ground surface. A 3-foot detector height is generally accepted, but not mandated, by the NRC. This height was impractical at the site given the relatively frequent tall brush, ravines, or fence gate crossings. A detector height of 4.5 feet was the lowest practical height for the system given site conditions. Experimental measurements were later performed to determine statistically equivalent readings as measured by a high-pressure ionization chamber (HPIC) at 3 feet above the ground surface (discussion to follow).

Based on previous observations and experience in the field under similar scanning geometries, lateral NaI detector response to significantly elevated planar (non-point) gamma sources at the ground surface is estimated to be about 5 feet, giving each detector an estimated "field of view" of about 10 feet in diameter at the ground surface. This does not imply a system detector can pick up gamma readings from a small point source 5 feet away, but does suggest that scattered photons from larger elevated source areas (e.g. 100

m^2) are likely to be detected at that distance. Within this conceptual framework, the scanning track width for each vehicle's scanning system is estimated to be about 25 feet across, perpendicular to the direction of travel. Vehicle scanning speeds ranged between 2 and 15 mph depending on the roughness of the terrain, with an estimated average speed of 8-10 mph.

In most portions of the proposed license area, 10-15 percent was the targeted scan coverage though practical considerations such as safety, terrain, and natural obstructions and other factors often dictated actual distances maintained between vehicles. For most areas of the site, a target distance of 300 feet between vehicles was a conservative goal employed during scanning, as this separation between vehicles is estimated to provide ground coverage of about 15 percent. In terrain deemed unsafe for OHV scanning, efforts were made to scan as closely as possible along the perimeters of such terrain.

Data was downloaded daily into a project database and plotted with special field mapping software (Tetra Tech Inc., 2006). Daily quality control (QC) measurements were performed to evaluate instrument performance and insure data quality (discussed later). Daily scan results were evaluated in terms of general agreement between onboard detectors and QC measurements to help identify any problems that may have occurred during data acquisition throughout the day. Gamma Viewer field maps also helped to assess adequacy of scan coverage on a daily basis.

2.9.2.1.2 Cross-calibration of NaI Detectors against a High-Pressure Ionization Chamber

Gamma exposure rates measured by NaI detectors represent only relative measurements as response characteristics of NaI detectors are energy dependent. True gamma exposure rates are best measured with a less energy dependent system such as a HPIC. Depending on the radiological characteristics of a given site, NaI detectors can have measurement values significantly different from corresponding HPIC measurement values.

NaI systems are useful for ISR recovery sites because they can quickly and effectively demonstrate relative differences between pre- and post operational gamma exposure rate conditions. Unless the same equipment and scanning geometry is used for both surveys, it is necessary to normalize the data to a common basis of comparison. This is the purpose of performing NaI/HPIC cross-calibration measurements. Cross calibration insures that the results of future gamma scans, which are likely to use different detectors (and perhaps different detector heights, detector models, or measurement technologies), can be meaningfully compared against the results of pre-ISR gamma surveys.

To perform NaI/HPIC cross-calibrations, static measurements were taken at various discrete locations covering a range of exposure rates representative of the site. These locations were identical to those used for gamma/Ra-226 correlation plot measurements (discussed in the next section). At each cross-calibration measurement location, 10 individual HPIC readings were recorded and averaged. The center of the sensitive volume for the HPIC is about 3 feet above the ground surface. The ground directly below the HPIC was marked to identify the exact measurement location for subsequent NaI measurements. Up to three of the same NaI detectors used for scanning the Ludeman site were located directly above this same location when taking measurements. For each NaI detector, 10 to 20 individual NaI readings at a 4.5-foot detector height were collected and averaged. Overall mean NaI values from each location were recorded to pair with corresponding mean HPIC readings for regression analysis and determination of a cross-calibration equation.

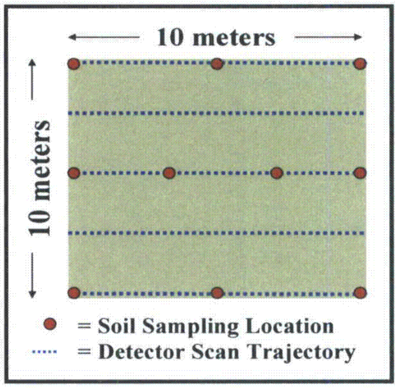
Pictures of the cross-calibration measurement process being conducted at other ISR sites in Wyoming are shown in Figure 2.9-5. The validity of applying a single cross-calibration equation to all data, based on measurements involving only a subset of the NaI detectors used for scanning the site can be linked to data quality control measurements showing acceptable consistency in readings between all detectors used for the gamma survey (discussed later).

Figure 2.9-5: Photos of NaI/HPIC cross-calibration measurements being performed at other ISR sites in Wyoming

2.9.2.1.3 Gamma / Soil Radionuclide Correlations

NRC Regulatory Guide 4.14 recommends that 40 baseline surface soil samples should be collected at 5-cm depths, extending in a radial grid pattern up to 1.5 kilometers away from the center of the "milling" area, with additional samples collected at air monitoring stations. NUREG-1569 suggests that 15-cm depths should also be sampled for consistency with decommissioning criteria. This guidance, combined with the large size of the proposed project area and previous success with correlation techniques, prompted a number of gamma/soil radionuclide correlation plots to be sampled. Depending on the statistical strength of the relationship between gamma readings and radionuclide concentrations in surface soils, such correlations can be used to estimate approximate soil concentrations (to a 15-cm depth) across the entire site based on gamma survey results. As specified in the regulatory guidance, uranium and associated decay series products are important with respect to baseline radiological soil characterizations.

Figure 2.9-6: Diagram of soil sampling and gamma measurement design for correlation plots



Correlation soil sampling was conducted as composite sampling over 10×10 meter plots (Figure 2.9-6). Within each plot, 10 soil sub-samples were collected to a depth of 15 cm then composited into a single sample. GPS coordinates were taken at the center of each sampling plot and recorded. Samples were sent to Energy Laboratories Incorporated (ELI) in Casper, Wyoming for analysis of Ra-226 and natural uranium (U-nat) concentrations. Samples were dried, crushed, and thoroughly homogenized prior to analysis to insure a representative average radionuclide concentration over each 100 m^2 plot. Samples were then canned, sealed, and held 21 days prior to counting. This allows for sufficient ingrowth of radon and short-lived progeny before Ra-226 analyses were performed using high-purity germanium (HPGe) gamma spectroscopy (method E901.1). Separate aliquots were analyzed for U-nat by ICP-MS (method SW6020).

Following methods described in Johnson et al. (2006), each 100 m^2 soil sampling plot was also scanned using the same OHV systems used to scan the entire site. One difference from the methods described in Johnson et al. (2006), was that the NaI detectors used for the survey were not shielded (collimated). The average NaI gamma reading over each plot was calculated and recorded to pair with the corresponding average Ra-226 or U-nat concentration. The general sampling/scanning design for correlation plot measurements is depicted in Figure 2.9-6.

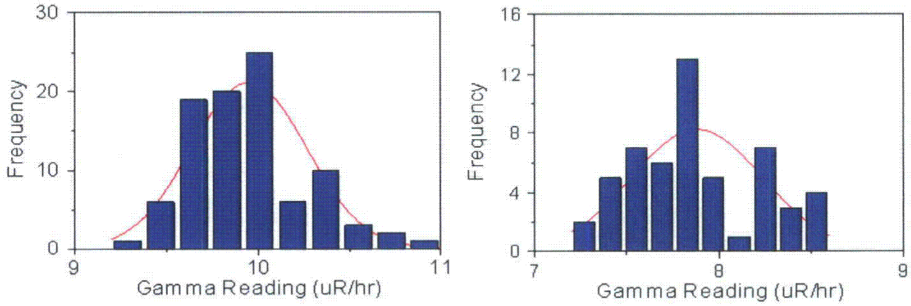
2.9.2.1.4 Data Quality Assurance / Quality Control

Data quality assurance and quality control issues for gamma surveys of the Ludeman Project area are addressed in various ways. In general, quality assurance (QA) includes qualitative factors that provide confidence in the results, while quality control (QC) includes quantitative evidence that enables estimation of data uncertainty (e.g. accuracy and precision).

Quality control documentation for this project includes the following:

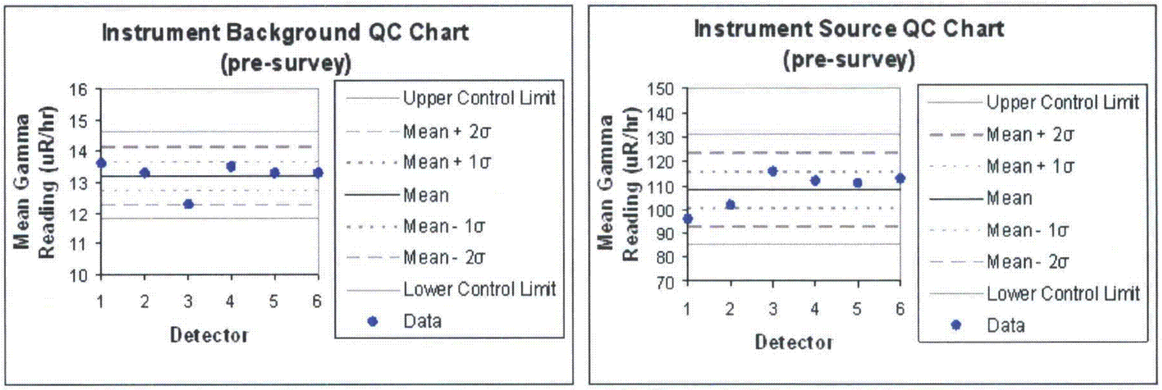
- Just prior to the survey, instrument QC measurements were performed at a designated indoor location (in Fort Collins, Colorado) for each NaI detector used to survey the site. This was done to quantify the consistency of readings between detectors under controlled measurement conditions prior to the survey. The mean of 20 individual QC measurements of ambient background, as well as from a Cs-137 check-source, were determined indoors under identical counting geometries. Under these conditions, all data from any given set of properly calibrated and correctly functioning NaI scanning detectors should approximate a normal (Gaussian) distribution (Fig. 2.9-7).

Figure 2.9-7: Example frequency histograms for two series of QC measurements from different NaI detector sets used for two separate gamma survey projects. Each series was taken indoors under controlled measurement geometries. The red lines represent theoretical normal distributions



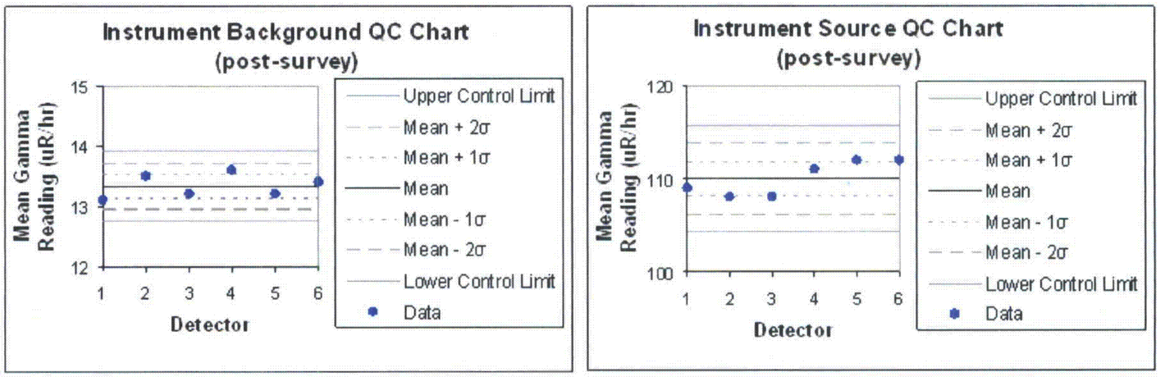
- For normally distributed data, over 99 percent of measurements are expected to fall within ± 3 standard deviations from the mean. Any instrument with a QC measurement result falling outside ± 3 standard deviations from the mean of all QC measurements on the applicable control chart warrants investigation. If a detector exceeds control limits on both background and check-source control charts, it is replaced with a factory-calibrated spare detector and sent back to the manufacturer for repair and recalibration. Prior to the survey, this set of detectors performed well within all applicable QC limits under these criteria (Figure 2.9-8).

Figure 2.9-9: Pre-survey instrument control charts



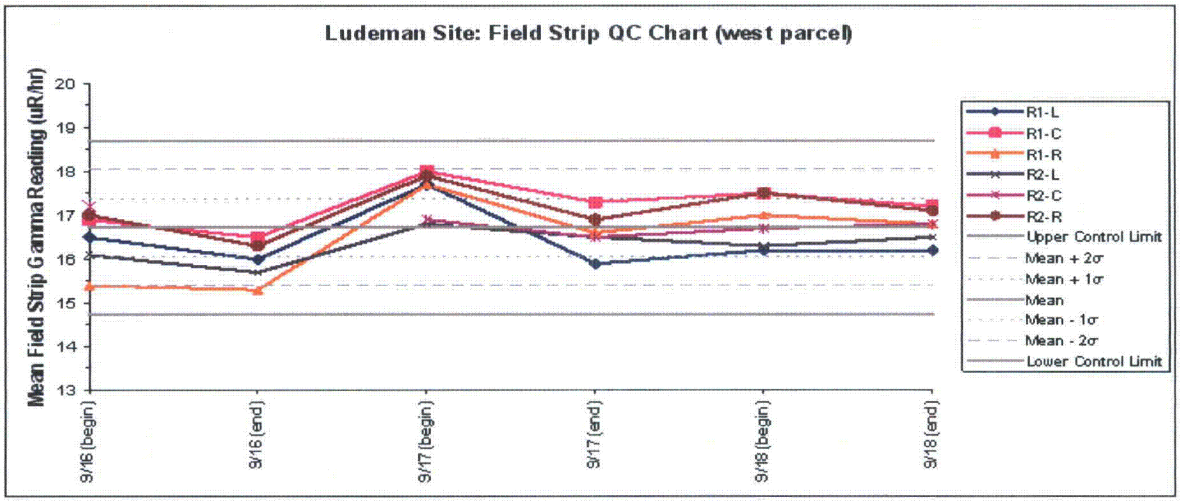
- Immediately after the survey, instrument QC measurements of background and a Cs-137 source were again performed under a controlled geometry (at the same designated indoor location as pre-survey QC measurements) for each NaI detector in use at the end of project survey activities. This was done to again quantify the consistency of readings between detectors under identical measurement geometries, and to also compare against pre-survey instrument control charts. This detector set also performed within acceptable QC limits (Figure 2.9-9), and results were similar to pre-survey QC measurements (Figure 2.9-8).

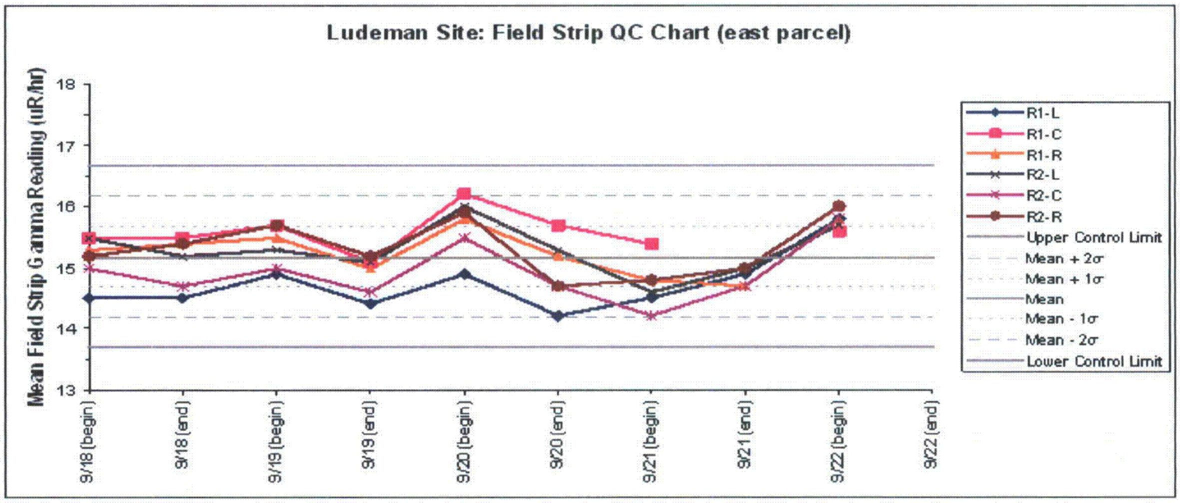
Figure 2.9-8: Post-survey instrument control charts



- During the survey, the actual performance of each scanning system was tested in the field each day by scanning along a designated strip near the vehicle staging area. These "field strip" scans were conducted before and after each day's scanning. There were two field strips for the project: one for the west scan parcel, one for the east scan parcel. The day that operations were moved from the west parcel to the east parcel (Sept. 18, 2008), field strip measurements were conducted at each of the two different locations with the same scanning detectors. This ties the two field strips together in terms of verification of system performance at the two different locations. Under actual field conditions, scanning systems performed within acceptable QC limits throughout the project (Figure 2.9-10). In cases where a detector developed suspect performance during the day's scanning (i.e. following morning QC measurements), the subject data files were eliminated from the project data base and the detector in question was replaced with a factory calibrated spare, itself then subject to routine field strip QC measurements to show consistency with the other detectors in use. In all such cases, replacement detectors demonstrated acceptable performance relative to all other properly functioning detectors in field strip QC tests.

Figure 2.9-10: Field strip control charts for west scan parcel (top) and east scan parcel (bottom)





- Re-scanning is an important tool for verification and demonstrating reproducibility of measurements in the field. Part of re-scan verification involved comparing data from various discrete, stationary measurements across the site (collected as part of HPIC cross-calibration and gamma/Ra-226 correlation activities) with original scan data. In general, these stationary measurement data showed good agreement with original continuous scan data.

- With respect to confirmatory soil sample analysis results from Energy Laboratories Inc. (Casper, WY), no flags or analytical problems were noted with respect to quality control assessments (e.g. duplicate sample analyses, laboratory control samples, etc.). Copies of these reports are available upon request.

Data quality assurance factors for this project include the following:

- All detectors used for gamma scanning at the proposed project site, along with the HPIC, were calibrated by the manufacturer within one year prior to the date of use on this project.
- A field log book of daily measurements, activities and problems was maintained.
- Chain-of-custody protocols were followed for soil sampling and contract laboratory analyses.
- Tetra Tech's Radiological Health Group staff has extensive qualifications and over 100 years worth of combined experience in performing radiological measurements and related site assessments (CV's provided on request).
- Scanning system methodologies and technology are published in peer-reviewed radiation protection and measurement research publications (Johnson et al., 2006; Meyer et al. 2005a; Meyer et al. 2005b; Whicker et al., 2008; Whicker et al., 2006).
- Daily scan results for each vehicle were reviewed for consistency along track paths for all onboard detectors. Obvious inconsistencies prompted further investigation. In cases where technical problems were discovered or where the data were otherwise clearly incorrect, the affected data were eliminated from the project database.

2.9.2.2 Gamma Survey Results

2.9.2.2.1 Baseline Gamma Survey Results

Descriptive statistics for raw gamma survey data from the proposed project site are shown in Figure 2.9-11. After thorough QC assessment of the scan data, nearly 350,000 individual gamma and paired GPS readings were included in the official final database of raw NaI measurements. The frequency histogram shows a highly right skewed distribution due to a few relatively small areas with pronounced sources of terrestrial radiation. Raw gamma survey data are mapped in Figure 2.9-12.

Figure 2.9-11: Frequency histogram and descriptive statistics for raw NaI-based survey data

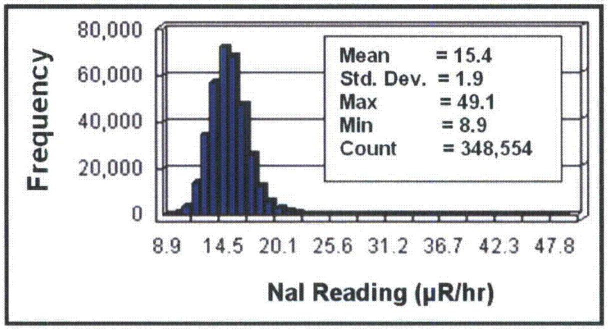
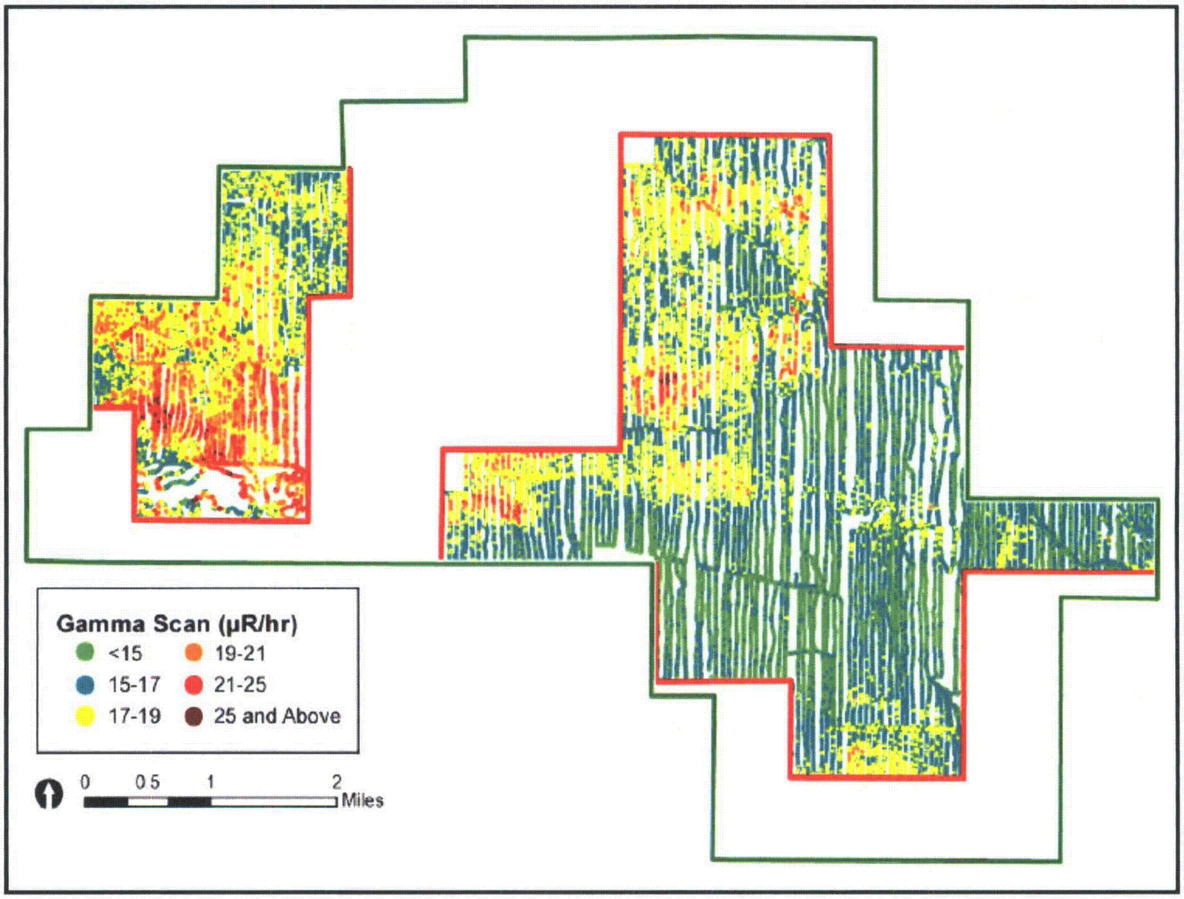


Figure 2.9-12: Raw, NaI-based gamma survey results for the Proposed Ludeman Project area

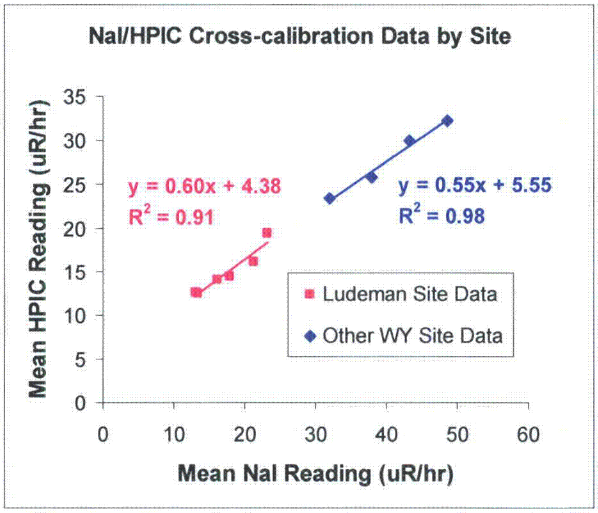


The vast majority of gamma readings in scanned areas were below 20 μR/hr. Data trends in a number of areas show several distinct regions with slightly higher gamma readings, indicative of higher levels of naturally occurring terrestrial radionuclides at or near the ground surface. Regions of significantly elevated gamma readings are very limited, and represent less than 1 percent of the survey area that possess gamma readings in excess of 25 μR/hr. In some cases, areas with higher readings have certain geomorphologic features that appear to be associated with higher gamma exposure rates (e.g. hill tops, eroded areas, outcrops of exposed rocks or unusually colored soils). In other cases, there are no obvious features associated with the higher observed readings.

2.9.2.2.2 HPIC / NaI Cross-calibration Results

Due to complications from the weather, only 6 of the planned 10 correlation plot/cross-calibration locations at the proposed project site were successfully measured and sampled during the scheduled field work. However, immediately following this work, 4 additional pairs of cross-calibration measurements were collected (using the same detectors) in conjunction with a separate project that was being conducted at a similar site in Wyoming. Linear regressions for data from the proposed project and the alternate site in Wyoming were plotted on the same graph for qualitative comparison, and the two curves appear nearly identical to one another in terms of slope and intercept (Figure 2.9-13).

Figure 2.9-13: Linear regression results for cross-calibration measurements collected at the Ludeman (pink) and an alternate ISR site in Wyoming (blue)



To statistically test for coincidence of the two regression lines in Figure 2.9-13, a multiple regression analysis was performed using a basic method as described in Dawson & Trapp (2004). The full regression model for this test is as follows:

$$Y = \alpha + \beta_1 X + \beta_2 Z + \beta_3 XZ$$

Where:

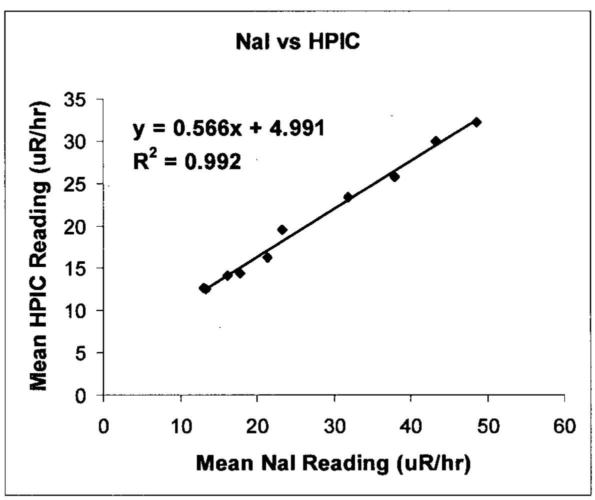
Y = μrem-meter reading (the dependent variable)
X = NaI reading (an independent variable)
Z = Location (an independent dummy variable where 1=Ludeman, 0=other WY site)
XZ = independent variable to test for interaction between X and Z
α = regression intercept coefficient
$\beta_{1,2,3}$ = regression slope coefficients for each independent variable in the model

The two regression lines in Figure 2.9-13 would have equal slopes and be parallel if $\beta_3 = 0$ (no interaction between NaI reading and location). If $\beta_2 = \beta_3 = 0$, then the two lines are statistically coincident. This latter equality serves as the relevant null hypothesis to be evaluated with t-tests in the multiple regression analysis. The key results from this analysis are the p-values for the regression coefficients as shown in Figure 2.9-14. Based on these p-values, the null hypothesis cannot be rejected at the 95 percent confidence level and the two lines are considered coincident. A similar analysis was conducted to specifically test for any confounding effects of location (without an interaction term in the full model, and using a null hypothesis of $\beta_2 = 0$). The results showed no statistical evidence of confounding effects from location when both NaI reading and location were included in the regression model.

Figure 2.9-14: Multiple regression analysis results to test for coincidence of cross-calibration curves from Ludeman and the alternate site

```
                 Multiple Regression Analysis Results
      ======================================================

Number of Points      = 10
Number of Variables   = 3
Dependent Variable    = HPIC
Independent Variable  = NaI
Independent Variable  = Location
Independent Variable  = NaI_x_Location

 Regression equation:
     HPIC        = 5.4943
                   +0.552741*NaI
                   -1.15059*Location
                   +0.0514303*NaI_x_Location

                     Regression Statistics
            ----------------------------------------

             R-Squared            = 0.99213441
      Adjusted R-Squared          = 0.98820161
Standard error of estimation      = 0.79499764
  Durbin-Watson statistics        = 2.44273006
      Mean absolute error         = 0.50221231
      Sum of squared error        = 3.79212753
      Mean squared error          = 0.63202126

    Estimate    Standard Errors    t-Value         P-Value
---------------+---------------+---------------+---------------
     5.4943          2.6220          2.0955          0.0810
     0.5527          0.0642          8.6164          0.0001
    -1.1506          3.0369         -0.3789          0.7178
     0.0514          0.1070          0.4809          0.6476
---------------+---------------+---------------+---------------
```

Figure 2.9-15: Cross-calibration curve for the HPIC versus NaI detectors positioned at a 4.5 foot detector height



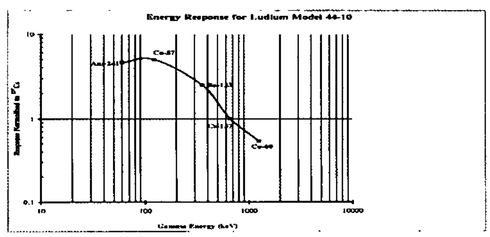
This statistical analysis indicates that the relationships between HPIC and NaI readings at the proposed project and at the alternate measurement site in Wyoming are essentially identical. This provides scientific justification for combining the two data sets to determine a single cross-calibration curve that spans most of the range of gamma data collected at the proposed project site. Results of this overall cross-calibration between the HPIC (at 3 feet above the ground surface) and NaI detectors (at 4.5 feet above the ground surface) are shown in Figure 2.9-15. Regression coefficients from the combined data set are consistent with those measured by Tetra Tech at other uranium recovery sites, including a number of sites in nearby regions of Wyoming. As is normal, the ratio of HPIC to NaI readings was inversely proportional to the magnitude of measured exposure rates. HPIC/NaI ratios ranged from 0.66 to 0.97, corresponding to locations with the highest and lowest measured readings.

Cross-calibration measurement locations with the lowest measured NaI readings (near 13 μR/hr) demonstrated only a slight difference between mean HPIC and NaI measurement values. As can be observed in Figure 2.9-11, about 10 percent of the survey data fell below this level. Scan data exceeding the upper range of cross-calibration measurements was well under 1 percent. Although extrapolation of the cross-calibration curve was necessary for conversion of all NaI data to approximate HPIC equivalents, the strength of the relationship (R^2 value of nearly 1) is highly significant. Tetra Tech has found NaI/HPIC cross-calibration relationships (from both direct measurements in the field as well as in the literature) to demonstrate linear characteristics (e.g. Whicker et al., 2008, Schiager, 1974). The slope and intercept can vary somewhat by site and by instrument, but across all ranges of observed values, a highly linear relationship between NaI and HPIC readings appears to be characteristic of such measurements. Extrapolation for the relatively small fraction of data outside the range of measured cross calibration values is thus unlikely to introduce significant error into the converted data set.

As with many sites, this regression model predicts a cross-over point in the statistical relationship where NaI and HPIC readings are essentially identical (in this case, at about 11.5 μR/hr). Below this value HPIC readings are slightly higher than NaI readings. This kind of relationship has been confirmed by direct field measurements at a number of project sites and is believed to be related to the ratio of cosmic to terrestrial sources of gamma radiation combined with the energy response characteristics of NaI detectors.

Ludlum Model 44-10 NaI detectors are calibrated against a Cs-137 source (Ludlum, 2006). At photon energies close to that of Cs-137 (662 keV), detector response will be close to 100 percent (Figure 2.9-16). In the case of Ra-226, the associated decay series product Bi-214 has similar photon emission energy (609 keV) while photon emission energies for Pb-214 are significantly lower (295 and 352 keV respectively). More importantly, the majority of all terrestrial gamma radiation that interacts with the NaI detector, including that from other gamma emitters such as K-40, involves scattered secondary photons of energies well below 662 keV. Thus, in areas where photons from terrestrial sources exceed a certain minimum percentage of the total ambient gamma field, detector response relative to Cs-137 will be greater than 100 percent and the detectors will over-predict true exposure rates. In areas where terrestrial radionuclide concentrations are very low, higher energy cosmic sources can dominate detector response and result in a slight under-prediction of true exposure rates.

Figure 2.9-16: Energy response characteristics of the Ludlum Model 44-10 NaI detector (Ludlum, 2006)



2.9.2.2.3 Final Gamma Exposure Rate Mapping

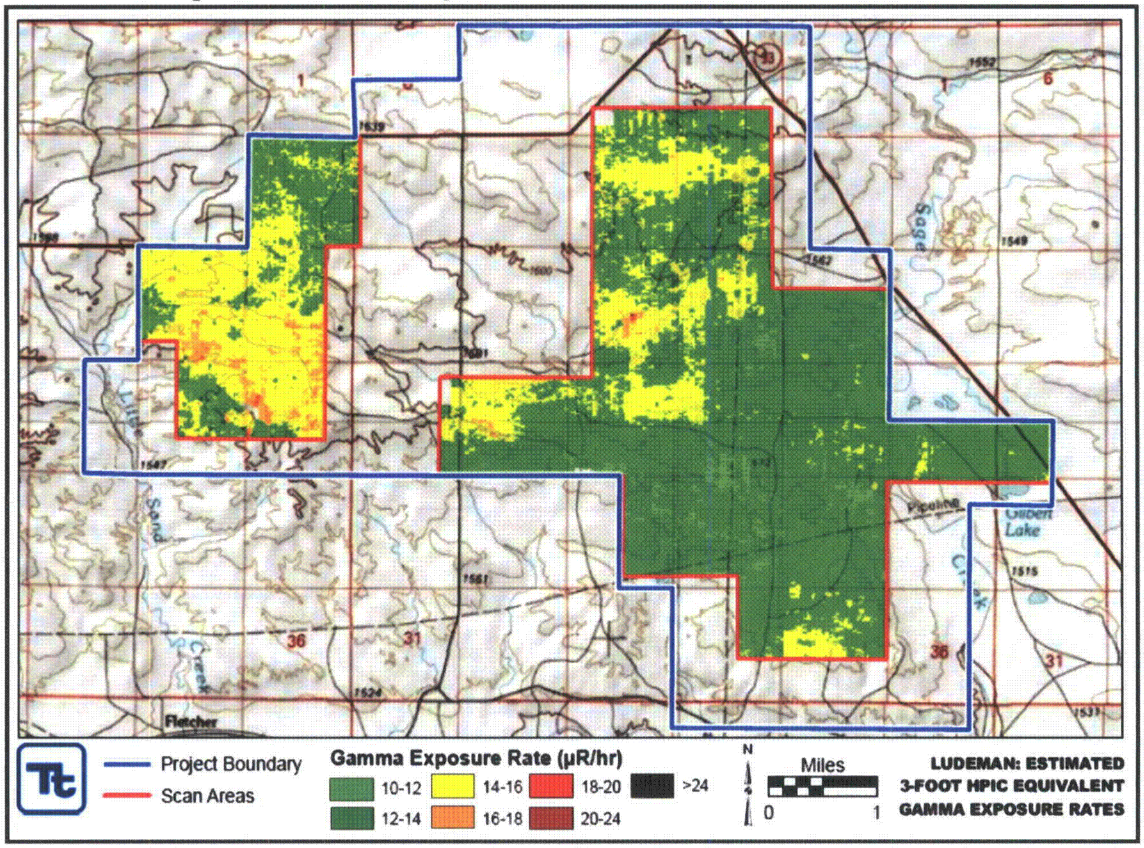
Using regression equation shown in Figure 2.9-15, all baseline gamma scan data collected with NaI detectors at the proposed project site were normalized to 3-foot HPIC equivalent measurements to produce the best possible estimate of true gamma exposure rate for each individual NaI reading. This converted data set, along with a special data kriging program in ArcGIS (ESRI, 2008), was used to develop continuous estimates of true gamma exposure rates at 3 feet above the ground surface (3-foot HPIC equivalent values) across all scanned areas.

Kriging is a geostatistical interpolation procedure that fits a mathematical function to a specified number of nearest points within a defined radius to determine an output value for each location. A given "location" is represented by a cell of specified areal dimensions that may or may not include any measured data points. Values closer to the cell are given more weight than values further away and distances, directions, and overall variability in the data set are all considered in the predictive semivariogram model. Approximate input parameters used for this application were as follows:

Cell size:	10 feet × 10 feet
Max search radius:	400 feet
Semivariogram model:	Exponential
Number of nearest data points:	10

A map of estimated 3-foot HPIC equivalent gamma exposure rates across the survey areas is shown in Figure 2.9-17.

Figure 2.9-17: Continuous, kriged estimates of 3-foot HPIC equivalent gamma exposure rates at the Proposed Ludeman Project site.

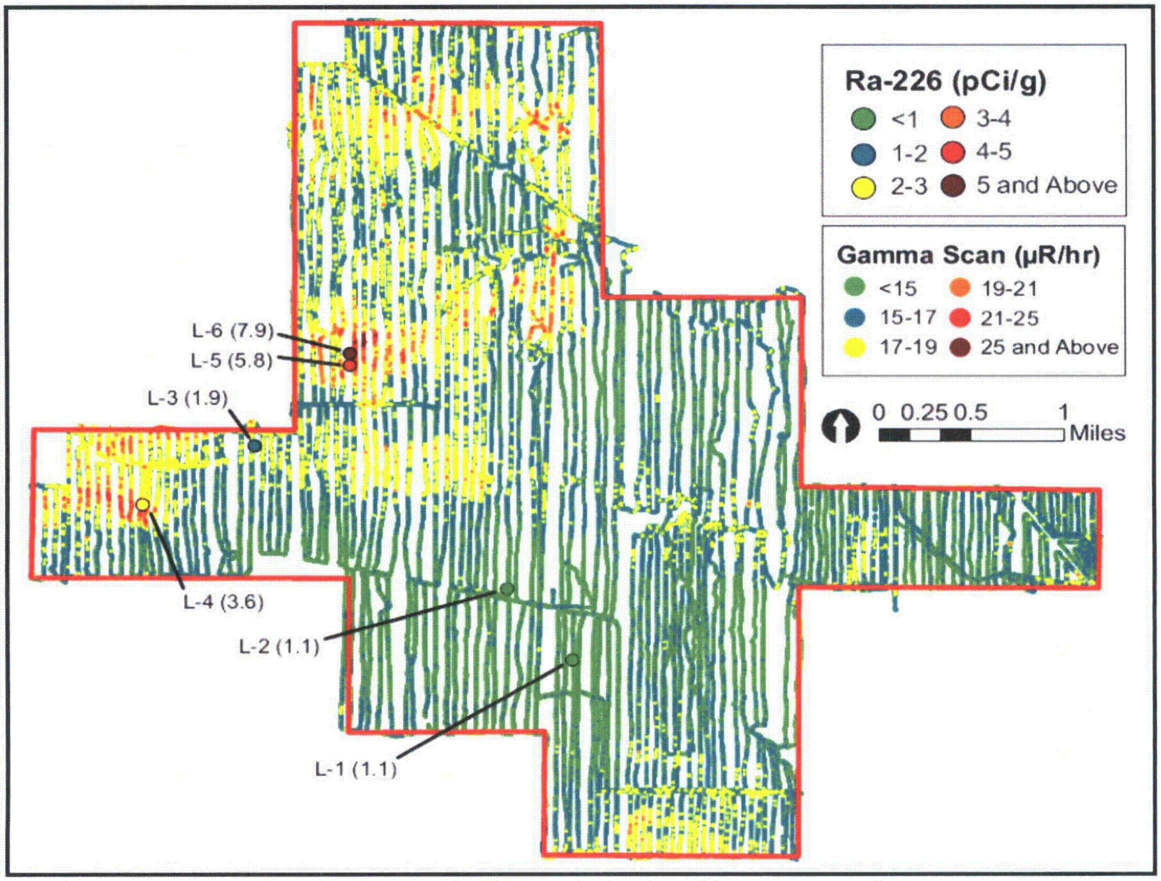


Note that the gamma scale legend increments differ between the raw NaI-based gamma scan track map shown in Figure 2.9-12, and the final official map of gamma survey results provided in Figure 2.9-17. This is because the data in the final map of official gamma survey results have been converted to 3-foot HPIC equivalent values and the range of values differs slightly.

2.9.2.2.4 NaI/Ra-226 Correlation Results

Overlays of correlation plot sampling locations, color-coded and annotated to show soil Ra-226 results on corresponding portions of the raw NaI gamma scan map, are shown in Figure 2.9-18. Soil sampling results represent average Ra-226 concentrations over 100 m^2 sampling plots to a depth of 15 cm.

Figure 2.9-18: Correlation plot measurement locations and annotated soil Ra-226 concentration results (pCi/g, in parentheses) overlain on the NaI scan track map.



The data in Figure 2.9-18 indicate a clear spatial association between the levels of measured soil Ra-226 concentrations and gamma scan readings in corresponding locations. Statistical regression analysis of the correlation plot data revealed a highly significant linear relationship between mean Ra-226 soil concentration and mean NaI gamma reading (Figure 2.9-19). Although only 6 correlation plots were sampled for reasons previously indicated, the variability about the regression line is very small, the R^2 value is nearly one, and the range of gamma values measured at these plots is evenly distributed across a range of values that includes nearly 90 percent of the scan data collected at the site. Assuming normal distributional characteristics and representativeness of correlation plot locations, the limits of the 2σ (95 percent) prediction band shown indicate that 95 percent of the time, local average Ra-226 in surface soils should be within about ± 1 pCi/g of a value predicted based on gamma readings and use of this correlation. The gamma/Ra-226 relationship observed at the Moore Ranch ISR site (EMC, 2007), located about 45 miles NNW of the proposed project, is remarkably similar (Figure 2.9-20), suggesting that this basic relationship is consistent across this region of Wyoming.

Figure 2.9-19: Linear correlation between Ra-226 soil concentration and NaI-based gamma exposure rate reading. Prediction band limits [1σ (68%) and 2σ (95%)] are shown

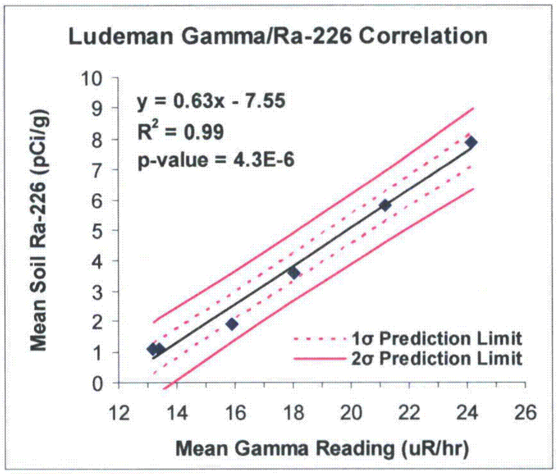
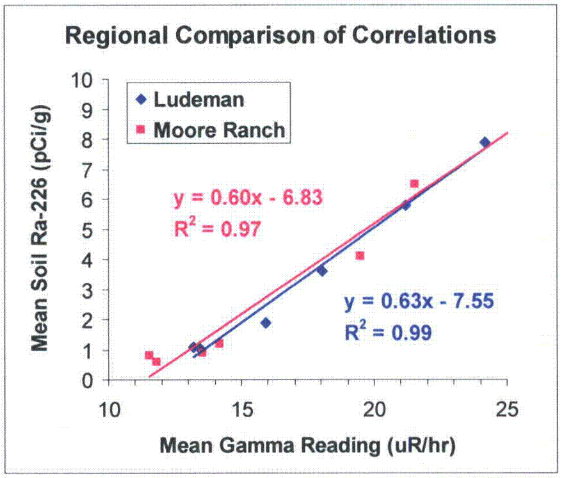


Figure 2.9-20: Comparison of gamma/Ra-226 correlations developed at Ludeman and Moore Ranch (about 45 miles NNW of Ludeman)



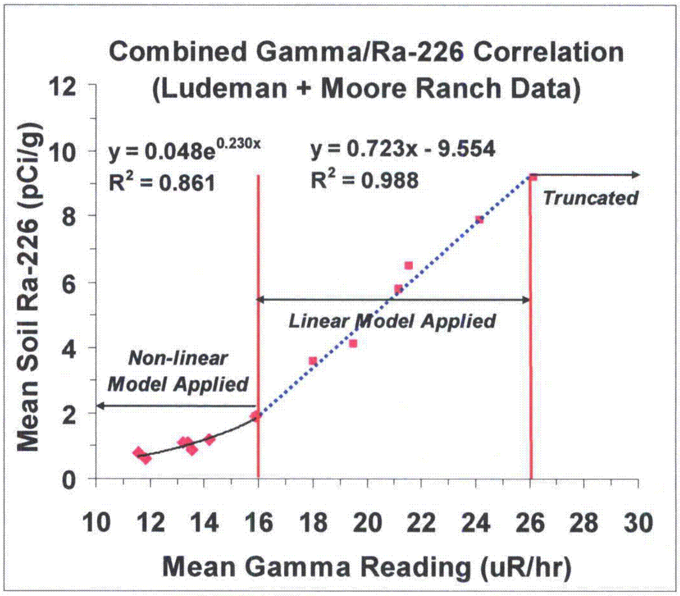
To test for any statistical differences between correlation curves for the two sites as shown in Figure 2.9-20, multiple regression analyses were performed using the same statistical methods presented in Section 2.9.2.2.2. The results indicated that these two regression lines are statistically indistinguishable from one another (i.e. coincident) at the 95 percent confidence level, and revealed no statistical evidence of a confounding effect of location due to data collected at the two different sites. These results provide reasonable scientific justification for combining the two data sets in order to achieve a more robust estimate of an average relationship between gamma readings and Ra-226 concentrations in surface soils at the proposed project site.

Although a linear regression of the combined Ludeman/Moore Ranch correlation data set is highly significant (p-value < 0.001, $R^2 = 0.98$), the data falling below about 16 μR/hr, suggest a slight non-linearity relative to the data above this range. This feature, though somewhat subtle, is apparent in the data shown in Figure 2.9-20, and is consistent with similar observations at a number of other sites in Wyoming (EMC, 2007; Uranium One, 2008; Whicker et al., 2008). This phenomenon is believed to be related to use of gross gamma measurements, the relative influences of cosmic and terrestrial sources of gamma radiation, and the energy dependence of NaI detectors (Whicker et al., 2008).

When soil Ra-226 concentrations are very low, cosmic radiation, direct and scattered photons from all terrestrial sources, will dominate detector response. In a context of gamma/Ra-226 correlation measurements, this is analogous to instrument background "noise". As soil Ra-226 concentrations increase, the signal to noise ratio gradually increases at an increasing rate (i.e. in a non-linear fashion), until a certain threshold is reached and a more significant (and generally linear) correlative impact on gross gamma readings becomes apparent. The level at which this "threshold" occurs at a given site may be related to the energy dependence of NaI detectors and the ratio of cosmic to terrestrial sources at the site.

Other soil radionuclides including Th-232 and its decay products, including K-40, may have an impact on such a threshold as well; or even on the effectiveness of the correlation itself, if levels relative to Ra-226 are high and/or are highly variable. At other Wyoming ISR sites sampled by Tetra Tech, soil radionuclides other than those radiologically linked to Ra-226, have been moderately variable, with average concentrations in the range of 1-2 pCi/g for Th-232, and 15-25 pCi/g for K-40. To date, such levels and associated variability have not previously demonstrated a significant confounding effect on the general reliability of gamma/Ra-226 correlations.

Figure 2.9-21: Partitioned correlation model for predicting Ra-226 concentrations in surface soils based on gamma readings at the Proposed Ludeman site.



When gamma/Ra-226 correlation data have non-linear properties, non-linear correlation models have generally demonstrated slightly better accuracy for predicting soil Ra-226, particularly in the low to mid ranges of gamma readings found at the site (EMC, 2007; Uranium One, 2008; Whicker et al., 2008). The combined data set was carefully evaluated and ultimately partitioned into several data categories for modeling, resulting in a partitioned overall model for predicting Ra-226 concentrations in surface soils based on gamma readings (Figure 2.9-21).

A gamma reading of 16 μR/hr was selected as a reasonable partition boundary line between use of a non-liner model for lower values, and a linear model for higher values. Above 26 μR/hr, estimates of soil Ra-226 based on the gamma survey data were artificially truncated at soil Ra-226 value of 9.3 pCi/g, to avoid model extrapolation on the highest end of the scale. On the lowest end of the scale, truncation was not considered necessary in terms of its potential to significantly impact kriging results. Issues and rationale for truncation are further discussed in Section 2.9.2.2.5.

In addition to Ra-226, correlation plot soil samples from the proposed project site were also analyzed for natural uranium (U-nat) by acid leaching followed by metals analysis via inductively coupled plasma mass spectrometry (ICP-MS). The mean ratio of U-nat/Ra-226 (± σ) for reported activity concentrations was 1.1 ± 0.7. Based on natural isotopic abundances and relative half lives, U-238 is responsible for about 49 percent of total radioactivity contained in U-nat, U-234 contributes about 49 percent, and U-235 contributes about 2 percent (NCRP, 1987). The mean U-238/Ra-226 activity ratio of for the correlation soil samples thus appears to be about 0.5 ± 0.3.

Despite considerable variability in U-nat/Ra-226 ratios for these samples, a linear correlation between U-nat and Ra-226 was statistically significant (Figure 2.9-22), and the regression should provide a reasonable estimate of an average relationship between the two parameters at the soil surface. Baseline estimates of Ra-226 at the soil surface could be converted into rough estimates of U-nat using this relationship, though such predictions are specific to the analytical methods used to measure each parameter in the correlation samples. Natural uranium itself does not have a significant gamma signature, but because of the radiological association with Ra-226 it can sometimes be significantly correlated with gamma exposure rates. The gamma/U-nat relationship for correlation plot data from the proposed project is shown in Figure 2.9-23.

Figure 2.9-22: Statistical relationship between mean U-nat and Ra-226 soil concentrations at correlation plot locations.

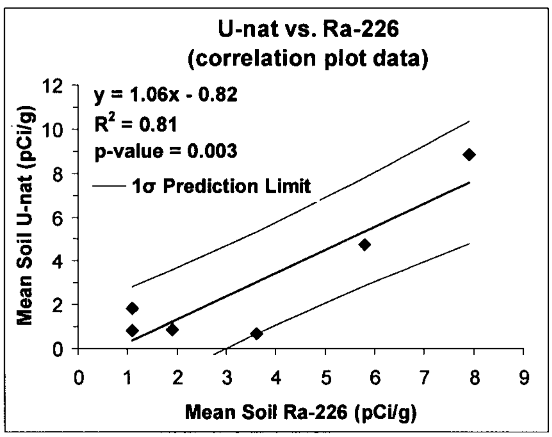
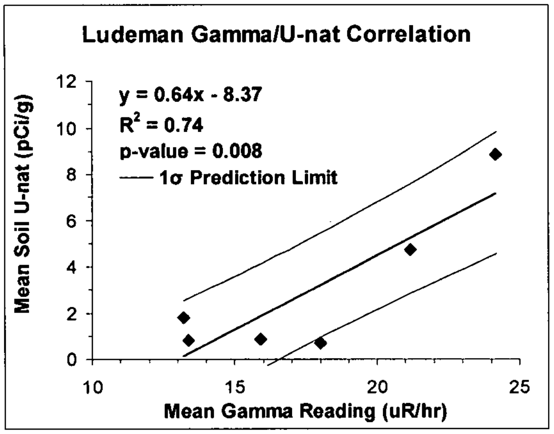


Figure 2.9-23: Statistical relationship between gamma readings and U-nat soil concentrations at correlation plot locations.

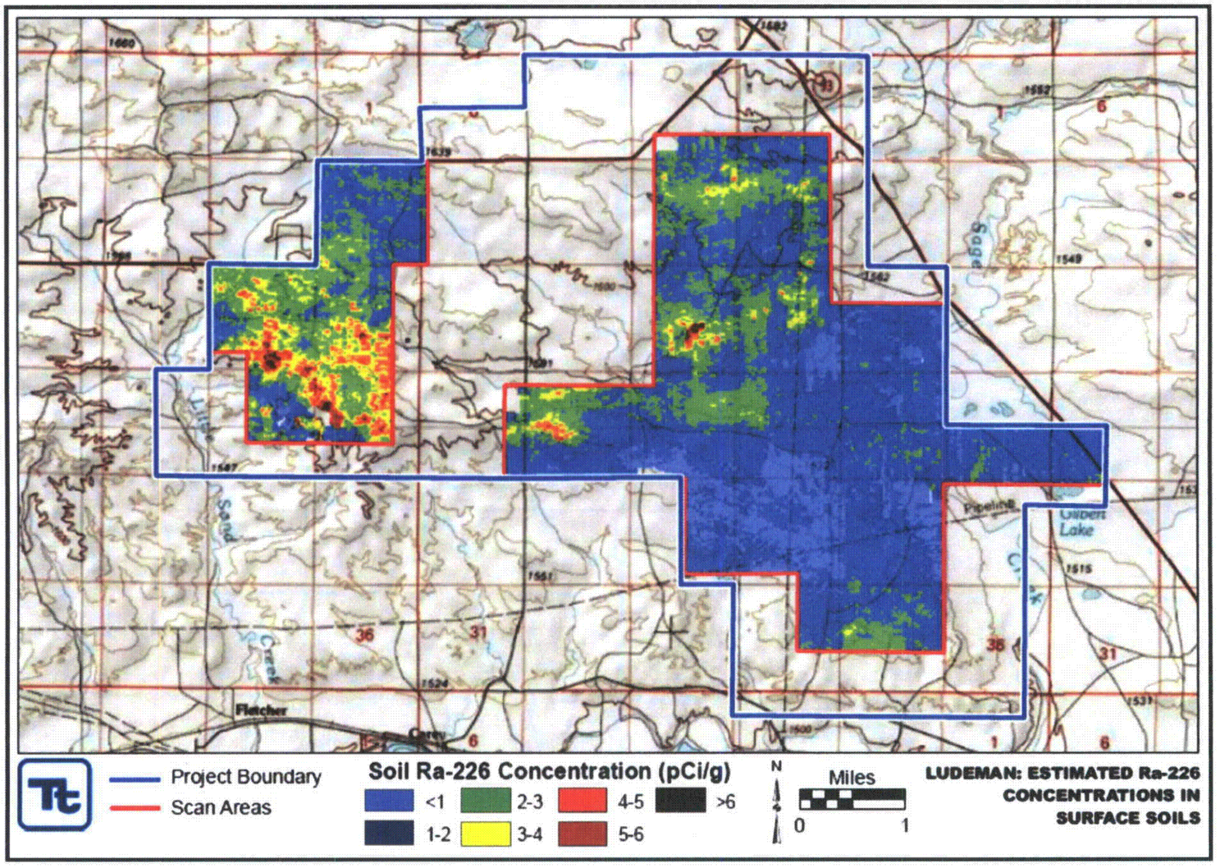


Under natural undisturbed soil conditions, U-238 and Ra-226 are often found in approximate secular equilibrium with one another; though some depletion of U-238, due to higher uranium mobility, can sometimes be indicated by the data. It is not uncommon to see considerable variability in U-238/Ra226 ratios, though apparent disequilibrium can result from analytical error and differing analytical methods (e.g. radiochemical separation versus gamma spectroscopy), particularly at low concentrations. For this reason, it would be questionable to conclude from this data that significant disequilibrium between U-238 and its decay series products occurs in soils at this site.

2.9.2.2.5 Soil Radionuclide Concentration Mapping

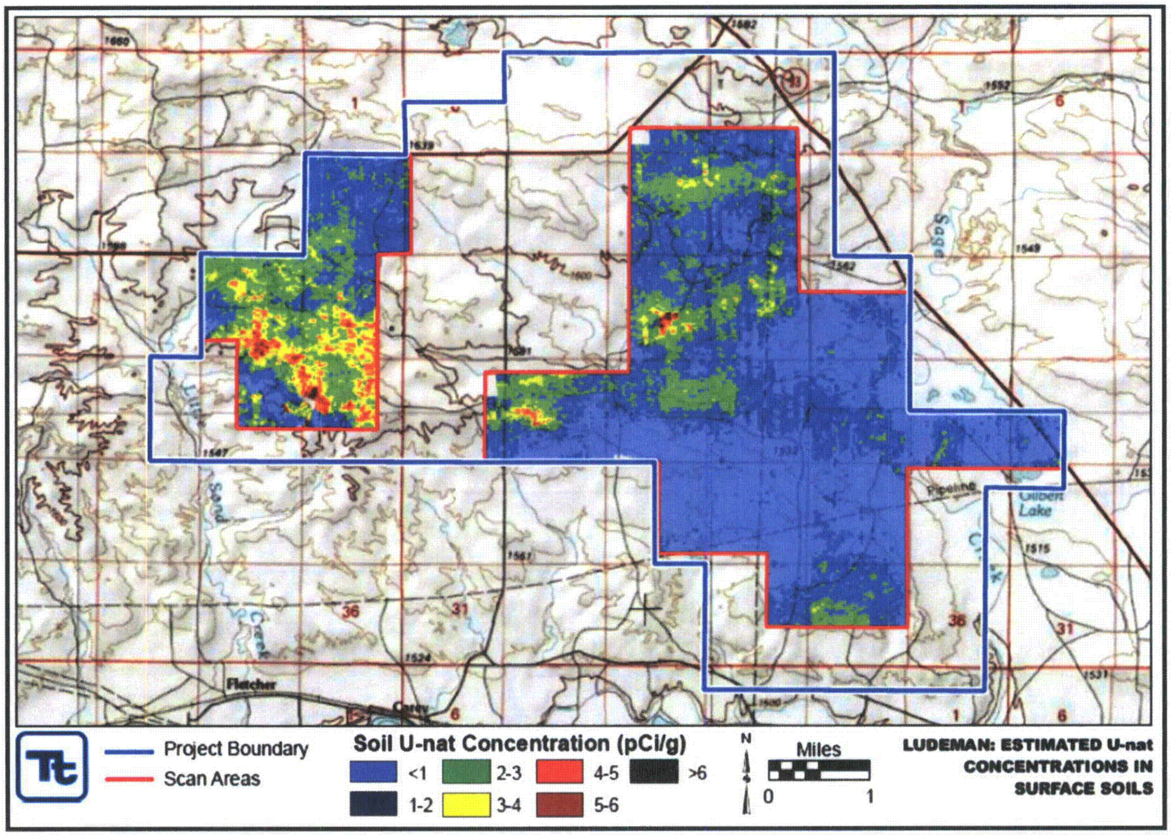
The partitioned gamma/Ra-226 correlation model shown in Figure 2.9-21, was used to convert raw NaI gamma scan readings from the site into estimates of Ra-226 concentrations in surface soils. Once converted, the resulting data set was kriged to provide continuous estimates of Ra-226 in surface soils (Figure 2.9-24).

Figure 2.9-24: Continuous, kriged estimates of Ra-226 concentrations in surface soils (0-15 cm depth) based on gamma survey results.



As previously indicated, conversion of scan data beyond the upper limit of gamma correlation plot data (26 μR/hr) involved artificial truncation at a fixed value (9.3 pCi/g), to avoid extrapolation of the predictive model. Above this range, the relationship is uncertain and model extrapolation has the potential to introduce localized spatial inaccuracies into respective kriging results. Though specific quantitative predictions regarding soil Ra-226 concentrations at gamma readings greater than 26 μR/hr are unjustified, this is unlikely to be problematic in a context of assessing impacts from site operations. While radiologically elevated, these locations are well delineated in terms of spatial extent and they represent only a tiny fraction of the overall survey area (Figure 2.9-24). Below the range of correlation plot data, truncation was not deemed necessary as the model decreases only slightly with decreasing readings and low-end extrapolation was not expected to significantly influence the spatial reliability of kriging results. Using similar data conversion protocols as described for estimation of soil Ra-226, the gamma/U-nat correlation equation (Figure 2.9-23) was used to convert raw NaI gamma scan readings into estimates of U-nat concentrations in surface soils. Converted data were then kriged to provide continuous estimates of U-nat in surface soils (Figure 2.9-25).

Figure 2.9-25: Continuous, kriged estimates of U-nat concentrations in surface soils (0-15 cm depth) based on gamma survey results.



As expected, the general spatial distribution of gamma-based estimates of soil U-nat concentrations across the surveyed areas is very similar to that of soil Ra-226.

2.9.2.3 Data Utility

The estimates of baseline gamma exposure rates provided in Figure 2.9-17 can be used to help assess respective changes due to operational activities at the site. If the same or similar models of NaI scintillation detectors are used for future gamma survey activities (e.g. factory calibrated Ludlum 44-10 detectors), the HPIC cross calibration regression model shown in Figure 2.9-15 can be used to convert field gamma readings to estimates of true exposure rate for direct comparison with the baseline estimates in corresponding areas as shown in Figure 2.9-17. If different types of gamma detectors are used, the HPIC cross calibration model provided in this report may not apply, as instrument energy dependence characteristics can differ.

The gamma-based estimates of baseline Ra-226 concentrations in surface soils provided in Figure 2.9-24, can be used to help assess potential changes in Ra-226 soil concentrations due to operational activities at the site. An important caveat is that future laboratory analysis of soil samples used for such comparisons should employ the same analytical method used to develop this baseline information (HPGe-based gamma spectroscopy by a qualified laboratory). Sodium iodide (NaI) based gamma scintillation detectors can be used as a field screening tool to help define the extent of potential contamination relative to the baseline estimates in corresponding areas as shown in Figure 2.9-24. If different types of gamma detectors are used, or if the suspected magnitude of potential contamination being surveyed is well above baseline conditions, the correlation model presented in this report may not apply as instrument energy dependence characteristics can differ. Another caveat is that a number of baseline soil samples from areas possessing higher gamma readings, had Ra-226 results that were significantly lower than indicated by gamma readings in the field, and a relatively small overall bias exists between the two estimation methods. These issues are discussed in more detail in Section 2.9.2.4.2.

Potential impacts from future site operations on soil U-nat concentrations can be assessed by comparison of soil sampling results against gamma-based estimates of baseline U-nat concentrations (Figure 2.9-25) in corresponding areas. However, the same analytical method employed for measuring U-nat in correlation plot samples (ICP-MS) should be used. Once ISR operations have commenced, gamma measurements are unlikely to be a reliable tool for evaluating uranium contamination in soil, since the correlation used for baseline estimation only applies to baseline soil conditions. Uranium itself has no significant gamma signature, and operational releases may involve different physical/chemical properties and different relative amounts of Ra-226 and U-nat.

All of the above options for assessment of potential radiological impacts from future site operations relative to the baseline radiological information generated by the proposed project gamma survey must consider data uncertainty in both the estimated baseline values and any future analytical information used for such comparisons. In all cases, analytical methods and instruments should be comparable to those used in this study. Use of several available assessment options should reduce overall potential for misidentification or erroneous quantification of possible future contamination.

2.9.2.4 Data Uncertainty

For comparison of operational/post-operational survey measurements against baseline survey data, it is necessary to take into account the degree of uncertainty in survey measurements. Sources of measurement uncertainty include (but may not be limited to):

- Instrument variability within and between gamma detectors
- Variations in count data associated with the random nature of radioactive decay
- Small-scale spatial variability in gamma exposure rates (differences in readings due to small differences in measurement geometry or location)
- Temporal variability in gamma exposure rates associated with:
  - Changes in natural shielding factors for terrestrial or cosmic sources such as changes in soil moisture or barometric pressure
  - Diurnal fluctuations in ambient radon concentrations in air
- Small inaccuracies in GPS readings
- Errors associated with soil sampling and laboratory analyses

Each radiological baseline parameter characterized in association with the gamma survey is evaluated in a context of total estimation uncertainty in the following sections.

2.9.2.4.1 Gamma Exposure Rates

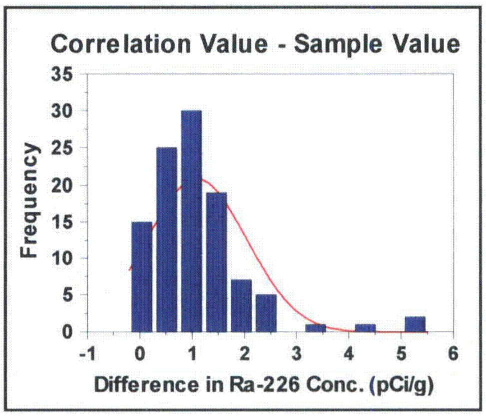
In general, scanning system measurements along QC field strips at the site provide an indication of total gamma measurement uncertainty including most of the above sources of variability in gamma exposure rate readings. Based on the data shown in Figure 2.9-10, the total range of potential uncertainty in NaI scanning measurements at field strip locations was about ± 2 μR/hr. Approximately the same amount of uncertainty should be applicable to 3-foot HPIC equivalent data at these locations. The field strips were located in areas having ambient gamma exposure rate readings in the range of 15-18 μR/hr (close to the average of all readings found at the site). In areas of significantly higher gamma exposure rates (e.g. above 25 μR/hr), the degree of uncertainty in measurements is likely to be somewhat higher; but again, these areas represent a very small fraction of the total area surveyed.

Given the general density of scan coverage attained at the proposed project site (on the order of 10-15 percent), larger-scale distributional characteristics are more likely to be accurately characterized as smaller-scale spatial variability in exposure rates between scan tracks from each survey vehicle is not measured. The kriging process for continuous estimation of overall baseline conditions is believed to "smooth" some variability associated with certain sources of data uncertainty in areas along individual gamma scan tracks (e.g. variability in response characteristics of different detectors, small inaccuracies in GPS readings). Although this smoothing effect is believed to improve estimation precision (reproducibility) along scan tracks, the accuracy of interpolated values between scan tracks is dependent on the degree of spatial uniformity in soil radionuclide concentrations.

2.9.2.4.2 Gamma-Based Soil Ra-226 Estimates

Gamma-based estimates of soil Ra-226 (Figure 2.9-24) were compared with independent soil sampling results at corresponding locations to help assess data uncertainty. Past results for estimating Ra-226 concentrations using these same characterization techniques have generally demonstrated differences between estimated and measured values in the range of ± 2 pCi/g (EMC, 2007; Uranium One, 2009; Whicker et al., 2008).

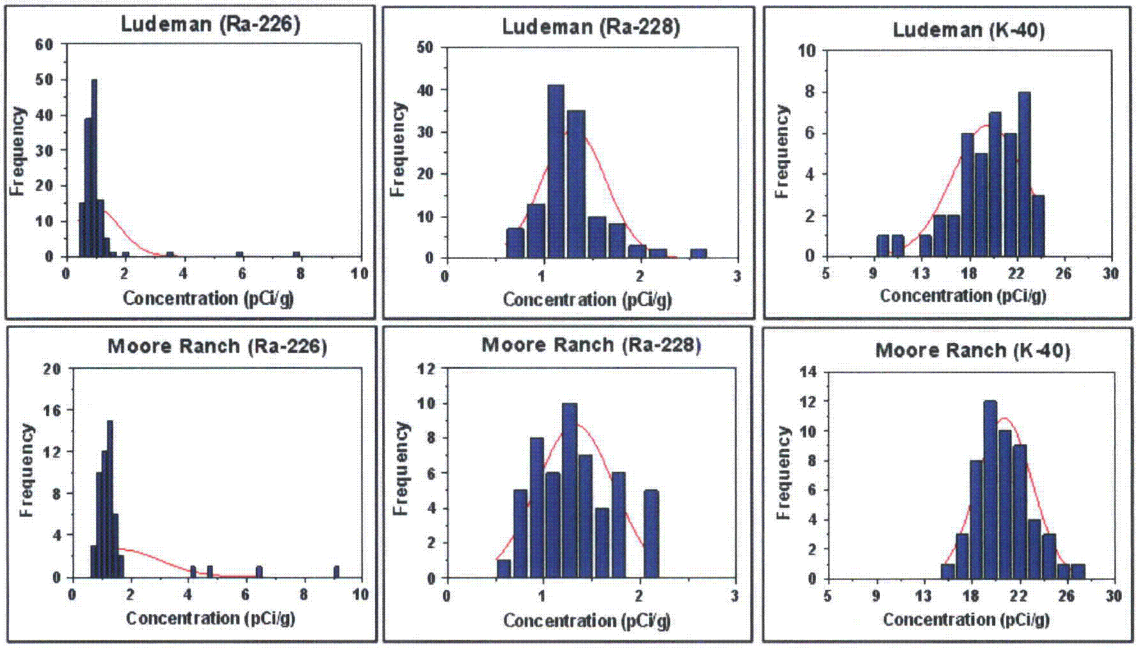
Figure 2.9-26: Frequency histogram of numerical differences between gamma-based estimates of Ra-226 in surface soils (correlation value) minus radial grid soil sampling results (sample value) at corresponding locations.



One hundred eighteen surface soil samples at the proposed project were collected along radial sampling grids among the three proposed Satellite facility locations according to Regulatory Guide 4.14 protocols. Radium-226 results for these samples were superimposed on the kriged map of gamma-based Ra-226 concentration estimates for surface soils and corresponding values were numerically compared. The vast majority of gamma-based estimates (correlation values) were within + 2 pCi/g of corresponding soil sampling results (Figure 2.9-26). Considerably larger differences are apparent in a few locations where higher gamma readings are present, and on average, an overall bias of about ± 1 pCi/g is evident between the two characterization parameters.

To evaluate apparent discrepancies and potential bias in either the gamma-based estimates or the soil sampling results, frequency histograms of analytical results for Ra-226, Ra-228, and K-40 in surface soils from the radial grid samples were generated (Figure 2.9-27). These histograms provide an indication of relative levels and variability for naturally occurring sources of terrestrial gamma radiation (U-238/Th-232 decay series and K-40). Because the gamma/Ra-226 correlation for Ludeman was essentially identical to that of Moore Ranch, corresponding frequency distributions for surface soil samples from the nearby Moore Ranch site are also shown for comparison.
Assuming approximate equilibrium conditions for decay series products associated with Ra-226 and Ra-228 (the U-238 and Th-232 decay series respectively), average levels and variability for naturally occurring gamma emitting radionuclides (including K-40) are very similar at both sites. At Moore Ranch, soil sample results for Ra-226 were generally within ± 1 pCi/g of corresponding gamma-based estimates (EMC, 2007) despite this amount of variability in Ra-228 and K-40 values. As previously indicated, differences at most Wyoming sites have been within ± 2 pCi/g under similar conditions.

Figure 2.9-27: Frequency histograms of Ra-226, K-40 and Ra-228 results for surface soil samples from Ludeman (top) and Moore Ranch (bottom). Values for both radial grid samples and correlation plot samples are included.

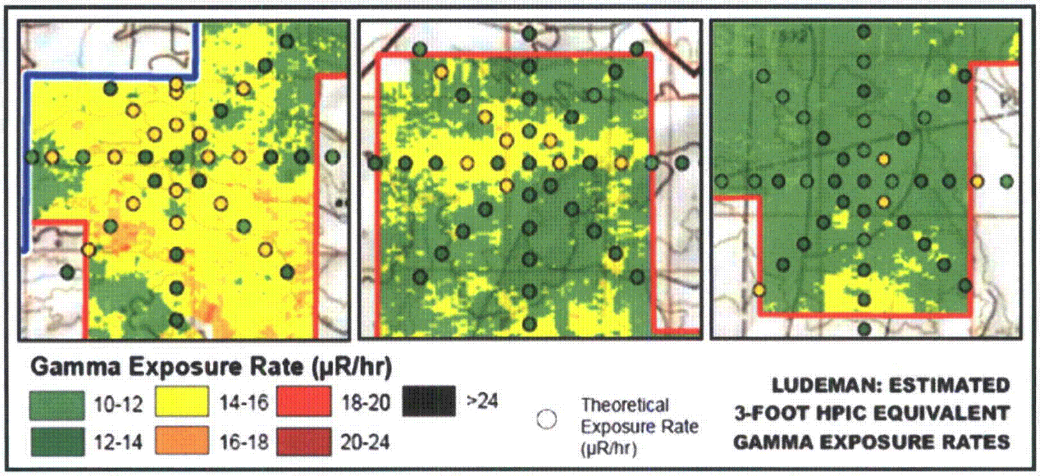


Gamma measurements and composite soil sampling at each correlation plot are designed to be spatially precise and highly representative of average conditions for each parameter. The correlation between field gamma readings and Ra-226 concentrations in surface soils at the proposed project demonstrated a very strong statistical relationship. Figure 2.9-18 clearly shows the spatial associations between these two parameters. The r-squared of 0.99 for the gamma/Ra-226 regression (Figure 2.9-19) suggests only a 1 percent probability that the observed statistical correlation was a result of random chance or a coincidental artifact of sampling/analytical error. The prediction limits on this regression indicate that 95 percent of the total estimation uncertainty associated with the correlation data is equivalent to about ± 1 pCi/g. This level of uncertainty and the regression coefficients are both nearly identical to corresponding parameters observed in the gamma/Ra-226 correlation for the nearby Moore Ranch site (Figure 2.9-20).

On the other hand, analytical laboratory results for soil Ra-226 concentrations in radial grid samples from the proposed project were generally low relative to Moore Ranch and other sites in Wyoming and showed little variation in association with the spatial distributions of measured gamma exposure rates. The average Ra-226 concentration among radial grid samples (0.9 pCi/g) was low relative to the average value across the site as predicted by field gamma measurements (1.9 pCi/g), and is also low relative to the average value for directly measured soil samples from Moore Ranch (1.5 pCi/g). It is also slightly low relative to national averages reported in the literature (1-2 pCi/g as cited in Myrick et al., 1983 and NCRP, 1987).

These soil sampling results prompted calculation of a theoretical gamma exposure rate at each radial grid location based on expected contributions to the total gamma radiation field from both cosmic and terrestrial sources. The cosmic component was modeled based on elevation (Stone et al. 1999). Terrestrial components were calculated based on measured radionuclides in the Ludeman radial grid soil samples and use of conversion factors given in NCRP Report 94 (NCRP, 1987). Results for Ra-226 and Ra-228 (analogs for the U-238 and Th-232 decay series, assuming equilibrium) along with K-40 were used for these calculations under an assumption that these soil parameters (and associated decay series products) are the primary terrestrial sources at Ludeman and that each discrete sampling result reflects uniform soil radionuclide concentrations in the area. Calculated total theoretical gamma exposure rates at radial grid soil sampling locations were then plotted on the kriged, HPIC-equivalent gamma exposure rate map for comparison (Figure 2.9-28).

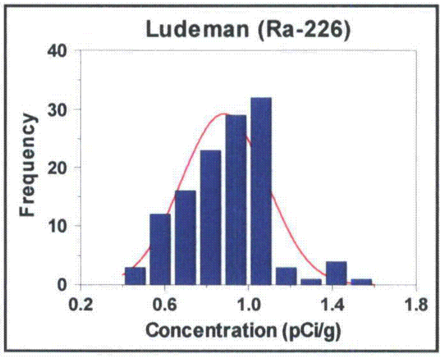
Figure 2.9-28: Calculated theoretical gamma exposure rate based on elevation and soil radionuclide concentrations at each radial grid sampling location, superimposed on the HPIC equivalent gamma survey map. Legend increments and color coding apply to both calculated theoretical values and kriged values based on the gamma survey.



In general, there is reasonably good spatial/quantitative agreement in many areas between theoretical gamma exposure rates at radial grid sampling locations and kriged, HPIC-equivalent estimates based on gamma survey measurements. However, there is an apparent trend of low theoretical values relative to kriged values at a significant number of locations, particularly in areas of consistently higher measured gamma readings. This suggests that soil radionuclide results for discrete soil samples collected in these areas may commonly under-represent average local concentrations. For example, if the average soil Ra-226 concentration in the vicinity of a given radial grid sampling location were underestimated by 1 pCi/g based on the point sample result, the calculated theoretical exposure rate could underpredict the actual exposure rate by as much as 1.8 μR/hr (due to this single source of terrestrial gamma radiation).

Radionuclide histograms for radial grid soil samples indicate that both Ra-228 and K-40 have roughly normal distributional characteristics, similar to those shown in Figure 2.9-27. Neither distribution is right-skewed (i.e. lognormal) and there was essentially no statistical correlation between the two radionuclides ($R^2 < 0.1$), thus neither source (alone or combined) is likely to be consistently responsible for higher gamma exposure rates in certain areas as identified and delineated by the gamma survey. This suggests that Ra-226 must be primarily responsible and should thus have at least a somewhat right skewed histogram, similar in nature to that shown in Figure 2.9-27 for all samples collected at the site (including the correlation plot samples).

Figure 2.9-29: Frequency histogram of analytical results for Ra-226 at radial grid soil sampling locations.



However, the histogram of Ra-226 values for radial grid samples is not right skewed. Instead, this distribution is unusual with an increasing frequency of occurrences building towards a value of 1.1 pCi/g, followed by an abrupt truncation above this value and only a few instances of slightly higher concentrations represented (Figure 2.9-29). This result is believed to be at least partly responsible for the low theoretical exposure rate values in areas of consistently higher measured gamma readings, and can thus potentially be linked to a low bias in soil sampling results versus gamma-based soil Ra-226 estimates.

Based on all available quantitative and qualitative evidence, the most likely explanations for apparent discrepancies and bias between gamma-based estimates of soil Ra-226 concentrations and directly measured Ra-226 concentrations in discrete radial grid soil samples include:

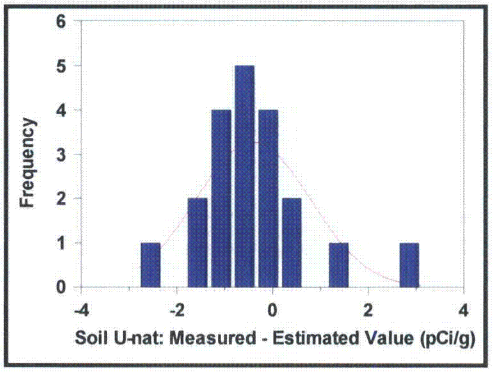
- Spatial heterogeneity in actual soil radionuclide concentrations relative to smoothly interpolated estimates between gamma survey tracks.
- Errors related to discrete point sampling versus composite sampling across more spatially representative areas (also a heterogeneity issue).
- Error in mapping the precise location where each radial grid sample was collected (GPS readings were recorded only at radial grid centers).
- Potential low bias in analytical laboratory results.

In general, the evidence tends to support an estimate of uncertainty in gamma based predictions of Ra-226 in surface soils that is consistent with values from other study sites in Wyoming (on the order of ± 2 pCi/g). Areas with the highest gamma readings at the site could have uncertainties that exceed this range, but such areas represent only small portions of the site and these areas are still well defined as being naturally elevated with respect to terrestrial sources of gamma radiation. In all cases, is important to recognize that kriged, gamma-based estimates of radionuclide concentrations in surface soils are based on the preponderance of gamma readings in any given area, and are thus most likely to reflect average soil concentrations across larger source areas.

2.9.2.4.3 Gamma-Based Soil U-nat Estimates

Regarding uncertainty in gamma-based estimates of soil U-nat concentrations (Figure 2.9-25), direct comparison between estimated and measured values demonstrate results that are consistent with the correlation results as well as with past results for this characterization technique. U-nat results for all soil and sediment samples (provided later in this report) are reasonably consistent with corresponding results from the nearby Moore Ranch site (EMC, 2008).

Figure 2.9-30 Histogram of differences between measured U-nat in soil samples and estimated U-nat values based on gamma readings in corresponding locations.



Comparisons of U-nat results from direct soil sampling against gamma-based estimates in corresponding locations suggests about ± 3.5 pCi/g of total estimation uncertainty (Figure 2.9-30). This amount of uncertainty is higher than indicated by the prediction limits on the gamma/U-nat correlation (Figure 2.9-23), likely due to variability in U-nat/Ra-226 ratios and the fact that the krig map involves interpolation between scan tracks where no actual measurements were collected.

Although a slight relative bias is apparent between estimated and measured U-nat values (about ± 0.5 pCi/g from an ideal mean difference of zero), the average difference is reasonably close to zero and the majority of individual differences are within ± 1 pCi/g of the mean. It is not clear whether the apparent bias is slightly high for estimated values, or slightly low for measured values.

2.9.2.5 Data Uncertainty Implications

Although the estimated total data uncertainty for gamma-based estimates of Ra-226 and U-nat in surface soils (± 2 pCi/g and 3.5 pCi/g respectively) appears high relative to the range of concentrations present, correlations generate the most probable statistical estimate of an equivalent measured concentration value at a given gamma reading based on average relationships from the correlation plot data. Assuming consistency in the analytical method used for soil sample analyses, the majority of measured concentration values should thus be closer to the estimated values versus respective bounds on estimated data uncertainty. This theoretical expectation is supported by the frequency histograms shown in Figures 2.9-26 and 2.9-30.

Because uncertainty is inherent in any type of survey data, statistical methods must be used to help account for such uncertainty when evaluating whether operational/post operational survey data are different from estimated baseline values at a given level of confidence, or whether they exceed applicable regulatory criteria relative to estimated baseline values. In addition to use of the kriged soil radionuclide concentration maps to help ascertain respective changes in radiological conditions (operationally or post operationally), the final kriged map of estimated baseline gamma exposure rates (Figure 2.9-17) should also be used. Gamma exposure rate results (cross-calibrated against the HPIC) are believed to be reliable and reproducible within a slightly smaller relative range of total data uncertainty.

When both spatial and quantitative aspects are considered, gamma based estimates of soil radionuclide concentrations across the site should result in considerably less overall uncertainty relative to direct soil sampling alone. This gamma survey methodology produces a spatial density of information on terrestrial sources of gamma radiation that is orders of magnitude greater than can be achieved by grid-based sampling or measurement approaches. Grid-based approaches rely more heavily on an assumption of spatial uniformity in soil concentrations. Survey data for this site, as well as for many other uranium recovery sites, demonstrate that baseline soil radionuclide concentrations can vary significantly across small areas. Grid-based survey approaches have a higher probability of missing or mischaracterizing the spatial distribution and extent of such features.

Direct, grid-based soil sampling data, however, are a necessary and important component of this overall characterization approach. Grid-based soil sampling is indicated in applicable regulatory guidance documents and also enables evaluation of the degree of uncertainty in gamma-based estimates (assuming consistency in analytical laboratory methods) as well as factors that may influence such uncertainty (e.g. heterogeneity, representativeness, etc.). The combination of both forms of radiological survey information is significantly more effective than either form alone.

2.9.2.6 Conclusions

The 2008 baseline gamma survey of the proposed project site in Converse County, Wyoming provides a detailed characterization of natural background gamma exposure rates and associated radionuclide soil concentrations at the site. The survey included high density gamma scanning using six independent (factory-calibrated) detectors, robust daily quality control measurements, NaI/HPIC cross calibrations, gamma/soil radionuclide correlations, in-depth statistical assessments, and geostatistical spatial analysis techniques in an effort to provide the most thorough characterization possible for a number of important baseline radiological parameters.

Gamma exposure rates and gamma-based estimates of soil radionuclide concentrations are similar to those observed at the nearby Moore Ranch site (EMC, 2007). Baseline gamma exposure rate characterization results along with gamma-based estimates of Ra-226 and U-nat concentrations in surface soils should meet regulatory standards for baseline characterizations. This information will help facilitate effective identification and assessment of any potential radiological contamination that could result from ISR activities. Future measurements of these parameters should use analytical methods consistent with the methods used in this survey. The technology and approaches used for this gamma survey have resulted in a level of understanding of radiological baseline characteristics at the proposed project site that is likely to benefit all stakeholders.

2.9.3 Soil Sampling

Soil sampling was conducted at the proposed project site in the fall of 2008 in accordance to NRC Regulatory Guide 4.14 protocols. Data from NRC Regulatory Guide 4.14, soil sampling represents discrete, systematic locations involving 5-cm sampling depths for surface soils, and incremental soil profile sampling to a depth of 1 meter for subsurface soils (NRC, 1980). Because gamma-based estimates of soil radionuclides were based on 15-cm surface soil depths, baseline soil radionuclide concentration data for both 5-cm and 15-cm soil depths are represented in this report in accordance with NRC Regulatory Guide 4.14 protocols and NUREG-1569 application review recommendations (NRC, 2003).

2.9.3.1 Methods

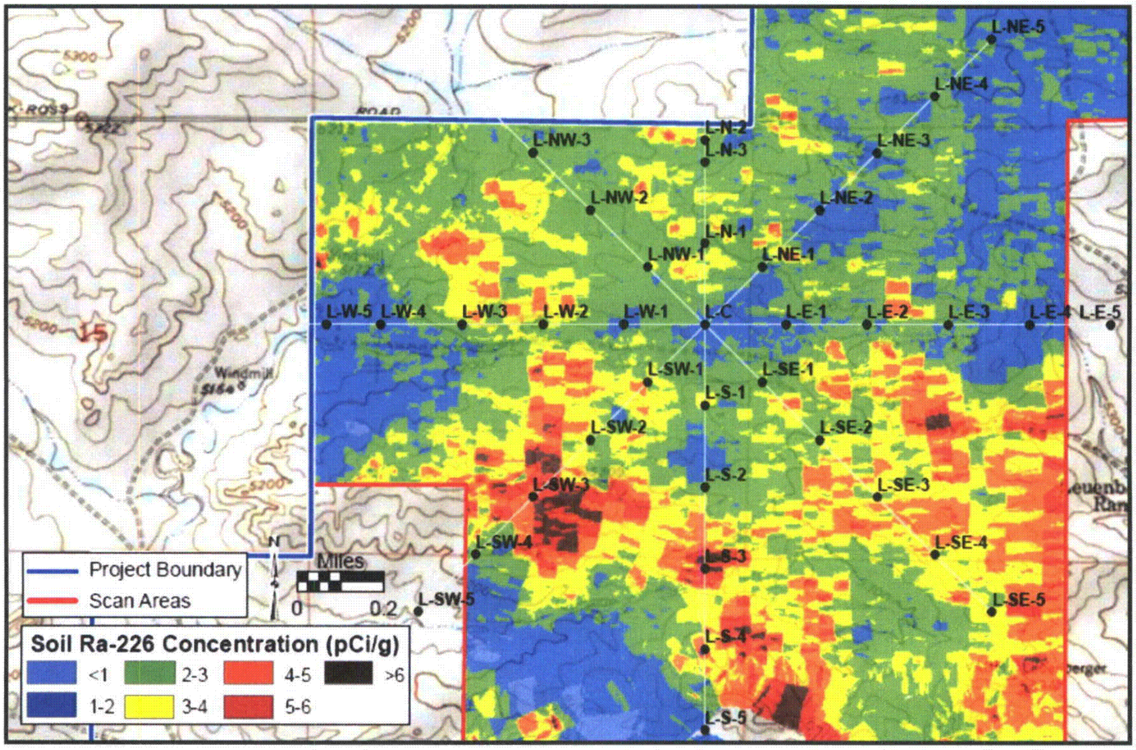
2.9.3.1.1 Surface Soil Sampling

The surface soil sampling design indicated in NRC Regulatory Guide 4.14 involves a radial grid pattern with the center of the grid located at the proposed processing facility. In this case, there are three proposed Satellite facility sites within the project area boundaries, each of which is separated by considerable distances (Figure 2.9-3). Discrete soil samples were collected along transects radiating in 8 compass directions from each of these facility locations at 300 meter intervals as is illustrated in Figure 2.9-31 for Facility Site 1 (the "Leuenberger" Facility Site).

Each radial grid sampling transect was about 1,500 meters long, resulting in the collection of 5 samples per transect for a total of 41 radial grid samples per Satellite facility. In a few cases, there were necessary omissions or spatial modifications to the radial sampling grid as planned locations were located off-site on private property, or in areas disturbed by pipeline installations. Soil samples were sent to ELI (Casper, Wyoming) for analysis of all analytes as specified in NRC Regulatory Guide 4.14.

Analytes included Ra-226 for all samples, with about 11 percent of the samples being further analyzed for natural uranium (U-nat), Th-230, and Pb-210. Additional surface soil samples were collected at each air particulate monitoring station and were analyzed per NRC Regulatory Guide 4.14 specifications. All radial grid and air station surface soil samples were collected with a shovel or hand trowel to a depth of 5 cm, double bagged, and labeled. Sampling tools were cleaned before each subsequent collection. A systematic location ID number (Facility Site name, transect compass heading, and transect sample number) for each sampling location, along with the collection date, were recorded in the field log book. GPS coordinates were taken at the center of each sampling grid. Sampling locations along each radial grid transect were determined in the field at approximate 300-meter intervals. Individual GPS coordinates or gamma readings were not taken at each location. Samples were sent to ELI in Casper, Wyoming along with chain of custody / analysis request forms. After receipt by ELI, samples were dried, crushed, ground, and thoroughly homogenized prior to analysis.

Figure 2.9-31 NRC Regulatory Guide 4.14 radial grid surface soil sampling locations (black dots) with annotated sample ID scheme for Satellite Plan Site 1 (the "Leuenberger" Facility Site). Gamma-based estimates of soil Ra 226 concentrations are also shown to illustrate the spatial distribution of local sources of terrestrial gamma radiation relative to grid locations.



2.9.3.1.2 Subsurface Soil Sampling

Five subsurface depth profile sampling locations in the vicinity of each Satellite facility were also selected based on NRC Regulatory Guide 4.14 recommendations. One location was at the approximate center of each planned Satellite facility location, with the other four samples collected along the same radial transects used for surface soil sampling, at 750 meters from the facility and in the four primary compass headings (N, E, S, and W).

Subsurface soil samples were collected with a 2-man gas powered auger with a 4-inch diameter bit with a 3-foot extension. At each location, three depth-integrated samples were successively collected at 33-cm increments, the final sample culminating at a total depth of 1 meter. After a sample was taken, the hole was cleaned out before going to the next required depth. Sample collection, lab delivery, chain of custody, sample preparation, and analysis protocols were the same as those described in the preceding section for surface soil samples. All soil depth profile samples were analyzed for Ra-226 by gamma spectroscopy (Method 901.1). At each of the three Satellite Site radial depth sampling grids, all samples from one location were further analyzed for natural U-nat, Th-230, and Pb-210 by wet radiochemical methods.

2.9.3.2 Soil Sampling Results

Annotated maps of Ra-226 concentration results from all radial grid surface soil samples collected at the site have been superimposed on the kriged gamma-based estimates of soil Ra-226 and are provided in this Section. Tabular summary statistics for all surface soil sampling results are also provided. The subsequent section provides tabular summary statistics for subsurface soil samples. Results for all radionuclides are reasonably consistent with results from Moore Ranch (EMC, 2008) though Ra-226 results for radial grid samples were generally low as discussed in Section 2.9.2.4.2.

2.9.3.2.1 Surface Soil Sampling Results

Color-coded, annotated soil Ra-226 results for all surface soil samples (0-5 cm depths) are provided for each radial sampling grid illustrated in Figures 2.9-32 through 2.9-34. Summary statistics for all radiological surface soil parameters as recommended in NRC Regulatory Guide 4.14 are shown in Table 2.9-1.

Figure 2.9-32: Facility Site 1 (Leuenberger) radial grid surface soil sampling results: annotated Ra-226 concentrations (pCi/g) for discrete samples collected at a 5-cm soil depth, superimposed on the gamma-based Ra-226 estimation map.

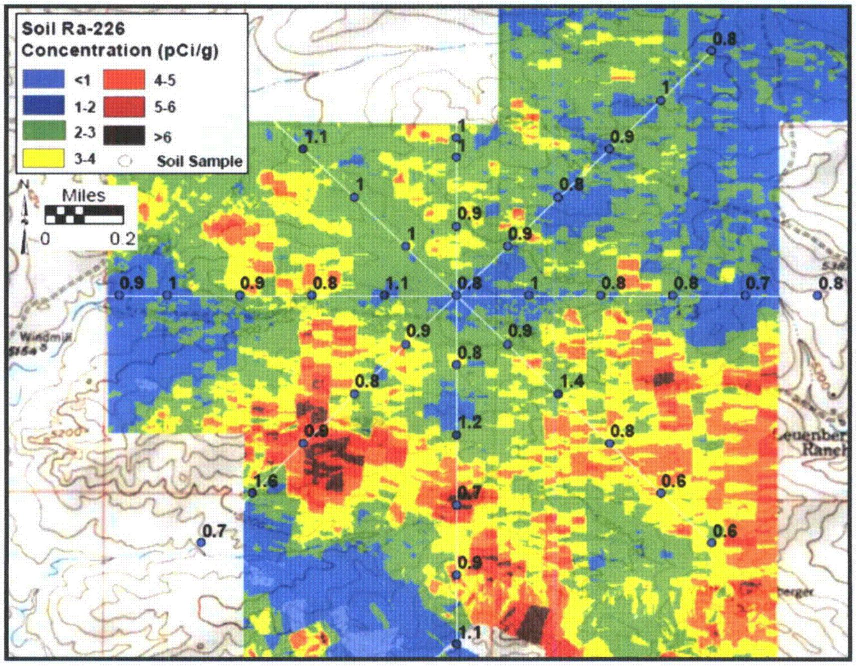


Figure 2.9-33: Facility Site 2 (North Platte) radial grid surface soil sampling results: annotated Ra-226 concentrations (pCi/g) for discrete samples collected at a 5-cm soil depth, superimposed on the gamma-based Ra-226 estimation map.

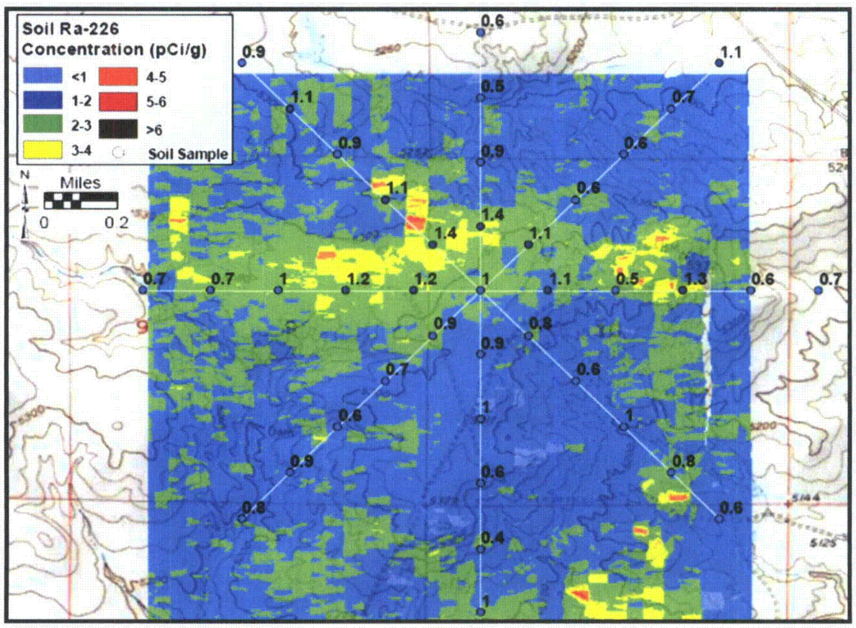


Figure 2.9-34: Facility Site 3 (Peterson) radial grid surface soil sampling results: annotated Ra-226 concentrations (pCi/g) for discrete samples collected at a 5-cm soil depth, superimposed on the gamma-based Ra 226 estimation map.

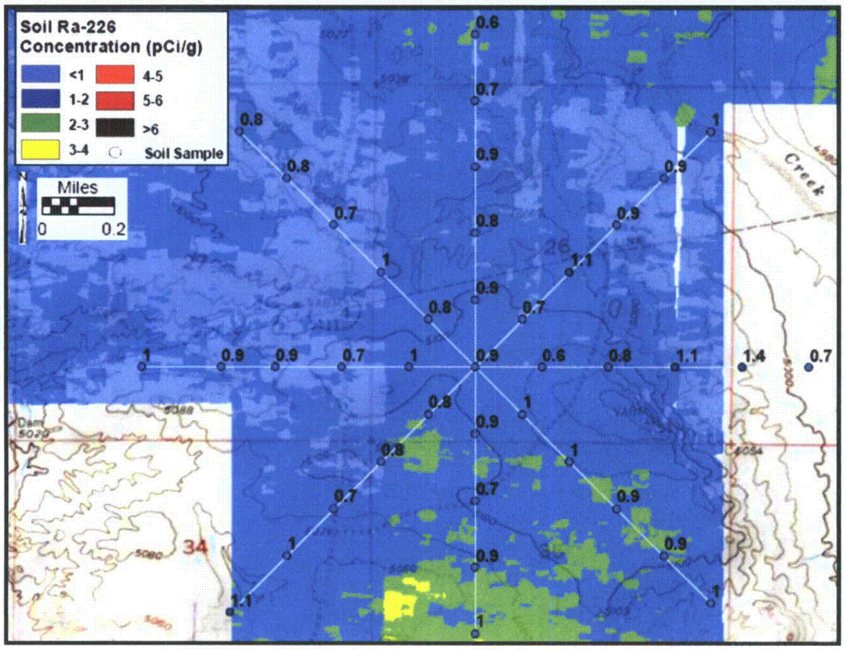


Table 2.9-1: Summary statistics for surface soil samples collected along the radial grids and at air particulate monitoring stations (discrete samples collected at 5-cm sampling depths).

Surface Soil Sample Series	Mean	Std. Dev.	Median	Max	Min	n
Ra-226 (pCi/g)						
Plant 1 (Leuenberger) Radial Samples	0.9	0.2	0.9	1.6	0.6	37
Plant 2 (North Platte) Radial Samples	0.9	0.3	0.9	1.4	0.4	41
Plant 3 (Peterson) Radial Samples	0.9	0.2	0.9	1.4	0.6	41
Air Particulate Station Samples	0.8	0.1	0.8	0.9	0.7	5
All Samples	0.9	0.2	0.9	1.6	0.4	124
U-nat (pCi/g)						
Plant 1 (Leuenberger) Radial Samples	0.9	0.2	0.9	1.0	0.7	3
Plant 2 (North Platte) Radial Samples	0.8	0.3	0.7	1.2	0.5	4
Plant 3 (Peterson) Radial Samples	0.6	0.1	0.6	0.8	0.5	4
Air Particulate Station Samples	0.8	0.2	0.7	1.1	0.7	5
All Samples	0.8	0.2	0.7	1.2	0.5	16
Th-230 (pCi/g)						
Plant 1 (Leuenberger) Radial Samples	0.3	0.1	0.3	0.4	0.2	4
Plant 2 (North Platte) Radial Samples	0.2	0.1	0.2	0.4	0.1	4
Plant 3 (Peterson) Radial Samples	0.4	0.1	0.4	0.5	0.3	4
Air Particulate Station Samples	0.3	0.1	0.3	0.4	0.1	5
All Samples	0.3	0.1	0.3	0.5	0.1	17
Pb-210 (pCi/g)						
Plant 1 (Leuenberger) Radial Samples	0.8	0.8	0.6	1.7	0.2	3
Plant 2 (North Platte) Radial Samples	1.6	0.6	1.5	2.3	1.0	4
Plant 3 (Peterson) Radial Samples	0.6	0.5	0.6	1.2	0.1	4
Air Particulate Station Samples	0.5	0.9	0.9	1.2	-0.9	5
All Samples	0.5	0.8	1.0	2.3	-0.9	16

Apparent discrepancies between soil sampling results for Ra-226 and gamma-based estimates in corresponding locations are discussed at length in Section 2.9.2.4.2. The evidence suggests that considerable heterogeneity in soil radionuclide concentrations may be responsible for such discrepancies. Given that gamma survey measurements define averages from terrestrial sources across larger source areas (e.g. 100 m^2), while discrete soil samples give only a point estimate. There is also evidence of a potentially low bias in soil sampling results for Ra-226, given the measured levels of other radionuclides such as Ra-228 and K-40 relative to the total gamma field at these locations. Gamma-based soil Ra-226 estimates are believed to provide a reliable characterization of average surface concentrations in the general vicinity of any given location.

2.9.3.2.2 Subsurface Soil Sampling Results

Summary statistics for subsurface samples by radionuclide and sampling depth increment across all subsurface sampling locations are shown in Table 2.9-2. There was no indication of any trends in soil concentration with depth at any of the radial sampling grids. This result suggests that soil concentration is generally independent of depth over the top 1 meter of the soil profile in most locations, and that surface soil sampling results and gamma-based estimates of soil radionuclides provide a reasonable indication of expected concentrations over this depth in the soil profile.

Table 2.9- 2: Summary statistics for all subsurface (depth profile) soil samples collected along NRC Regulatory Guide 4.14 radial grids (includes grids for all three Satellite facility locations).

Soil Sampling Depth (cm)	Mean	Std. Dev.	Median	Max	Min	n
Ra-226 (pCi/g)						
0-33	1.0	0.2	0.9	1.2	0.7	15
33-66	0.9	0.2	1.0	1.3	0.5	15
66-100	1.0	0.3	0.9	1.7	0.6	15
U-nat (pCi/g)						
0-33	0.7	0.2	0.7	0.9	0.5	3
33-66	0.7	0.2	0.7	0.9	0.5	3
66-100	0.9	0.2	0.9	1.0	0.6	3
Th-230 (pCi/g)						
0-33	0.4	0.2	0.5	0.5	0.2	3
33-66	0.0	0.3	-0.2	0.4	-0.2	3
66-100	0.1	0.4	0.1	0.4	-0.3	3
Pb-210 (pCi/g)						
0-33	0.1	0.7	0.4	0.5	-0.7	3
33-66	0.1	1.1	-0.3	1.3	-0.8	3
66-100	-0.3	0.9	-0.7	0.7	-1.0	3

2.9.3.3 Conclusions

Baseline radiological soil sampling data for the proposed project site were collected in accordance with NRC Regulatory Guide 4.14 protocols. These data sets, combined with correlated soil sampling results and continuous kriged estimates of Ra-226 and U-nat soil concentrations based on gamma survey data (Section 2.9.2.2.5) provide a comprehensive characterization of existing soil radionuclide concentrations across the site. This information should meet respective baseline characterization requirements as indicated by the U.S. Nuclear Regulatory Commission and the Wyoming Department of Environmental Quality / Land Quality Division for ISR licensing/permitting applications.

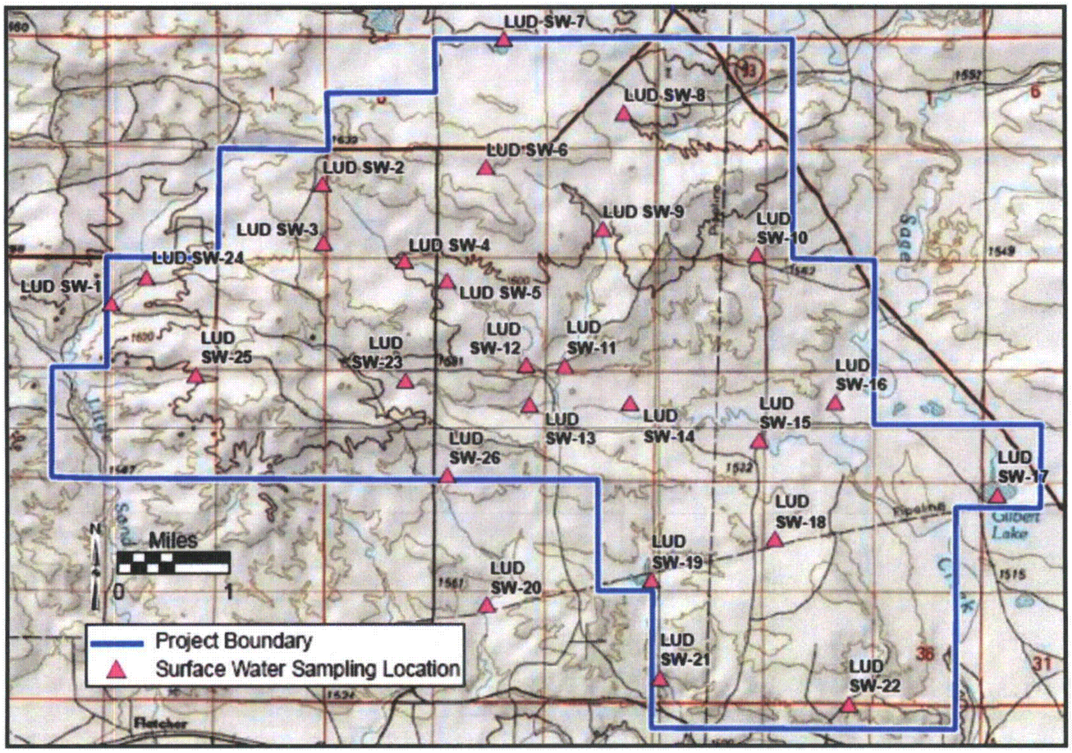
2.9.4 Sediment Sampling

In August of 2008, baseline sediment sampling was conducted at the proposed project site in general accordance with NRC Regulatory Guide 4.14 protocols (NRC, 1980). Although this guidance calls for two separate sampling events (spring and fall) for stream sediments, respective sediment sampling at other ISR sites in the region show that measured differences in sediment radionuclide concentrations between runoff season (spring) and low-flow (fall) hydrologic conditions are very similar, generally falling within the range of normal sampling and analytical variability (EMC, 2008; Uranium One, 2009).

Figure 2.9-35: Example of an ephemeral stream drainage channel at the Ludeman Project.

Selected sediment sampling locations were the same as those used for surface water sampling locations (Figure 2.9-35). This included stock ponds, small natural impoundments and ephemeral stream drainage channels. These locations are widely distributed across the site, including locations generally upstream and downstream from proposed Satellite facility locations (Figure 2.9-36).

Figure 2.9-36: Surface water / sediment sampling locations.



2.9.4.1 Methods

At each sediment sampling location, a soil sample was collected with a hand trowel to a depth of 5 cm. Location ID numbers, date, and GPS coordinates for each sampling location were recorded in the field log book. Samples were sent to Energy Laboratories, Inc. in Casper, Wyoming along with chain of custody / analysis request forms. Samples were dried, crushed, ground, and thoroughly homogenized prior to analysis. Sediment samples were analyzed for Ra-226 content by gamma spectroscopy (Method 901.1). Other analytes were measured by standard wet radiochemical methods.

2.9.4.2 Sediment Sampling Results

Individual sampling locations and respective Ra-226 results are shown in Figure 2.9-37. Individual results for all radionuclides by location are shown in Figure 2.9-38. Descriptive summary statistics of all sediment data are provided in Table 2.9-3. On average, baseline sediment radionuclide results are slightly higher compared to surface soil data (Section 2.9.3.2.1), and considerably higher for Pb-210. One unusually high U-nat value was reported.

Figure 2.9-37: Sediment sampling locations (same as surface water sampling locations) and annotated sediment Ra-226 concentration results.

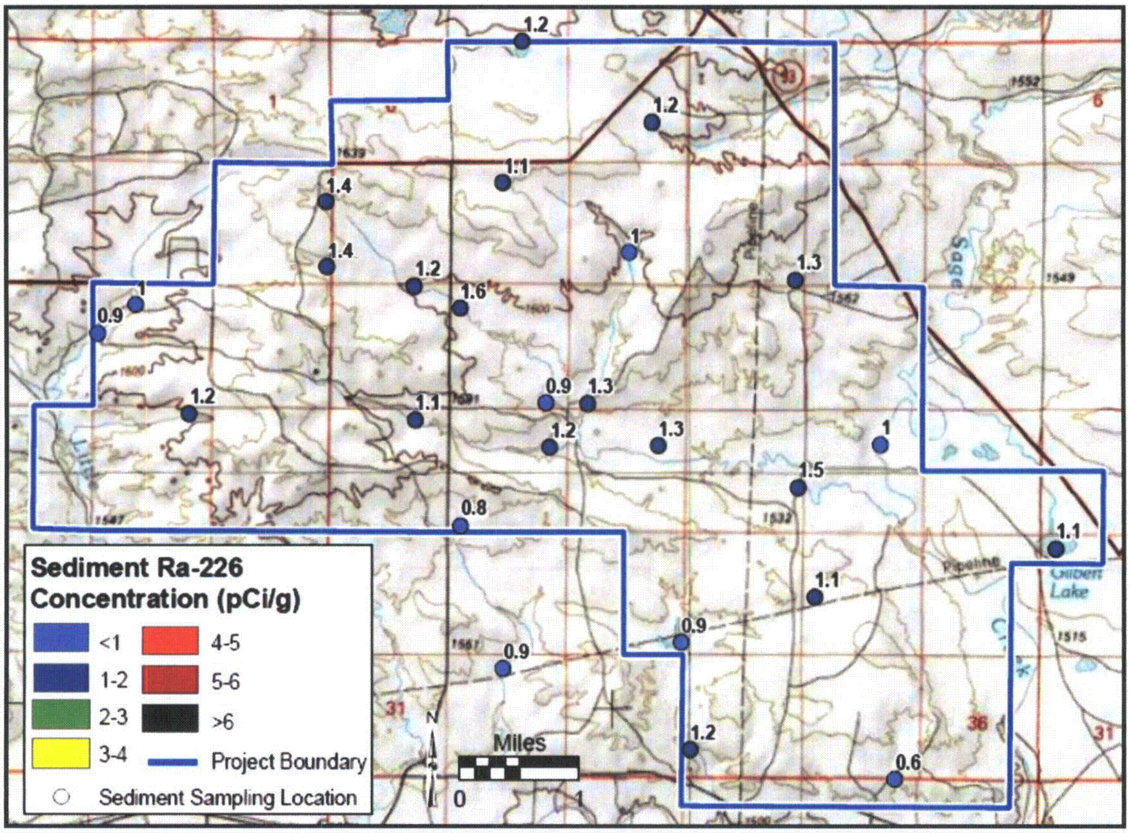


Figure 2.9- 38: Individual sediment sampling results by radionuclide and location.

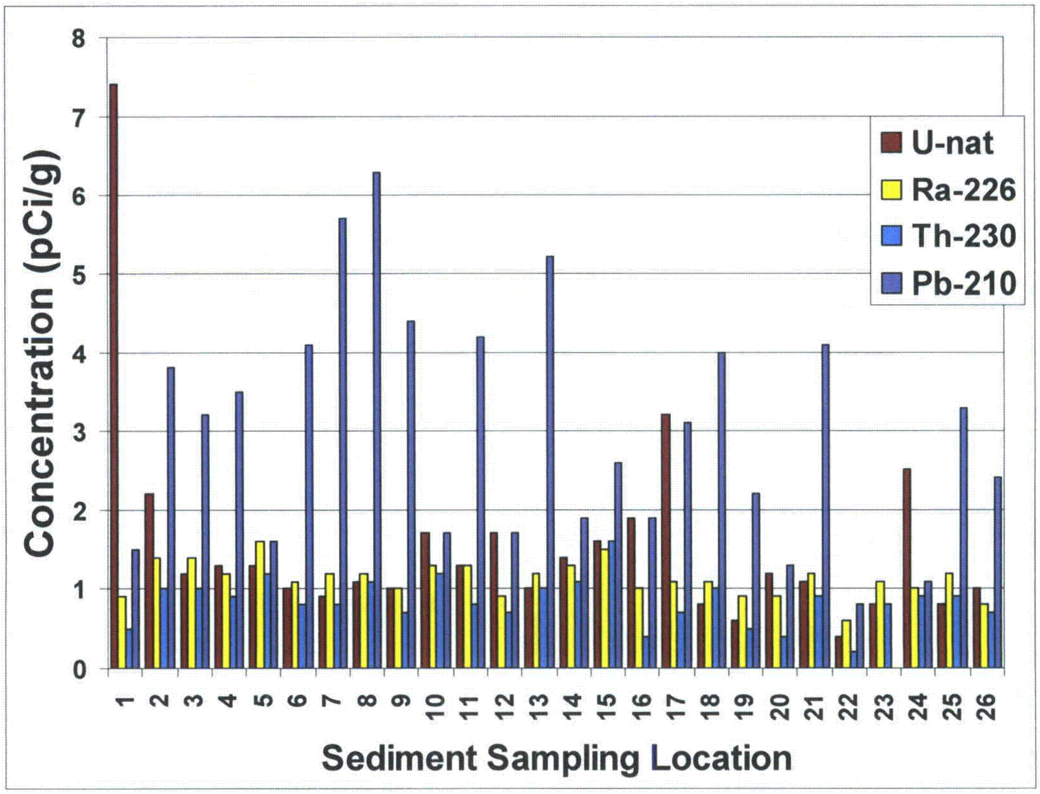


Table 2.9-3: Descriptive Statistics for Stream Sediment Samples.

Analyte	Mean	Std. Dev. (pCi/g)	Median (pCi/g)	Max (pCi/g)	Min (pCi/g)	n
Ra-226	1.1	0.2	1.2	1.6	0.6	26
U-nat	1.6	1.3	1.2	7.4	0.4	26
Th-230	0.8	0.3	0.9	1.6	0.2	26
Pb-210	3.0	1.5	3.1	6.3	0.8	25

The high uranium concentration detected in sediment at location 1 (LUD SW-1), appears to be a legitimate analytical result, as surface water samples collected at this same location at different times also yielder higher uranium concentrations (see Section 2.9.9).

2.9.4.3 Conclusions

Baseline sediment radionuclide data for the proposed project site were collected and analyzed according to NRC Regulatory Guide 4.14 protocols. This information should be sufficient to meet respective baseline survey requirements as indicated by the U.S.

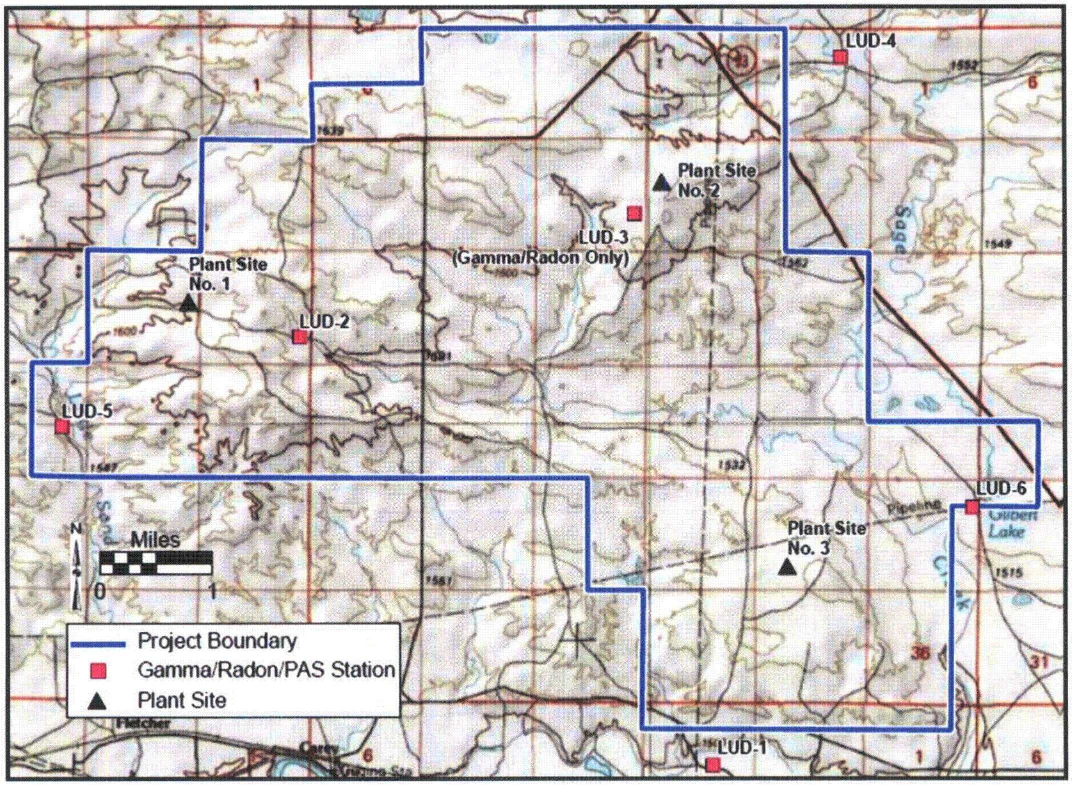
Nuclear Regulatory Commission and the Wyoming Department of Environmental Quality / Land Quality Division with respect to ISR licensing/permitting applications.

2.9.5 Ambient Gamma Dose Rate and Radon Monitoring

Continuous passive monitoring of ambient gamma dose rates and radon concentrations within the project area was initiated in March 2008. NRC Regulatory Guide 4.14 calls for 12 consecutive months of respective monitoring data as part of the overall radiological characterization of the site (NRC, 1980). This data was collected and reported on a quarterly basis.

Passive devices for monitoring average ambient gamma dose rates and radon levels are housed within each monitoring station. Station locations were selected based on NRC Regulatory Guide 4.14, including locations of Satellite facilities, prevailing wind directions, corresponding locations with air particulate monitoring stations, adjacent residences, practical access, and consideration for continued monitoring during operational phases of the project. In all, 6 of these stations were installed, one at each particulate air sampling (PAS) location. Locations of passive gamma/radon and PAS monitoring stations are shown in Figure 2.9-39.

Figure 2.9-39: Approximate station locations for combined monitoring of ambient baseline gamma dose rate, radon, and air particulates (Gamma/Radon/PAS stations



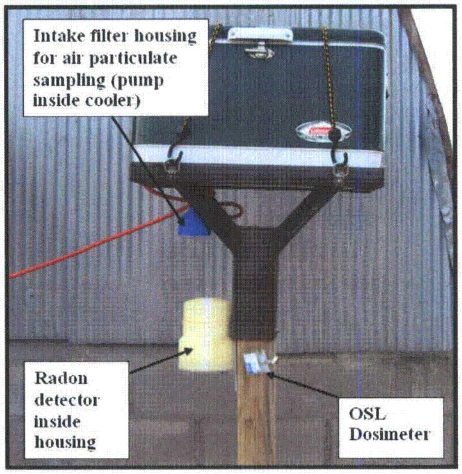
2.9.5.1 Methods

2.9.5.1.1 Ambient Gamma Dose Rate Monitoring

Passive monitoring of gamma dose rates at the site is being conducted with optically stimulated luminescent dosimeters (OSLs) supplied by Landauer, Incorporated. The OSLs are attached to air particulate monitoring stations (Figure 2.9-40).

Each batch of OSLs contains a "transit" and "deploy" control OSL badge to account for background doses received by field badges when not actually deployed at the site. Both control badges were stored at Uranium One's office in Casper, Wyoming (away from any radioactive sources), except while in transit to and from Landauer; and as applicable, to and from the site during quarterly field badge change outs. One of the control badges is taken into the field during quarterly field dosimeter change-outs to account for any additional dose exposure to field badges during this period. However in this case, the distance and time required for this to occur was negligible, relative to the overall monitoring period; and thus, slight differences between transit and deploy control badge dose results are not considered a reliable measure of this dose, particularly in a context of potential uncertainties in such measurements.

Figure 2.9-40: Passive gamma/radon monitoring station equipment attached to air particulate sampling station.



Landauer reports a "net" dose result, calculated by subtracting the deploy control badge result from each field badge result. This gives a net above background dose, which is useful for occupational dose assessments relative to regulatory dose limits, but is not applicable for environmental monitoring where the total dose received at the site during the monitoring period is of interest. For this, a different calculation is required, one that subtracts only the fraction of control badge dose representing the amount of time the field badges are not actually deployed at the site. For this project, the calculations used to obtain this gamma dose value are outlined as follows:

1. Determine the average daily dose rate for the transit control badge:
   - Assuming the control badge receives background doses at a relatively constant rate, this is calculated as the gross reported dose (mrem), divided by the total number of days from OSL issuance to OSL analysis by the dosimetry vendor.
2. Determine the total dose to the field dosimeter while not deployed at the site:
   - Assume the field badge receives the same average daily dose rate as the transit control badge for all periods while stored or transported together with the transit control badge.

- Calculate the total dose to the field dosimeter while not deployed at the site as: (Result from step 1 above) × (number of days from OSL issuance to OSL analysis, minus the number of days the field badge was actually deployed at the site)

3. Calculate the total dose received by the field OSL while deployed at the site:
   - Assume additional background dose received by the field badge during deployment to and from the site is negligible relative to the overall monitoring period.
   - Subtract the result in step 2 above from the gross result for the field OSL as reported by the vendor.

2.9.5.1.2 Ambient Radon-222 Monitoring

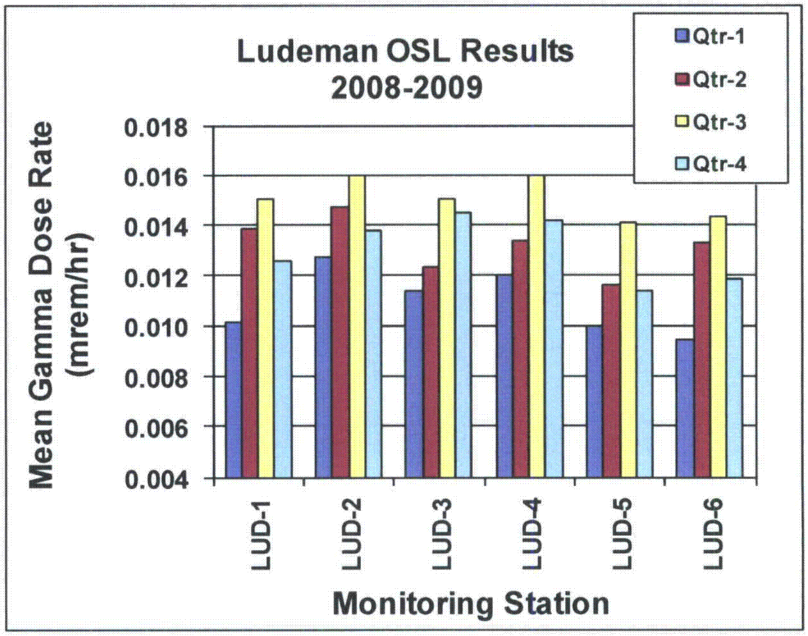
Passive monitoring of average Rn-222 air concentrations at the site is being conducted with Radtrak® alpha-track radon gas detectors supplied by Landauer. These radon detectors, also attached to air particulate stations, are housed in special plastic containers from the OSL dosimetry provider (Figure 2.9-40). The radon detectors are supplied by the vendor in special sealed packages designed to prevent detector radon exposures prior to the beginning of the monitoring period. Upon completion of the site monitoring period, film-foil sealing stickers supplied by the vendor are applied to detector openings to prevent further radon exposure until the device is analyzed by the vendor for average Rn-222 concentration (in pCi/L).

2.9.5.2 Ambient Gamma Dose Rate and Radon Results

2.9.5.2.1 Ambient Gamma Dose Rate Results

Passive gamma dose monitoring results are presented graphically in Figure 2.9-41 and in tabular format in Table 2.9-4. In general, measured dose rates ranged between 0.009 and 0.015 mrem/hr. Assuming a radiation weighting factor of 1 for photons, these dose rates are generally consistent with the gamma survey results, which averaged 13.7 μR/hr (HPIC-normalized) across the areas surveyed.

Figure 2.9-41: Mean gamma dose rate results by quarter for each monitoring station



The OSL data suggest that quarterly differences in average gamma dose rates at a given location can vary significantly (over ± 0.004 mrem/hr in one case). In addition to actual temporal variability in background sources of gamma radiation, measurement error may have contributed to this apparent degree of temporal variation.

Table 2.9-4: Average ambient gamma dose rate monitoring results by quarter.

Passive Monitoring Station ID	OSL Issue Date	Field Installation Date	Monitoring End Date	Landauer GROSS Result (mrems)	Estimated Field Dose During Monitoring Period (mrem)	Estimated Daily Field Dose (mrem)	Estimated Field Dose Rate (mrem/hr)
QUARTER 1 (2008)							
LUD-1	1/1/2008	3/4/2008	4/14/2008	30.1	8.5	0.208	0.009
LUD-2	1/1/2008	3/4/2008	4/14/2008	34.9	13.3	0.325	0.014
LUD-3	1/1/2008	3/4/2008	4/14/2008	32.2	10.6	0.259	0.011
LUD-4	1/1/2008	3/4/2008	4/14/2008	33.5	11.9	0.291	0.012
LUD-5*	1/1/2008	-	-	34.8	-	-	-
LUD-6*	1/1/2008	-	-	34.1	-	-	-
Transit control	1/1/2008		4/14/2008	34.6	-	-	-
Deploy control	1/1/2008		4/14/2008	34.6	-	-	-
QUARTER 2 (2008)							
LUD-1	4/1/2008	4/14/2008	7/1/2008	35.1	28.3	0.295	0.012
LUD-2	4/1/2008	4/14/2008	7/1/2008	39.0	32.2	0.335	0.014
LUD-3	4/1/2008	4/14/2008	7/1/2008	34.9	28.1	0.293	0.012
LUD-4	4/1/2008	4/14/2008	7/1/2008	37.6	30.8	0.321	0.013
LUD-5*	4/1/2008	-	-	39.5	-	-	-
LUD-6*	4/1/2008	-	-	39.9	-	-	-
Transit control	4/1/2008		7/1/2008	36.3	-	-	-
Deploy control	4/1/2008		7/1/2008	36.9	-	-	-
QUARTER 3 (2008)							
LUD-1	7/1/2008	7/1/2008	10/2/2008	35.4	33.4	0.341	0.014
LUD-2	7/1/2008	7/1/2008	10/2/2008	37.1	35.1	0.359	0.015
LUD-3	7/1/2008	7/1/2008	10/2/2008	35.4	33.4	0.341	0.014
LUD-4	7/1/2008	7/1/2008	10/2/2008	37.7	35.7	0.365	0.015
LUD-5	7/1/2008	7/1/2008	10/2/2008	32.1	30.1	0.308	0.013
LUD-6	7/1/2008	7/1/2008	10/2/2008	35.4	33.4	0.341	0.014
Transit control	7/1/2008		10/2/2008	38.3	-	-	-
Deploy control	7/1/2008		10/2/2008	37.0	-	-	-
QUARTER 4 (2008)							
LUD-1	10/1/2008	10/2/2008	1/9/2009	34.0	31.7	0.302	0.013
LUD-2	10/1/2008	10/2/2008	1/9/2009	37.1	34.8	0.331	0.014
LUD-3	10/1/2008	10/2/2008	1/9/2009	38.8	36.5	0.347	0.014
LUD-4	10/1/2008	10/2/2008	1/9/2009	38.1	35.8	0.341	0.014
LUD-5	10/1/2008	10/2/2008	1/9/2009	31.1	28.8	0.274	0.011
LUD-6	10/1/2008	10/2/2008	1/9/2009	32.3	30.0	0.286	0.012
Transit control	10/1/2008		1/9/2009	40.6	-	-	-
Deploy control	10/1/2008		1/9/2009	37.7	-	-	-

*Station not installed until quarter 3, 2008

2.9.5.2.2 Ambient Rn-222 Monitoring Results

A summary of average baseline Rn-222 results by quarter is shown in Figure 2.9-42. Tabular data for individual stations are presented in Table 2.9-5. Ambient baseline radon concentrations were generally slightly higher than an estimated national average value (about 0.4 pCi/L as reported by Foster, 1993), but apparent differences may be within the range of normal measurement uncertainty. Given analytical uncertainties, the reported values are reasonably consistent with findings at the nearby Moore Ranch ISR site in Wyoming (Figure 2.9-42, right). The measured annual average baseline Rn-222 concentration at Ludeman was 0.8 ± 0.3 pCi/L.

Figure 2.9-42: Average ambient baseline Rn-222 results across all stations by quarter for Ludeman (left), and for the Moore Ranch ISR site (right; EMC, 2008) which is located approximately 45 miles NNW of Ludeman.

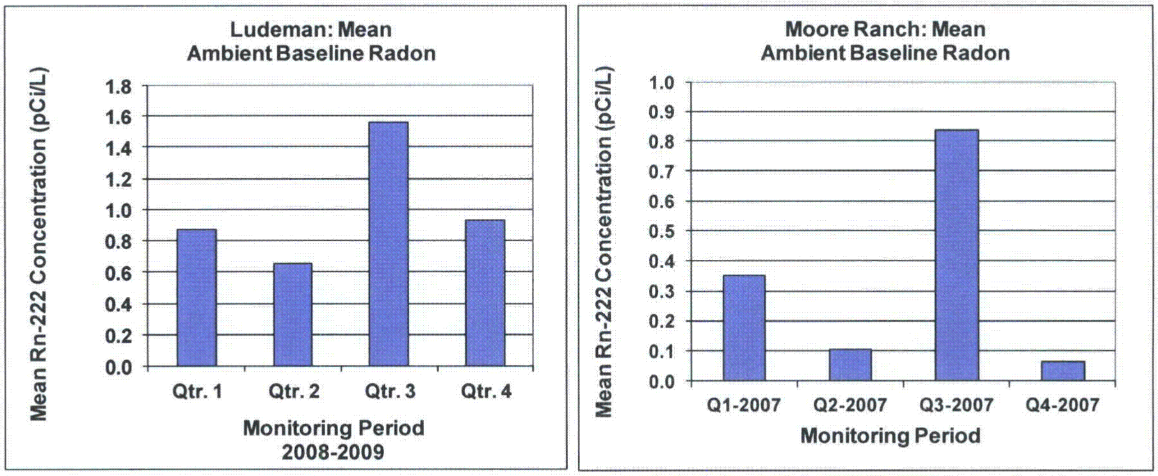


Table 2.9-5: Ambient baseline Rn-222 monitoring data.

Passive Monitoring Station ID	Field Installation Date	Quarter End (seal) Date	Quarterly Result (pCi-days/l)	Quarterly Results (pCi/l)
QUARTER 1 (2008)				
LUD-1	3/4/2008	4/14/2008	30	0.7
LUD-2	3/4/2008	4/14/2008	30	0.7
LUD-3	3/4/2008	4/14/2008	41	1
LUD-4	3/4/2008	4/14/2008	47	1.1
LUD-5	Not Sampled	-	-	-
LUD-6	Not Sampled	-	-	-
QUARTER 2 (2008)				
LUD-1	4/14/2008	7/1/2008	30	0.4
LUD-2	4/14/2008	7/1/2008	30	0.4
LUD-3	4/14/2008	7/1/2008	30	0.4
LUD-4	4/14/2008	7/1/2008	30	0.4
LUD-5	Not Sampled	-	-	-
LUD-6	Not Sampled	-	-	-
QUARTER 3 (2008)				
LUD-1	7/1/2008	10/2/2008	31.7	0.3
LUD-2	7/1/2008	10/2/2008	70.4	0.8
LUD-3	7/1/2008	10/2/2008	130.7	1.4
LUD-4	7/1/2008	10/2/2008	84.7	0.9
LUD-5	8/4/2008	10/2/2008	35.7	0.6
LUD-6	8/4/2008	10/2/2008	83.7	1.4
QUARTER 4 (2008)				
LUD-1	10/2/2008	1/9/2009	55.1	0.6
LUD-2	10/2/2008	1/9/2009	70.7	0.7
LUD-3	10/2/2008	1/9/2009	128.3	1.3
LUD-4	10/2/2008	1/9/2009	126.2	1.3
LUD-5	10/2/2008	1/9/2009	65.5	0.7
LUD-6	10/2/2008	1/9/2009	107.4	1.1
QUARTER 1 (2009)				
LUD-1	1/9/2009	4/1/2009	30	0.4
LUD-2	1/9/2009	4/1/2009	30	0.4
LUD-3	1/9/2009	4/1/2009	117.4	1.4
LUD-4	1/9/2009	4/1/2009	62.5	0.8
LUD-5	1/9/2009	4/1/2009	156.8	1.9
LUD-6	1/9/2009	4/1/2009	47.5	0.6
QUARTER 2 (2009)				
LUD-1	4/1/2009	7/14/2009	42.4	0.4
LUD-2	4/1/2009	7/2/2009	74.9	0.7
LUD-3	4/1/2009	7/14/2009	122.3	1.2
LUD-4	4/1/2009	7/14/2009	162.9	1.8
LUD-5	4/1/2009	7/14/2009	55.2	0.5
LUD-6	4/1/2009	7/14/2009	71.9	0.7
QUARTER 3 (2009)				
LUD-1	7/14/2009	9/1/2009	30.9	0.6
LUD-2	7/14/2009	9/1/2009	30.9	0.6
LUD-3	7/14/2009	9/1/2009	66.5	1.4
LUD-4	7/2/2009	9/1/2009	102.3	1.7
LUD-5	7/14/2009	9/22/2009	514.9	7.4
LUD-6	7/14/2009	9/1/2009	75.7	1.5

2.9.5.3 Conclusions

Baseline ambient gamma dose rate and radon-222 air concentration data for the proposed project was collected and analyzed according to NRC Regulatory Guide 4.14 protocols. Gamma dose rate results are consistent with gamma exposure rate survey data. In a context of possible sampling and measurement uncertainties, ambient radon concentration results were consistent with the reported national average as well as with results from the nearby Moore Ranch ISR site.

2.9.6 Air Particulate Monitoring

Continuous monitoring of baseline air particulate radionuclide concentrations was initiated in late April 2008. NRC Regulatory Guide 4.14 calls for 12 consecutive months of respective monitoring data as part of the overall radiological characterization of the site (NRC, 1980). This data was collected and reported on a quarterly basis.

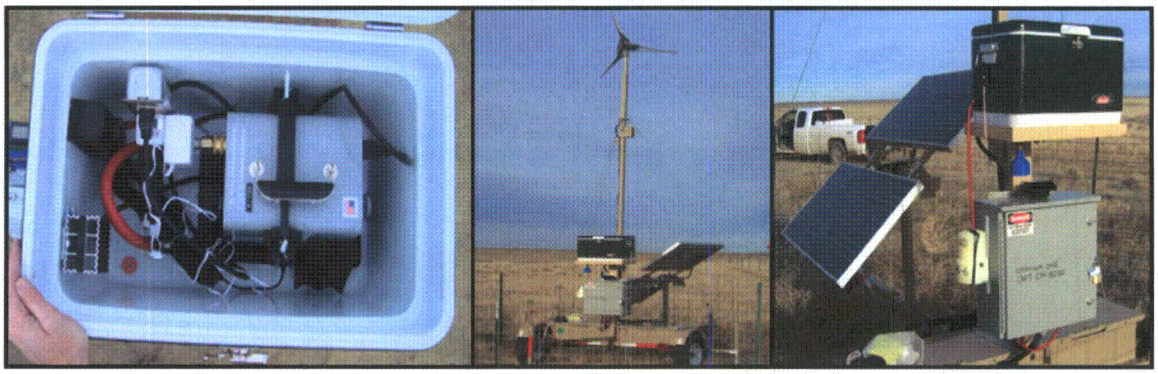
Low-volume air particulate sampling station locations were selected based on NRC Regulatory Guide 4.14, including consideration for the locations of Satellite facilities, prevailing wind directions, adjacent residences, hard line power availability, and practical access for both baseline and future operational monitoring programs. An off-site location is also part of the air particulate monitoring program. In cases where existing power supply was unavailable, stations were set up using solar/wind generation equipment to supply electrical power to the air samplers. Locations of air particulate monitoring stations at each site are shown in Figure 2.9-39 of the previous section of this report.

2.9.6.1 Methods

The air particulate monitoring program is being conducted with the Model DF-40L-8 electric powered air sampler from F&J Specialty Products, Inc. (Figure 2.9-43). These samplers are calibrated by the manufacturer and programmed to draw approximately 30 liters of air intake per minute through a 47 mm glass fiber air sampling filter. The air samplers are housed in protective coolers mounted on elevated steel platforms, so that the intake and sample filter holder assembly is positioned at about 5 feet above the ground surface (Figure 2.9-44). This is intended to approximate an average breathing zone height.

Figure 2.9-43: F&J air particulate sampler.

Figure 2.9-44: Air sampling station equipment and solar/wind powered system setup.



Filters are collected weekly to help prevent dust loading and are composited on an approximate quarterly basis to provide respective estimates of average radionuclide concentrations as specified in NRC Regulatory Guide 4.14. Each quarterly batch of air filters from the four monitoring stations is submitted to ELI in Casper, Wyoming for analysis of Ra-226, U-nat, Th-230, and Pb-210.

2.9.6.2 Air Particulate Sampling Results

A graphical summary of baseline air particulate sampling results by quarter for the Ludeman site is shown in Figure 2.9-45. Historical mean values at other uranium recovery sites in this region of Wyoming are shown in Figure 2.9-46. In general, baseline air particulate radionuclide concentrations at the Ludeman site appear consistent with baseline values measured at other sites in the region.

Figure 2.9-45: Mean baseline radionuclide levels (error bars represent + 1σ from the mean) in air particulate samples from the Ludeman Project. Negative values were excluded for this graphical data summary, and for results below detection limits, the detection limit

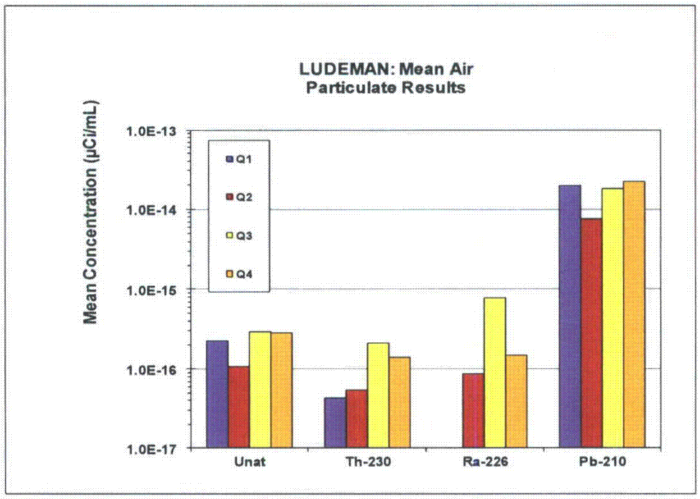
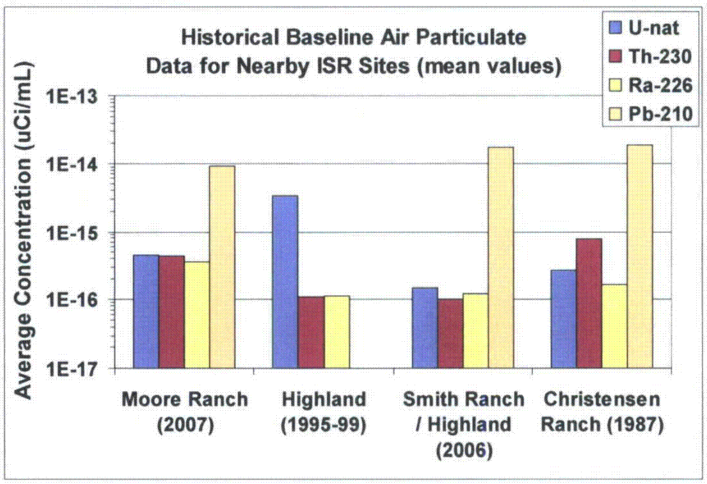


Figure 2.9-46: Average air particulate results for nearby uranium recovery sites in the region (adapted from EMC, 2007).



All individual air particulate monitoring station results to date for the proposed project site are provided in Table 2.9-6. Baseline monitoring continues, and remaining data will be provided to regulatory agencies when available. In most cases, analytical results are above the lower limits of detection (LLD). The LLD values listed in Table 2.9-6 are those specified in NRC Regulatory Guide 4.14. The effluent concentration values are provided by ELI as a relevant part of reporting for these data because they represent regulatory limits for each listed radionuclide in terms of doses to the public. This gives an indication of baseline conditions; and in this context, will help with evaluations of above background internal dose assessments via inhalation and ingestion pathways for data collected during ISR recovery operations.

Table 2.9-6: Air particulate radionuclide data for the Ludeman Project

Air Station ID	Qtr - Collection Date	Air Volume Sampled (mL)	Radionuclide	Concentration (µCi/mL)	Error Estimate (µCi/mL)	LLD (µCi/mL)	Effluent Conc. (µCi/mL)	% Effluent Concentration
LUD-1	Qtr2 - 2008	2.35E+09	U-nat	1.00E-16	N/A	1.00E-16	9.00E-14	1.11E-01
			Th-230	1.00E-16	N/A	1.00E-16	3.00E-14	3.33E-01
			Ra-226	1.00E-16	N/A	1.00E-16	9.00E-13	1.11E-02
			Pb-210	1.11E-14	8.51E-15	2.00E-15	6.00E-13	1.85E+00
	Qtr3 - 2008	1.94E+09	U-nat	1.55E-16	N/A	1.00E-16	9.00E-14	1.72E-01
			Th-230	2.47E-16	9.79E-17	1.00E-16	3.00E-14	8.23E-01
			Ra-226	6.70E-16	6.70E-16	1.00E-16	9.00E-13	7.44E-02
			Pb-210	1.60E-14	1.08E-14	2.00E-15	6.00E-13	2.67E+00
	Qtr4 - 2008	2.54E+09	U-nat	1.18E-16	N/A	1.00E-16	9.00E-14	1.31E-01
			Th-230	3.03E-16	3.46E-16	1.00E-16	3.00E-14	1.01E+00
			Ra-226	1.00E-16	N/A	1.00E-16	9.00E-13	1.11E-02
			Pb-210	1.22E-14	9.45E-15	2.00E-15	6.00E-13	2.03E+00
	Qtr1 - 2009	2.28E+09	U-nat	2.84E-16	N/A	1.00E-16	9.00E-14	3.16E-01
			Th-230	-4.08E-16	2.44E-16	1.00E-16	3.00E-14	-1.36E+00
			Ra-226	1.04E-17	3.60E-16	1.00E-16	9.00E-13	1.15E-03
			Pb-210	1.71E-14	7.54E-15	2.00E-15	6.00E-13	2.85E+00
	Qtr2 - 2009	2.30E+09	U-nat	1.12E-16	N/A	1.00E-16	9.00E-14	1.24E-01
			Th-230	2.15E-16	1.26E-16	1.00E-16	3.00E-14	7.17E-01
			Ra-226	-1.10E-16	2.86E-17	1.00E-16	9.00E-13	-1.22E-02
			Pb-210	1.06E-14	5.91E-15	2.00E-15	6.00E-13	1.77E+00
	Qtr3 - 2009	1.57E+09	U-nat	1.01E-16	N/A	1.00E-16	9.00E-14	1.12E-01
			Th-230	-3.19E-16	1.68E-16	1.00E-16	3.00E-14	-1.06E+00
			Ra-226	6.36E-17	1.54E-16	1.00E-16	9.00E-13	7.07E-03
			Pb-210	2.22E-14	7.75E-15	2.00E-15	6.00E-13	3.70E+00
LUD-2	Qtr2 - 2008	1.66E+09	U-nat	1.00E-16	N/A	1.00E-16	9.00E-14	1.11E-01
			Th-230	3.42E-16	3.43E-16	1.00E-16	3.00E-14	1.14E+00
			Ra-226	1.00E-16	N/A	1.00E-16	9.00E-13	1.11E-02
			Pb-210	2.00E-15	N/A	2.00E-15	6.00E-13	3.33E-01
	Qtr3 - 2008	4.44E+09	U-nat	1.00E-16	N/A	1.00E-16	9.00E-14	1.11E-01
			Th-230	1.00E-16	N/A	1.00E-16	3.00E-14	3.33E-01
			Ra-226	1.35E-16	2.93E-16	1.00E-16	9.00E-13	1.50E-02
			Pb-210	3.83E-15	4.73E-15	2.00E-15	6.00E-13	6.38E-01
	Qtr4 - 2008	2.77E+09	U-nat	2.89E-16	N/A	1.00E-16	9.00E-14	3.21E-01
			Th-230	1.00E-16	N/A	1.00E-16	3.00E-14	3.33E-01
			Ra-226	1.00E-16	N/A	1.00E-16	9.00E-13	1.11E-02
			Pb-210	1.70E-14	9.03E-15	2.00E-15	6.00E-13	2.83E+00
	Qtr1 - 2009	2.56E+09	U-nat	1.49E-16	N/A	1.00E-16	9.00E-14	1.66E-01
			Th-230	2.37E-16	2.73E-16	1.00E-16	3.00E-14	7.89E-01
			Ra-226	-2.27E-17	2.89E-16	1.00E-16	9.00E-13	-2.52E-03
			Pb-210	1.99E-14	6.75E-15	2.00E-15	6.00E-13	3.32E+00
	Qtr2 - 2009	2.36E+09	U-nat	8.30E-17	N/A	1.00E-16	9.00E-14	9.22E-02
			Th-230	-1.89E-16	8.86E-17	1.00E-16	3.00E-14	-6.29E-01
			Ra-226	4.63E-18	3.92E-17	1.00E-16	9.00E-13	5.14E-04
			Pb-210	5.51E-15	1.17E-15	2.00E-15	6.00E-13	9.19E-01
	Qtr3 - 2009	1.30E+09	U-nat	1.80E-16	N/A	1.00E-16	9.00E-14	2.00E-01
			Th-230	-5.12E-17	2.19E-16	1.00E-16	3.00E-14	-1.71E-01
			Ra-226	7.80E-17	1.88E-16	1.00E-16	9.00E-13	8.67E-03
			Pb-210	1.91E-14	3.80E-15	2.00E-15	6.00E-13	3.18E+00
LUD-4	Qtr2 - 2008	9.25E+08	U-nat	1.00E-16	N/A	1.00E-16	9.00E-14	1.11E-01
			Th-230	1.08E-16	2.05E-16	1.00E-16	3.00E-14	3.60E-01
			Ra-226	1.00E-16	N/A	1.00E-16	9.00E-13	1.11E-02
			Pb-210	2.00E-15	N/A	2.00E-15	6.00E-13	3.33E-01
	Qtr3 - 2008	2.46E+09	U-nat	2.03E-16	N/A	1.00E-16	9.00E-14	2.26E-01
			Th-230	2.32E-16	1.18E-16	1.00E-16	3.00E-14	7.73E-01
			Ra-226	6.91E-16	5.69E-16	1.00E-16	9.00E-13	7.68E-02
			Pb-210	1.83E-14	8.54E-15	2.00E-15	6.00E-13	3.05E+00
	Qtr4 - 2008	2.40E+09	U-nat	2.50E-16	N/A	1.00E-16	9.00E-14	2.78E-01
			Th-230	1.00E-16	N/A	1.00E-16	3.00E-14	3.33E-01
			Ra-226	1.00E-16	N/A	1.00E-16	9.00E-13	1.11E-02
			Pb-210	2.58E-14	1.04E-14	2.00E-15	6.00E-13	4.30E+00
	Qtr1 - 2009	2.26E+09	U-nat	2.84E-16	N/A	1.00E-16	9.00E-14	3.16E-01
			Th-230	3.68E-16	4.05E-16	1.00E-16	3.00E-14	1.23E+00
			Ra-226	3.86E-16	4.22E-16	1.00E-16	9.00E-13	4.28E-02
			Pb-210	2.79E-14	7.69E-15	2.00E-15	6.00E-13	4.64E+00
	Qtr2 - 2009	2.27E+09	U-nat	9.11E-17	N/A	1.00E-16	9.00E-14	1.01E-01
			Th-230	1.02E-16	1.19E-16	1.00E-16	3.00E-14	3.39E-01
			Ra-226	-2.12E-17	4.09E-17	1.00E-16	9.00E-13	-2.26E-03
			Pb-210	1.41E-14	5.98E-15	2.00E-15	6.00E-13	2.36E+00
	Qtr3 - 2009	1.26E+09	U-nat	1.60E-15	N/A	1.00E-16	9.00E-14	1.78E+00
			Th-230	1.91E-15	6.14E-16	1.00E-16	3.00E-14	6.37E+00
			Ra-226	9.48E-17	2.29E-16	1.00E-16	9.00E-13	1.05E-02
			Pb-210	1.60E-14	9.50E-15	2.00E-15	6.00E-13	2.67E+00

Table 2.9-7: Air particulate radionuclide data for the Ludeman Project (Cont.)

Air Station ID	Qtr - Collection Date	Air Volume Sampled (mL)	Radionuclide	Concentration (µCi/mL)	Error Estimate (µCi/mL)	LLD (µCi/mL)	Effluent Conc. (µCi/mL)	% Effluent Concentration
LUD-5	Qtr3 - 2008	1.41E+09	U-nat	2.13E-16	N/A	1.00E-16	9.00E-14	2.37E-01
			Th-230	1.00E-16	N/A	1.00E-16	3.00E-14	3.33E-01
			Ra-226	2.13E-16	7.80E-16	1.00E-16	9.00E-13	2.37E-02
			Pb-210	2.06E-14	1.49E-14	2.00E-15	6.00E-13	3.43E+00
	Qtr4 - 2008	2.57E+09	U-nat	4.28E-16	N/A	1.00E-16	9.00E-14	4.76E-01
			Th-230	1.00E-16	N/A	1.00E-16	3.00E-14	3.33E-01
			Ra-226	3.50E-16	5.06E-16	1.00E-16	9.00E-13	3.89E-02
			Pb-210	2.49E-14	9.73E-15	2.00E-15	6.00E-13	4.15E+00
	Qtr1 - 2009	2.34E+09	U-nat	1.90E-16	N/A	1.00E-16	9.00E-14	2.11E-01
			Th-230	-7.14E-17	4.35E-16	1.00E-16	3.00E-14	-2.38E-01
			Ra-226	-1.41E-16	3.18E-16	1.00E-16	9.00E-13	-1.57E-02
			Pb-210	2.02E-14	7.39E-15	2.00E-15	6.00E-13	3.36E+00
	Qtr2 - 2009	2.09E+09	U-nat	8.21E-17	N/A	1.00E-16	9.00E-14	9.12E-02
			Th-230	-1.09E-16	9.76E-17	1.00E-16	3.00E-14	-3.64E-01
			Ra-226	-4.94E-17	3.61E-17	1.00E-16	9.00E-13	-5.49E-03
			Pb-210	7.27E-15	1.32E-15	2.00E-15	6.00E-13	1.21E+00
	Qtr3 - 2009	1.48E+09	U-nat	8.48E-17	N/A	1.00E-16	9.00E-14	9.42E-02
			Th-230	-3.21E-17	1.16E-16	1.00E-16	3.00E-14	-1.07E-01
			Ra-226	5.78E-16	2.85E-16	1.00E-16	9.00E-13	6.42E-02
			Pb-210	1.67E-14	3.27E-15	2.00E-15	6.00E-13	2.78E+00
LUD-6	Qtr3 - 2008	1.75E+09	U-nat	1.71E-16	N/A	1.00E-16	9.00E-14	1.90E-01
			Th-230	1.00E-16	N/A	1.00E-16	3.00E-14	3.33E-01
			Ra-226	5.14E-15	7.43E-16	1.00E-16	9.00E-13	5.71E-01
			Pb-210	1.83E-14	1.20E-15	2.00E-15	6.00E-13	3.05E+00
	Qtr4 - 2008	2.41E+09	U-nat	3.32E-16	N/A	1.00E-16	9.00E-14	3.69E-01
			Th-230	1.00E-16	N/A	1.00E-16	3.00E-14	3.33E-01
			Ra-226	1.00E-16	N/A	1.00E-16	9.00E-13	1.11E-02
			Pb-210	2.99E-14	1.04E-14	2.00E-15	6.00E-13	4.98E+00
	Qtr1 - 2009	2.41E+09	U-nat	2.12E-16	N/A	1.00E-16	9.00E-14	2.36E-01
			Th-230	9.27E-17	3.21E-16	1.00E-16	3.00E-14	3.09E-01
			Ra-226	-3.78E-16	2.35E-16	1.00E-16	9.00E-13	-4.19E-02
			Pb-210	1.19E-14	7.06E-15	2.00E-15	6.00E-13	1.98E+00
	Qtr2 - 2009	1.61E+09	U-nat	1.96E-16	N/A	1.00E-16	9.00E-14	2.18E-01
			Th-230	-1.35E-16	2.23E-16	1.00E-16	3.00E-14	-4.50E-01
			Ra-226	5.69E-16	9.89E-17	1.00E-16	9.00E-13	6.32E-02
			Pb-210	8.08E-15	1.71E-15	2.00E-15	6.00E-13	1.35E+00
	Qtr3 - 2009	9.85E+08	U-nat	1.03E-16	N/A	1.00E-16	9.00E-14	1.14E-01
			Th-230	-1.91E-16	3.47E-16	1.00E-16	3.00E-14	-6.37E-01
			Ra-226	1.84E-16	3.26E-16	1.00E-16	9.00E-13	2.04E-02
			Pb-210	2.52E-14	5.02E-15	2.00E-15	6.00E-13	4.20E+00

2.9.6.3 Conclusions

Baseline air particulate concentration data for the proposed project site were collected and analyzed based on NRC Regulatory Guide 4.14 recommendations, along with other considerations in a context of both pre-operational and operational phases of the project. This information should be sufficient for review by the NRC and WDEQ/LQD.

2.9.7 Radon Flux Measurements

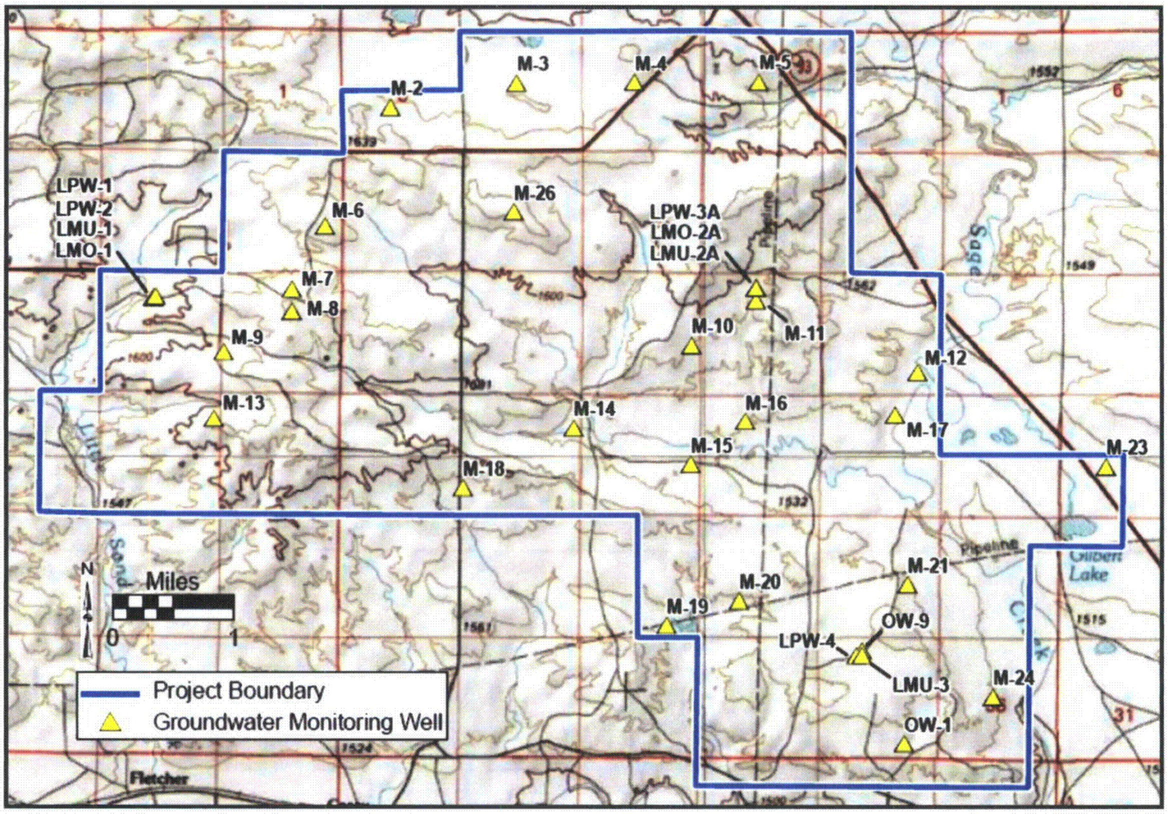
NRC Regulatory Guide 4.14 indicates that radon flux measurements should be conducted at eight locations within 1.5 km of the mill, during three separate months between spring and fall when the ground is thawed (NRC, 1980). Since there will be no tailings impoundments at this ISR site, radon flux is not an applicable radiological parameter for baseline characterization.

2.9.8 Groundwater Sampling

Baseline groundwater sampling was conducted at the proposed project area in accordance with NRC Regulatory Guide 4.14 protocols (NRC, 1980). In this case, however, there are no tailings impoundments and respective guidance has been interpreted accordingly. A map of approximate groundwater monitoring well locations is shown in Figure 2.9-47. The nomenclature and meaning of well ID numbers is as follows:

- M = Monitoring well for Production Zone
- LPW = Ludeman pump test well for Production Zone
- LMU = Ludeman monitoring well underlying Production Zone
- LMO = Ludeman monitoring well overlying Production Zone
- OW = Other well, previously existing (e.g. from historical pump testing)

Figure 2.9-47: Groundwater monitoring well locations.



Comprehensive information on well locations, depths, all groundwater quality parameters and respective detection limits is provided in various sections of this ISR licensing application that are related specifically to groundwater (Section 2.7). Sampling of existing wells used for livestock watering or other purposes has been initiated, though this sampling was delayed because these wells are turned off on a seasonal basis. Results from this additional groundwater sampling effort will be submitted to the NRC and WDEQ/LQD upon receipt of analytical data from the laboratory.

2.9.8.1 Methods

Prior to sampling a groundwater well, static water levels are monitored using an electrical measuring line (an "e-line"). All readings are reported to within at least one tenth of a foot and preferably to within a hundredth of a foot. After the static water level is measured, wells are purged at a sufficient volume to induce the flow of formation water through the well screen. Wells with a high enough yield are purged for a minimum of three well volumes, and also until one or more indicator parameters are stable. Parameters monitored for stabilization include pH, temperature, and conductivity. For low yielding wells, the wells are pumped dry then allowed to recover. Samples are taken after sufficient well recovery. Accurate records of well purging are maintained to document the number of casing volumes purged from the well before sampling.

Groundwater field measurements and samples are taken as soon as the well is adequately purged. Sampling container(s) are completely filled, so all air is excluded from the container. Field measurements including pH, conductivity, and temperature are taken and recorded. Meters used to take field measurements are calibrated daily.

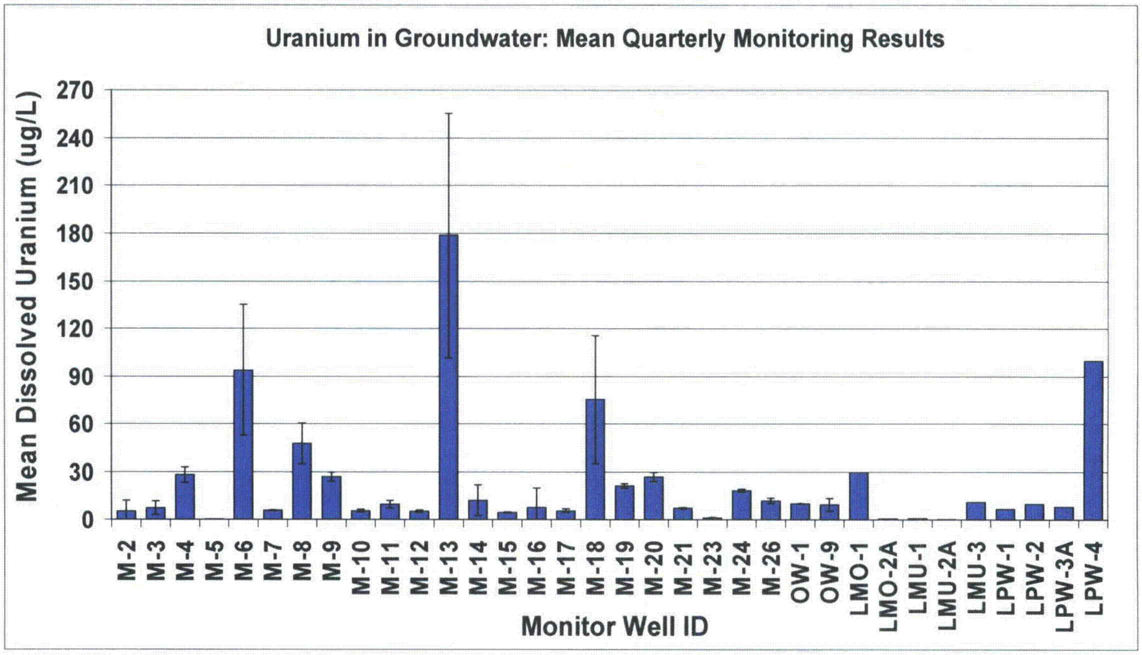
2.9.8.2 Groundwater Sampling Results

Summary statistics for dissolved radionuclides in groundwater across all individual quarterly samples collected to date are provided in Table 2.9-7. Average quarterly results ($\pm 1\sigma$) to date by well location for dissolved radiological groundwater parameters are shown graphically in Figures 2.9-48 through 2.9-53. The error bars on the graphical data provide an indication of quarterly variability in analytical results for each parameter and well location. In some cases, log scales are also presented to better illustrate the range of mean values on the lowest end of the scale. Parameters in suspended form were also evaluated – results were generally similar and are not presented here (those data, reporting limits, and other details can be found in Section 2.7.2 of the application pertaining specifically to groundwater).

Table 2.9-8: Summary statistics for dissolved radionuclide's in groundwater across all individual quarterly samples collected to date within the Ludeman Project area.

Analyte	Mean	Std. Dev.	Median	Max	Min	n
U-nat (µg/L)	25	42	10.2	267	0.3	79
Th-230 (pCi/L)	0.04	0.10	0.0	0.60	-0.1	79
Ra-226 (pCi/L)	133	305	14.5	1490	0.3	73
Pb-210 (pCi/L)	14.3	31.3	2.8	213	-10.9	79
Po-210 (pCi/L)	1.1	1.9	0.5	12.4	-0.4	79
Ra-228 (pCi/L)	1.2	1.6	0.9	9.7	-2.0	79

Figure 2.9-48: Mean quarterly uranium results (± 1σ) by groundwater monitoring well location (top) and same results on a log scale (bottom).



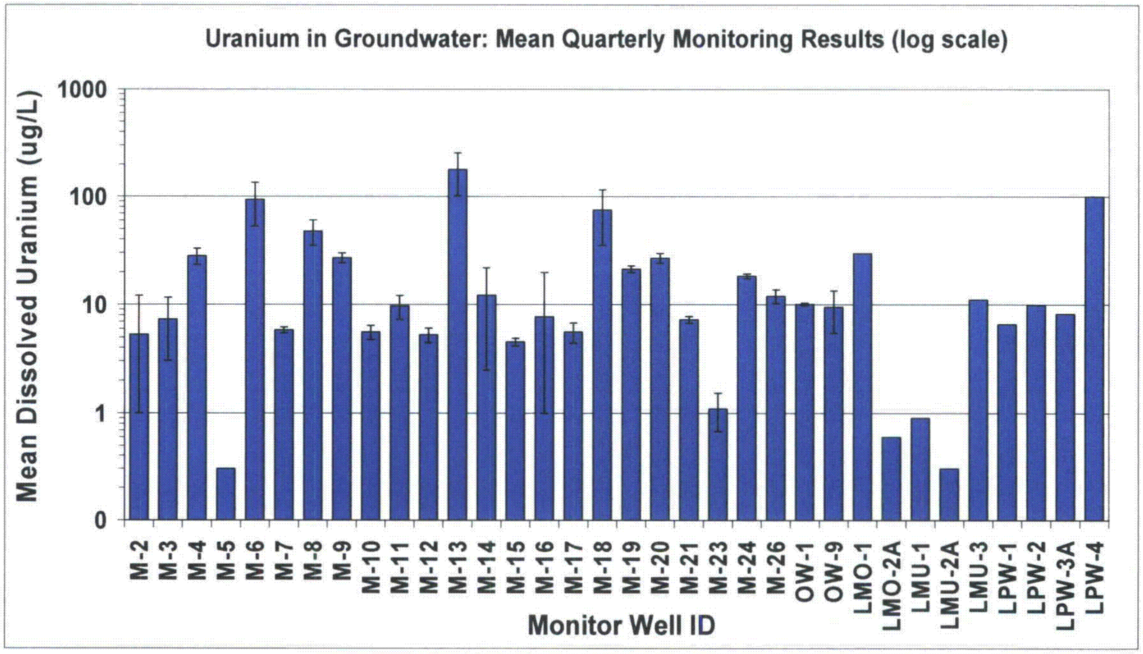
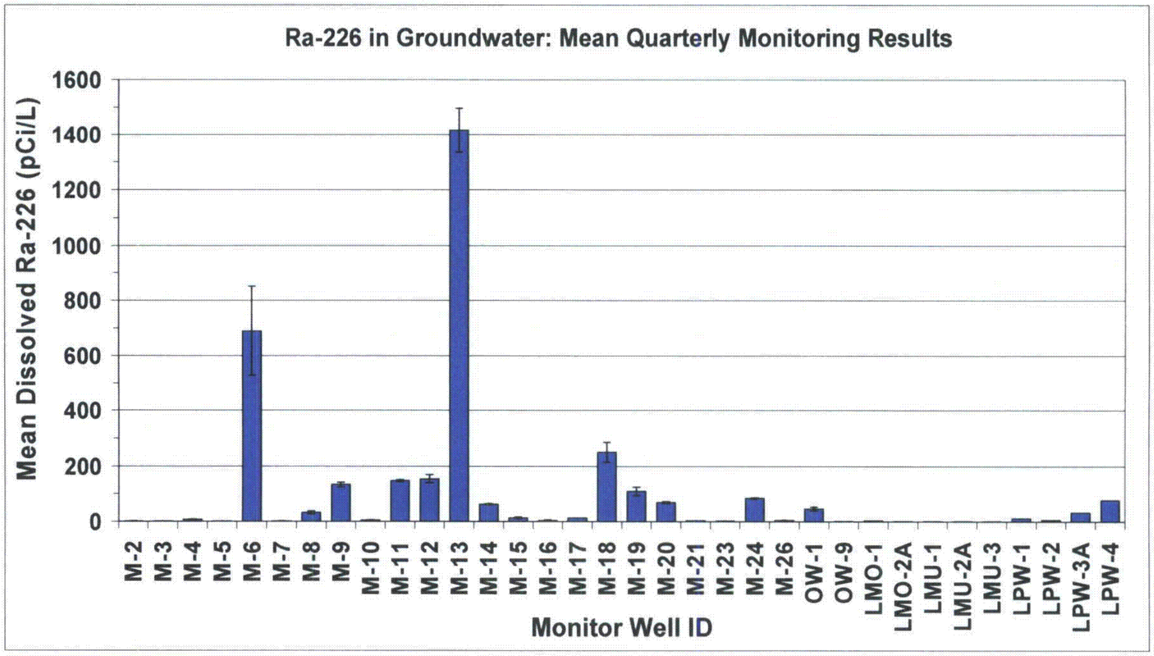


Figure 2.9-49: Mean quarterly Ra-226 results (± 1σ) by groundwater monitoring well location (top) and same results on a log scale (bottom)



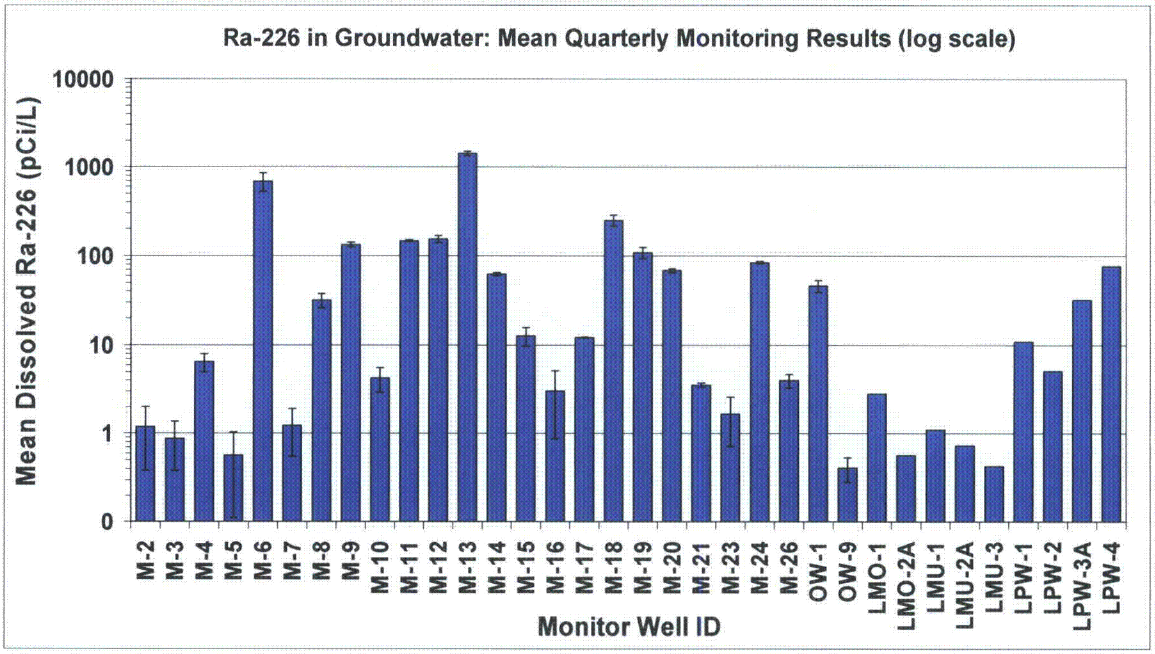


Figure 2.9- 50: Mean quarterly Th-230 results (± 1σ) by groundwater monitoring well location.

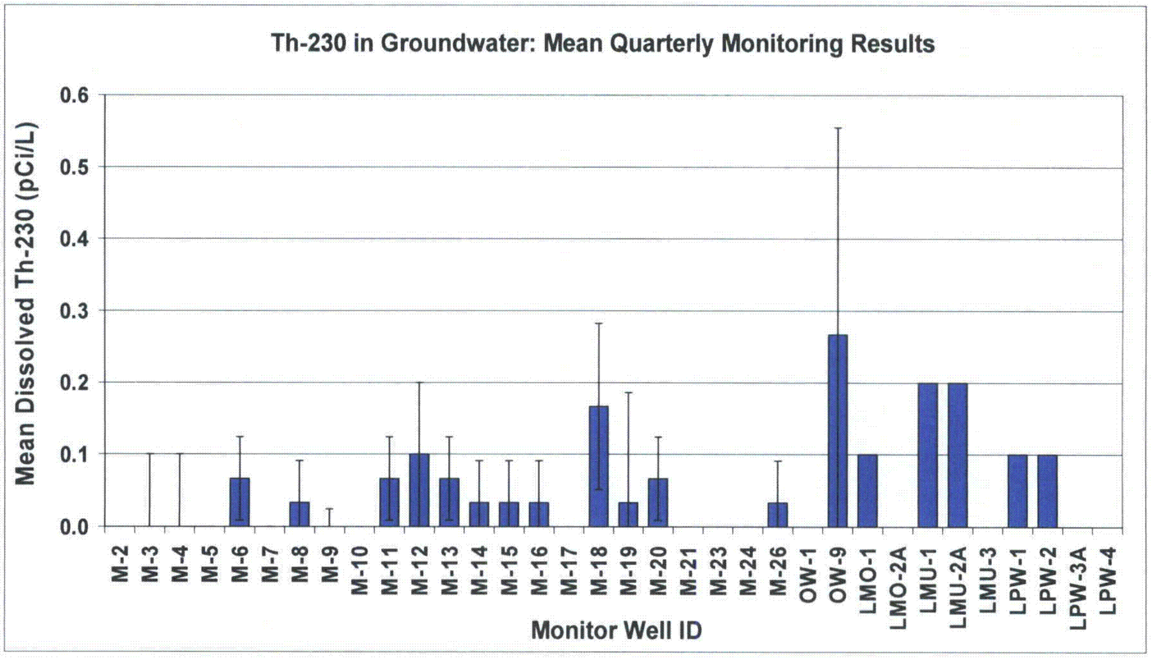


Figure 2.9-51: Mean quarterly Pb-210 results (± 1σ) by groundwater monitoring well location.

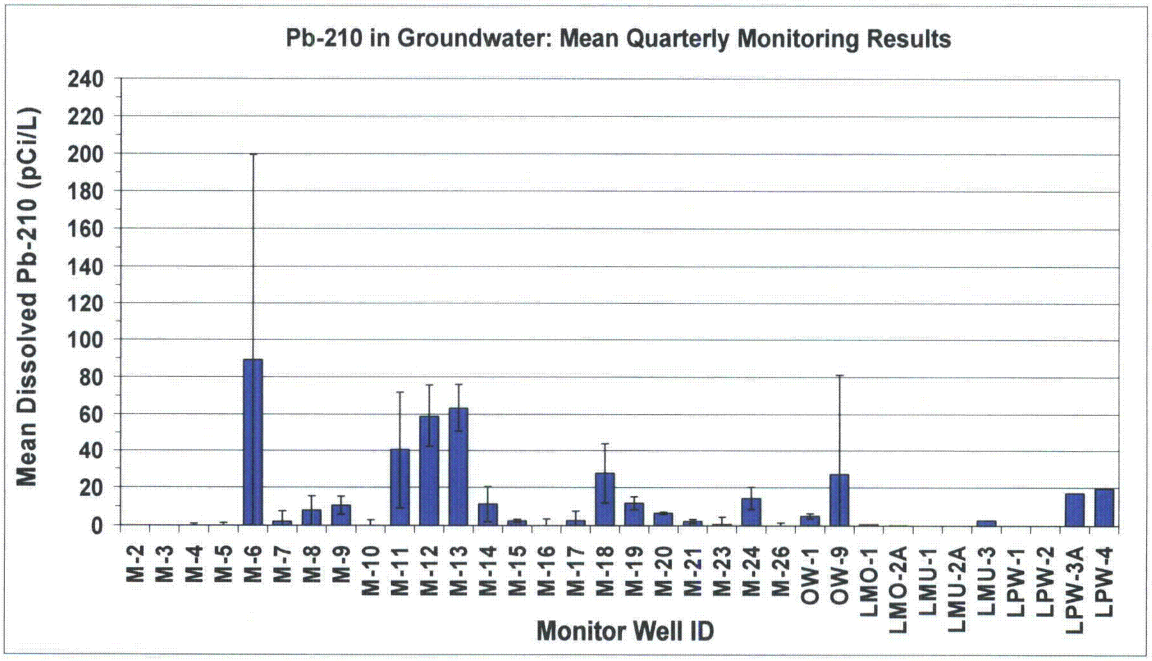


Figure 2.9-52: Mean quarterly Po-210 results (± 1σ) by groundwater monitoring well location.

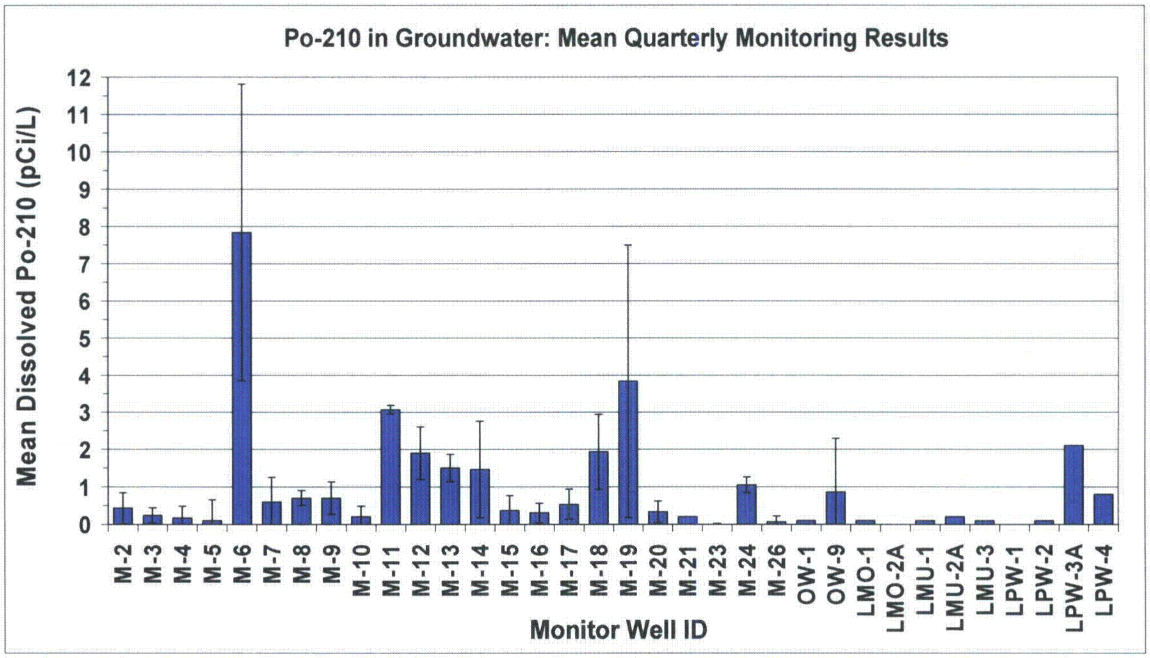
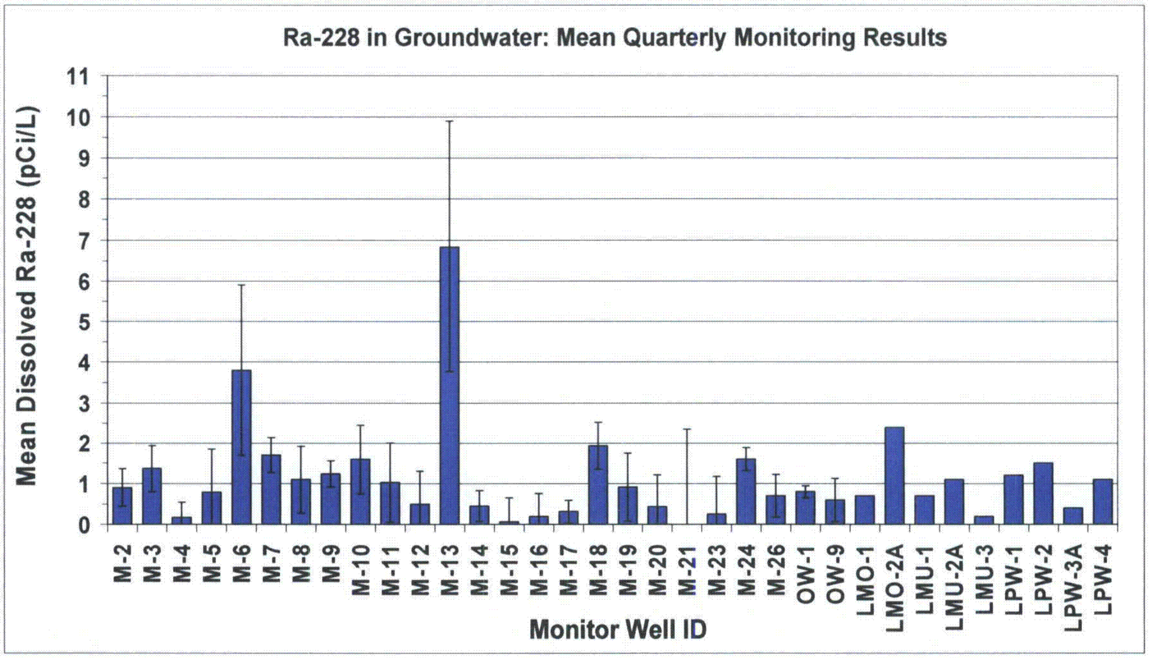


Figure 2.9-53: Mean quarterly Ra-228 results (± 1σ) by groundwater monitoring well location.



A number of wells had pre-operational baseline groundwater concentrations of uranium and/or combined Ra-226/Ra-228 that exceeded respective maximum contaminant levels (MCLs) listed by the U.S. Environmental Protection Agency (EPA) for drinking water (30 ug/L for uranium, 5 pCi/L for combined Ra-226/Ra-228; EPA, 2000). These include the following wells:

- Monitor wells, Production Zone (M): 4, 6, 8, 9, 11, 12, 13, 14, 15, 17, 18, 19, 20, 24,
- Pump test wells, Production Zone (LPW): 1, 3A, 4
- Other wells, Production Zone (OW): 1

Wells M-6, M-13, M-18, and LPW-4 had results that exceeded MCLs for both uranium and combined Ra-226/Ra-228. All results in excess of MCLs for uranium and/or combined Ra-226/Ra-228 represent natural, pre-existing conditions in the proposed Production Zone. This is not unexpected given the known natural mineralization of uranium and associated radionuclides within this zone. Baseline groundwater conditions in the proposed Production Zone at this site are not suitable for domestic uses.

None of the monitoring wells underlying or overlying the Production Zone had baseline groundwater results in excess of MCLs for uranium or combined Ra-226/Ra-228. However, this doesn't necessarily mean that baseline groundwater conditions in aquifers above or below the Production Zone are below MCLs in all locations at the site. The gamma survey shows evidence of elevated uranium and Ra-226 at the ground surface in certain areas, and surface water results for one pond show significantly elevated levels (see Section 2.9.9). It is possible that pockets of naturally elevated concentrations of radionuclides outside the proposed Production Zone could influence localized baseline groundwater quality conditions in underlying or overlying aquifers.

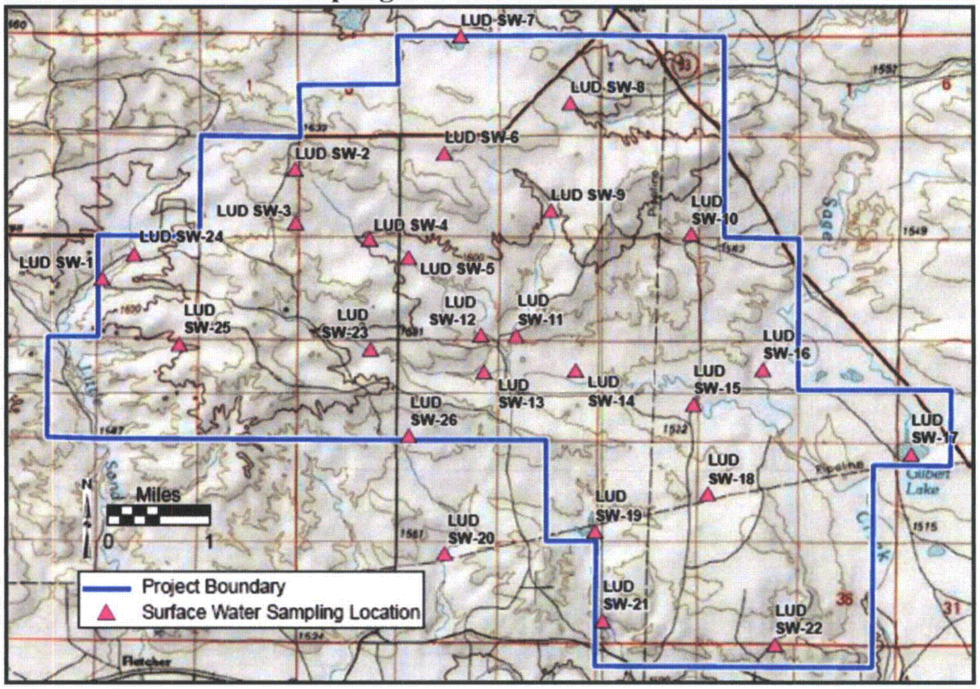
2.9.8.3 Conclusions

Radiological baseline groundwater data for the proposed project area presented in this section provide a characterization of baseline radionuclide concentrations in groundwater for review by the NRC and WDEQ/LQD with respect to licensing/permitting applications. Baseline groundwater conditions within the proposed Production Zone show elevated levels of uranium and/or Ra-226 and other radionuclides in many locations.

2.9.9 Surface Water Sampling

Baseline surface water sampling at the proposed project site is being conducted on a quarterly basis. Surface water sampling locations are shown in Figure 2.9-54. This sampling includes stock ponds, small natural impoundments and ephemeral stream drainage channels where surface waters are present at least part of the year. These locations are widely distributed across the site, including locations generally upstream and downstream from proposed processing Satellite facility locations. Data to date for radiological parameters are presented in this section. Data for all surface water quality parameters are provided in this ISR licensing application related specifically to surface water (Section 2.7.1).

Figure 2.9-54: Surface water sampling locations.



2.9.9.1 Methods

Surface water samples were collected in the appropriate containers provided by the contract laboratory. Field meters were used to measure pH, specific conductance, and temperature of water samples and calibrated before each day's use as directed by the Owner's Manual. The bottle is then filled directly from the stream or pond in a manner to prevent collecting unwanted debris, or filled by using an alternate clean container. All samples analyzed by a contract laboratory are accompanied by a chain of custody to ensure that the sample is properly tracked and relinquished in the appropriate manner.

2.9.9.2 Surface Water Sampling Results

Summary statistics for dissolved radionuclide's in surface water across all individual quarterly samples collected to date are provided in Table 2.9-8. Average quarterly results (± 1σ) by sample location to date for dissolved radiological surface water parameters are presented graphically in Figures 2.9-55 through 2.9-60. The error bars in the graphs provide an indication of quarterly variability in analytical results for each parameter and sampling location. In some cases, log scales are also presented to better illustrate the range of mean values on the lowest end of the scale. Parameters in suspended form were also evaluated – results are generally similar and are not presented here (those data, reporting limits, and other details can be found in Section 2.7.1 of the application pertaining specifically to surface water).

Table 2.9- 9: Summary statistics for dissolved radionuclides in surface water across all individual quarterly samples collected to date within the Ludeman Project area.

Analyte	Mean	Std. Dev.	Median	Max	Min	n
U-nat (µg/L)	11	25	1.1	123	0.3	73
Th-230 (pCi/L)	0.1	0.2	0.1	1.0	-0.6	73
Ra-226 (pCi/L)	0.9	1.1	0.5	5.0	-0.3	73
Pb-210 (pCi/L)	0.5	4.4	0.0	13	-9.9	73
Po-210 (pCi/L)	0.3	0.5	0.3	2.9	-0.4	73
Ra-228 (pCi/L)	0.6	0.8	0.5	2.9	-1.0	73

Figure 2.9-55: Mean quarterly Ra-226 results (± 1σ) by surface water sampling location.

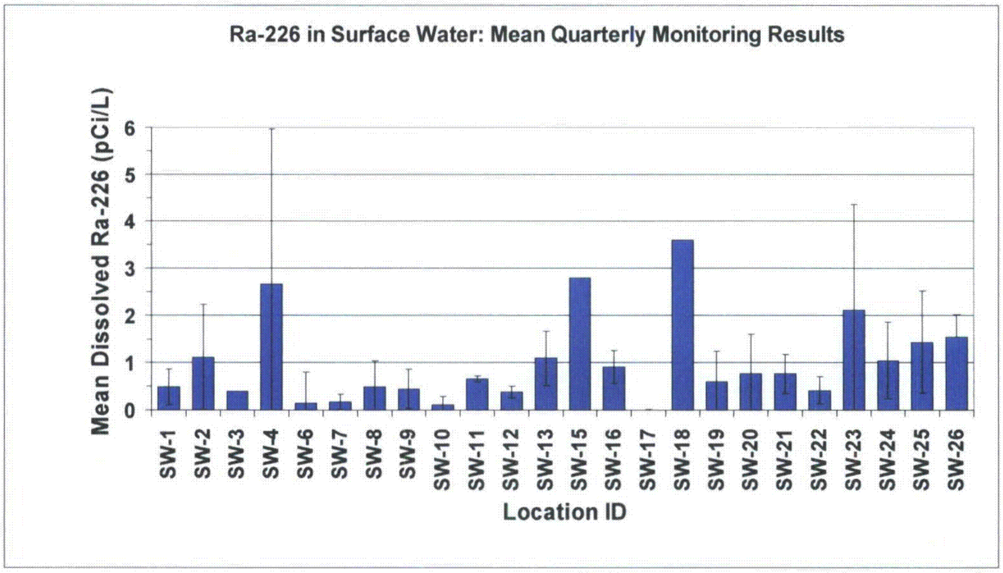
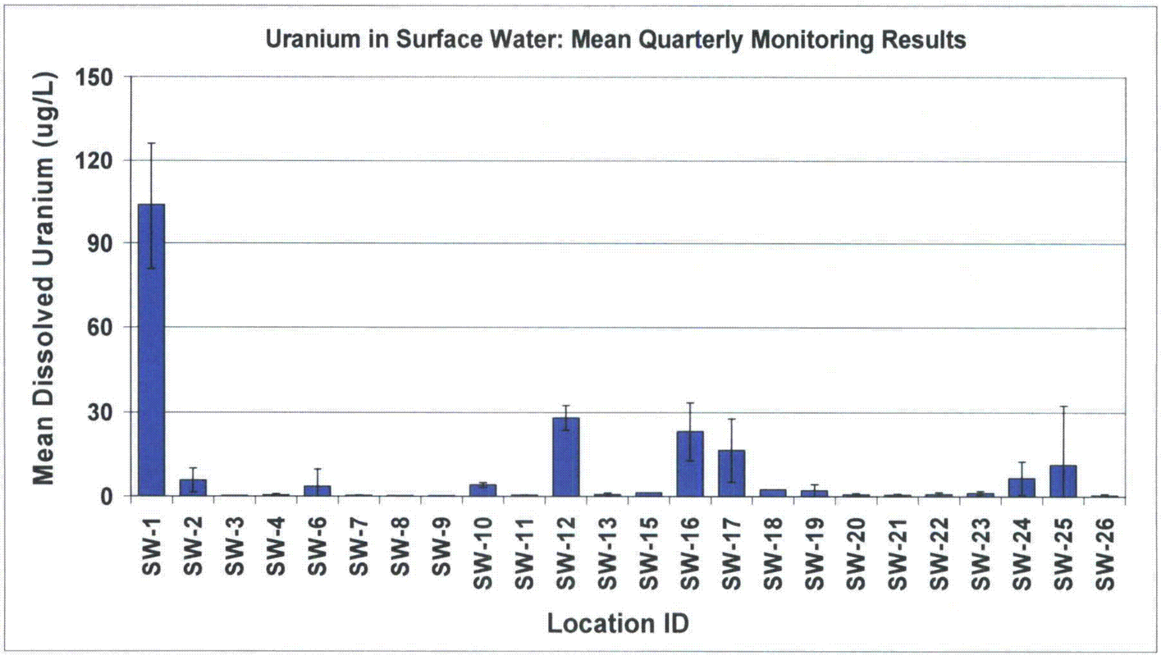


Figure 2.9- 56: Mean quarterly uranium results (± 1σ) by surface water sampling location (top) and same results on a log scale (bottom).



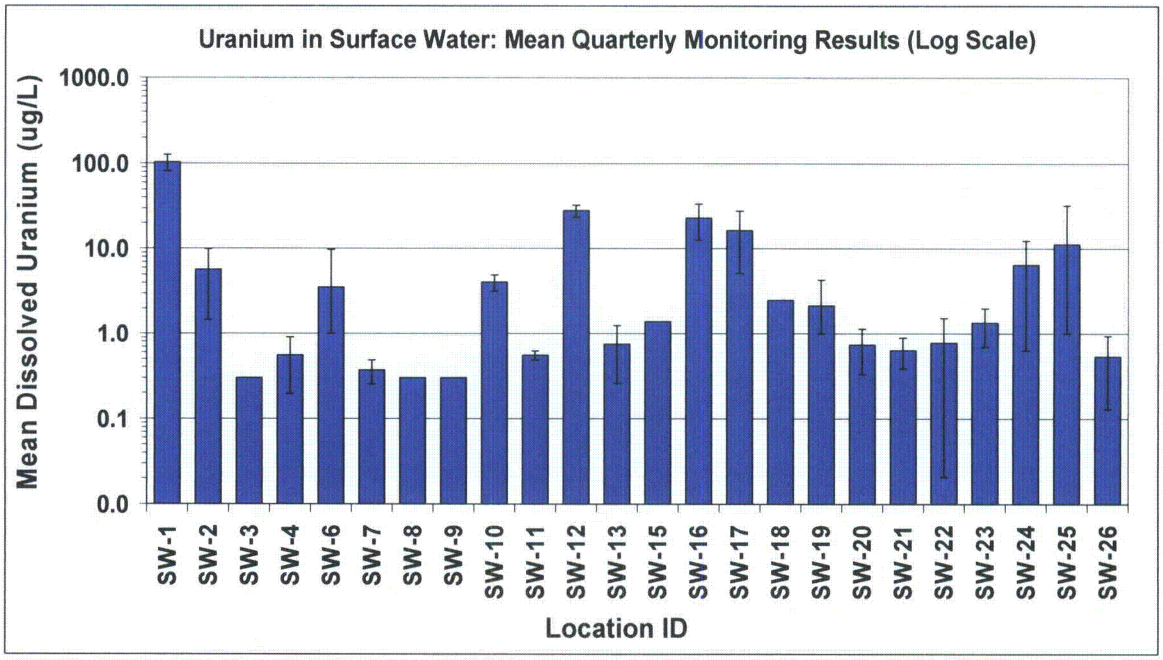


Figure 2.9-57: Mean quarterly Th-230 results (± 1σ) by surface water sampling location.

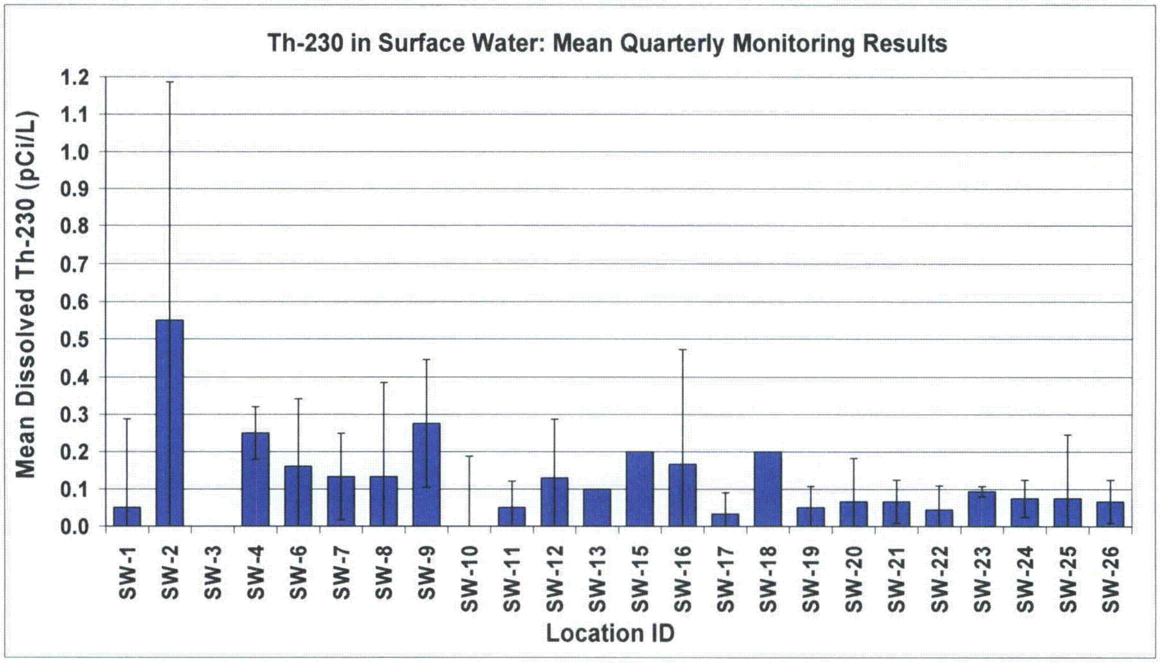


Figure 2.9-58: Mean quarterly Pb-210 results (± 1σ) by surface water sampling location.

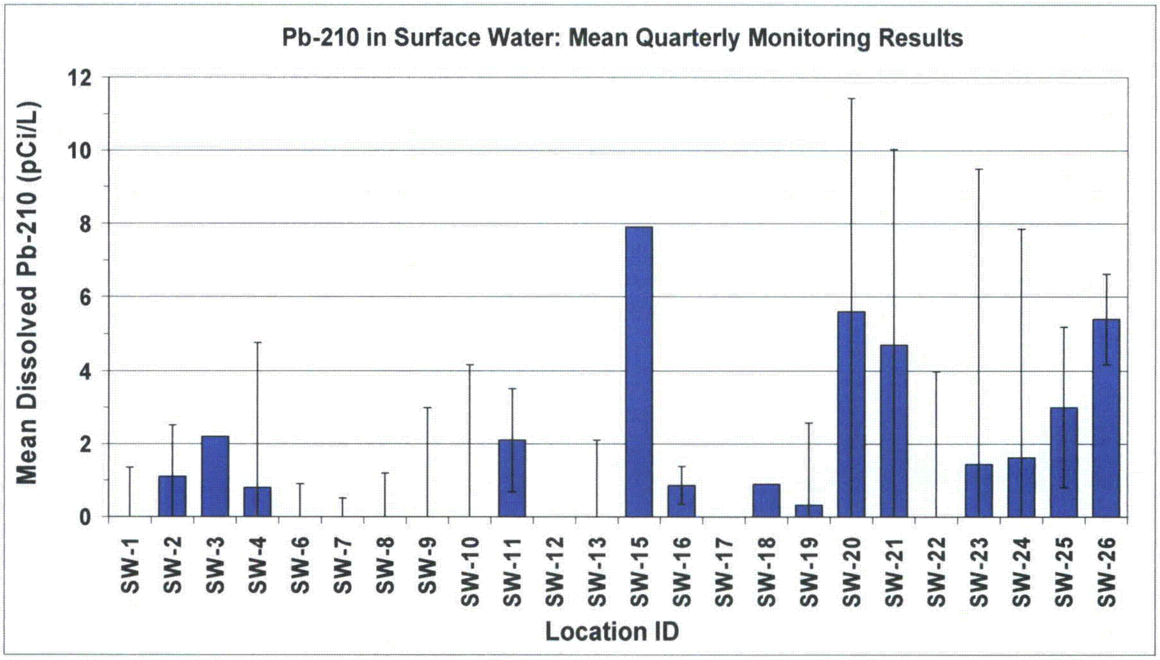


Figure 2.9- 59: Mean quarterly Po-210 results (± 1σ) by surface water sampling location.

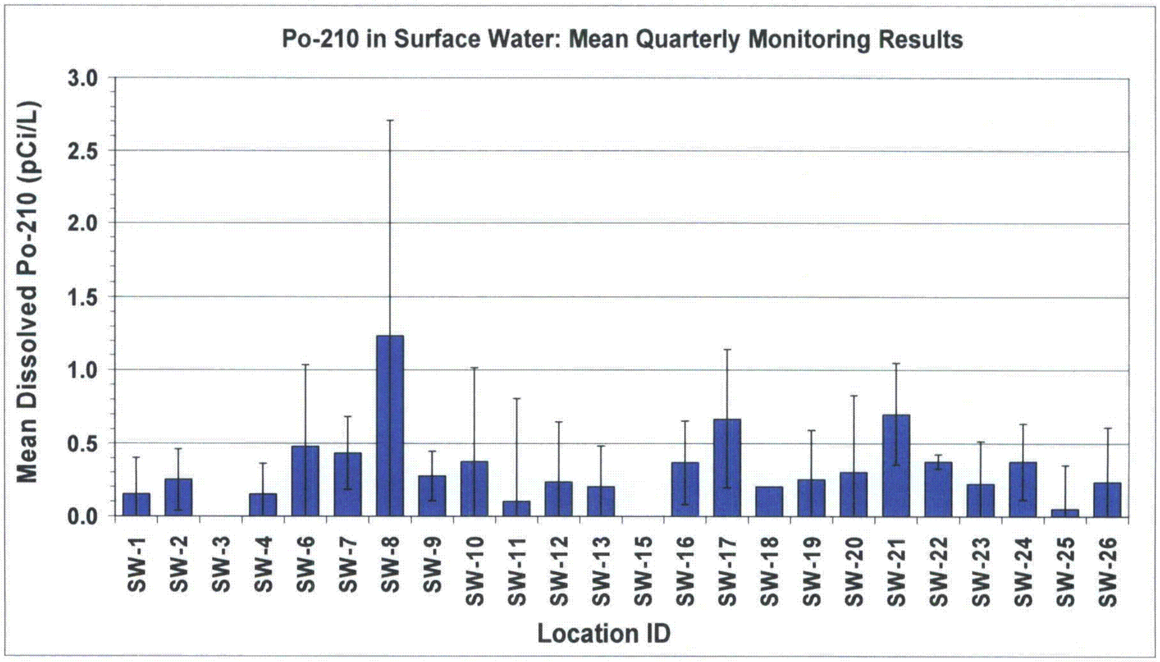
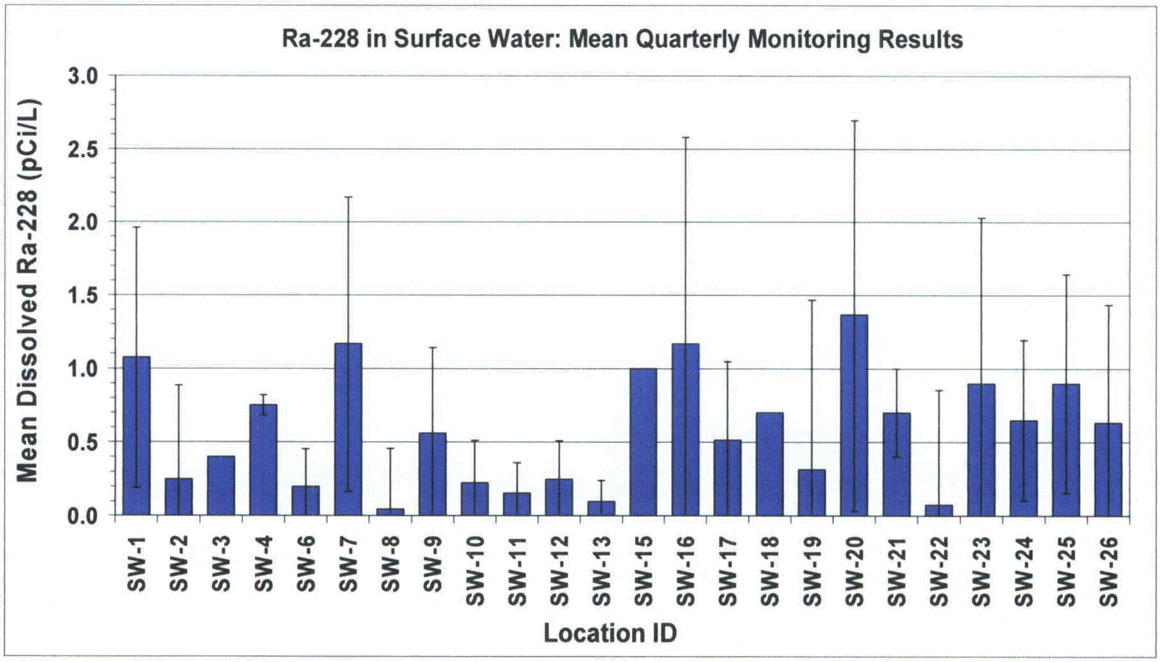


Figure 2.9-60: Mean quarterly Ra-228 results (± 1σ) by surface water sampling location.



A number of locations had baseline surface water samples with uranium and/or combined Ra-226/Ra-228 concentrations that exceeded respective MCLs listed by the EPA for drinking water (30 ug/L for uranium, 5 pCi/L for combined Ra-226/Ra-228; EPA, 2000). These include the following locations:

- SW-1, SW-4, SW-12, SW-16, and SW-23

The most notable case of elevated radionuclide concentrations in pre-operational baseline surface waters was observed at location SW-1, where elevated U-nat concentrations were also observed in sediment (see Section 2.9.4). Given the localized pockets of elevated uranium and Ra-226 in surface soils identified by the gamma survey, it is possible that accumulations of radionuclide-bearing sediments could occur in certain surface water impoundments. Source areas for such accumulations could potentially originate from outside the proposed project area boundaries; and thus would not be identified by the radiological baseline characterizations provided in this Section of the Technical Report.

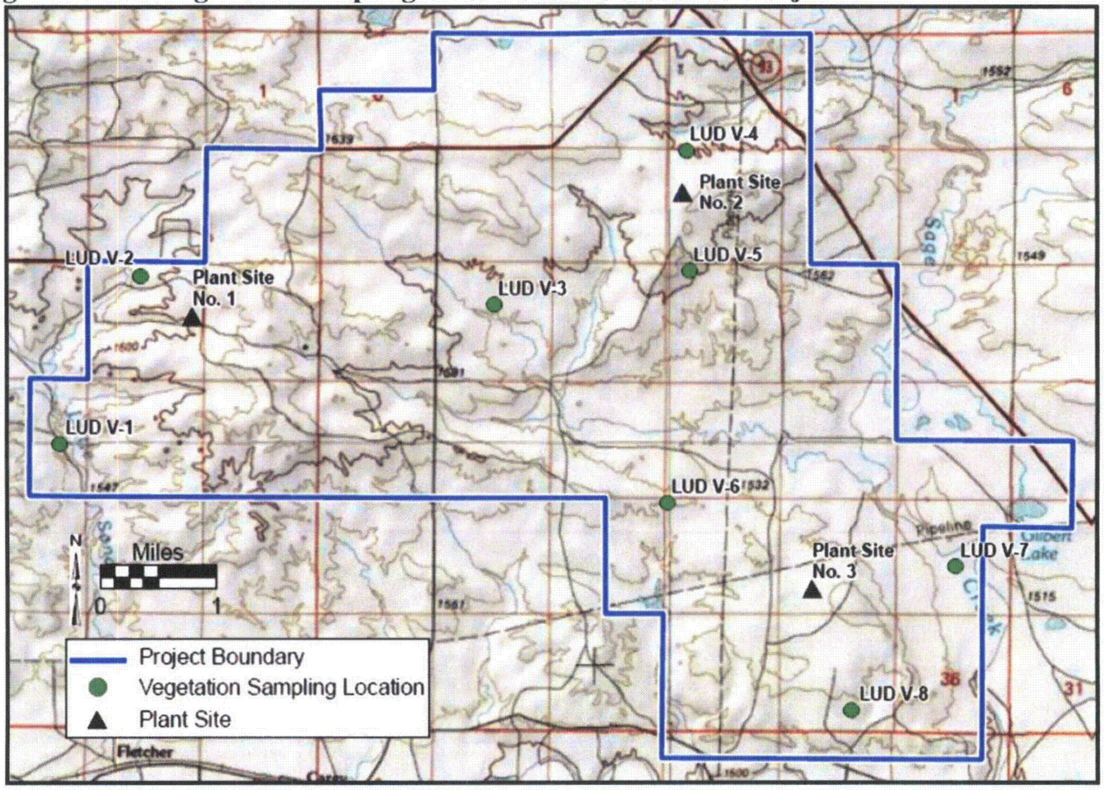
2.9.9.3 Conclusions

Radiological surface water data collected as part of baseline characterizations for the Ludeman ISR site are being collected on a quarterly basis. The data obtained to date should provide an adequate characterization of baseline radionuclide concentrations in surface waters for review by the NRC and WDEQ/LQD with respect to licensing/permitting applications.

2.9.10 Vegetation Sampling

NRC Regulatory Guide 4.14 calls for several vegetation sampling events during the growing season (NRC, 1980). Vegetation samples were collected in early July, August, and September of 2008. Data from these sampling events are presented in this section to complete a baseline radiological characterization of vegetation. Vegetation sampling locations (Figure 2.9-61) were selected based on proximity to potential wellfield areas and processing facilities, along with consideration for prevailing wind directions and convenient access.

Figure 2.9-61: Vegetation sampling locations at the Ludeman Project



2.9.10.1 Methods

Vegetation samples were collected using ordinary gardening tools (pruning shears, etc.) as mixed, above-ground growth across several hundred square meter areas at each sampling location. An estimated 3-5 kilograms of total vegetation biomass per sample was collected. Samples were collected in large plastic bags and were sent to ELI in Casper, Wyoming along with chain of custody forms. Analytes requested included all radiological parameters as recommended in NRC Regulatory Guide 4.14.

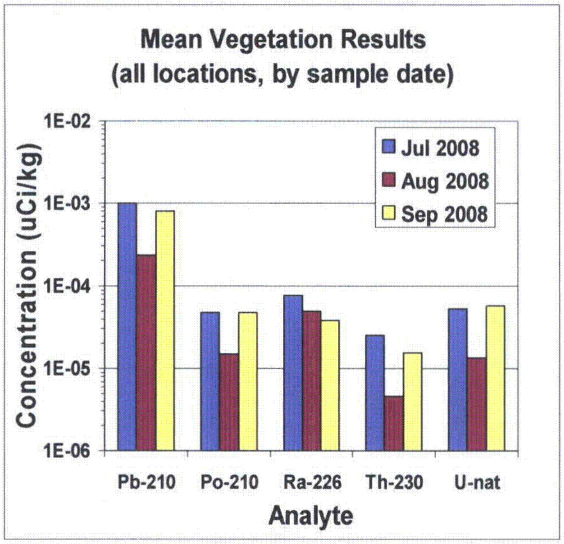
2.9.10.2 Vegetation Sampling Results

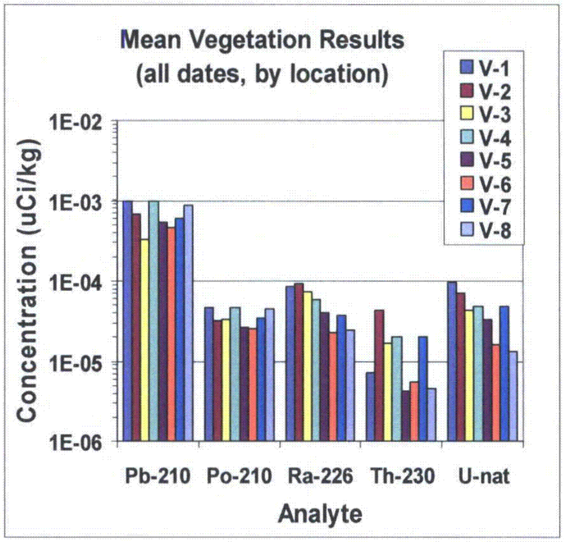
Summary statistics for baseline vegetation sampling results to date are presented in Table 2.9-9 and illustrated in Figure 2.9-62. There is an apparent trend for lower radionuclide concentrations in vegetation during the August 2008 sampling event (Figure 2.9-62), though such differences may be within a normal range of sampling and measurement variability. Similarly, some differences in mean radionuclide concentrations by sampling location may be attributed to sampling and measurement variability, as consistent trends are not apparent.

Table 2.9- 10: Summary statistics for radionuclide's in vegetation for all sampling dates and locations.

Analyte	Mean (uCi/kg)	Std. Dev. (uCi/kg)	Median (uCi/kg)	Max (uCi/kg)	Min (uCi/kg)	n
Pb-210	1.3E-03	4.5E-04	1.2E-03	1.9E-03	8.7E-04	6
Po-210	1.6E-04	6.5E-05	2.0E-04	2.1E-04	5.8E-05	6
Ra-226	2.3E-04	8.9E-05	2.2E-04	3.7E-04	1.0E-04	6
Th-230	6.5E-05	2.8E-05	6.4E-05	1.1E-04	2.3E-05	6
U-nat	1.2E-04	4.0E-05	1.3E-04	1.6E-04	4.3E-05	6

Figure 2.9-62: Mean analytical results for all vegetation samples by sampling date (left) and by location (right).





Across all vegetation samples, lead-210 has the greatest activity levels of the five radionuclide's analyzed, which is likely due to a higher relative abundance of Pb-210 in air particulates from radon decay products. This latter observation is supported by the air particulate data presented in Section 2.9.6.

2.9.10.3 Conclusions

Baseline vegetation sampling data for the proposed project site was collected and analyzed according to NRC Regulatory Guide 4.14 protocols. The results presented in this Section should complete relevant baseline characterization requirements for licensing/permitting evaluations by the NRC and WDEQ/LQD.

2.9.11 Food Sampling

Sampling of food items from the site such as meat from local grazing livestock is not planned at this time. All radiological baseline parameters relevant to food chain dose pathways (e.g. soil, sediment, air particulate samples, water, and vegetation) are comprehensively characterized in this section. Changes in these parameters due to site operations could be used to model corresponding radiological changes in food items such as meat or milk from agricultural livestock. Respective radionuclide transfer factors can be found in the literature (e.g. IAEA, 1994; Yu, 2001). Larger game animals such as deer or pronghorn have extensive ranges, and the potential for bioaccumulation of radionuclide's in these animals due to site operations is unlikely to be significant, as they would likely derive only a small fraction of their total sustenance needs from the site.

2.9.12 Summary and Overall Conclusions

Comprehensive baseline radiological surveys of the proposed project area in Converse County, Wyoming, have been conducted in a manner consistent with NRC Regulatory Guide 4.14 recommendations (NRC, 1980) and other applicable regulatory guidance documents as part of licensing/permitting application submittals to the U.S. Nuclear Regulatory Commission and Wyoming Department of Environmental Quality / Land Quality Division. The data provided in this Section of the Technical Report is considered sufficient for complete review by applicable regulatory agencies.

The gamma exposure rate survey data, collected with the latest GPS-based scanning system technologies, represents increased survey coverage than was practical or possible at the time NRC Regulatory Guide 4.14 was published. This data, combined with established analysis techniques and state-of-the-art mapping approaches, provides a detailed characterization of the magnitude and spatial variability in background gamma exposure rates and associated soil radionuclide concentrations across the site. The approach of high-density gamma scanning, gamma/soil radionuclide correlations, HPIC cross-calibrations, and integrated use of GIS for spatial analyses and data presentation, should meet or exceed current regulatory guidelines for baseline characterizations. Respective results as presented in this Report are expected to benefit all stakeholders.

2.9.13 References

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3.0 DESCRIPTION OF PROPOSED FACILITY

The proposed Ludeman Project (proposed project) area encompasses approximately 19,890 acres. The proposed project will be developed by constructing three Satellite facilities, wellfields, and ISR recovery support facilities. The North Platte, Leuenberger and Peterson Satellite facilities will each be located within an approximate 5-acre fenced area in the SW¼ NW¼, Section 10, T34N, R73W, SE¼ NE¼ of Section 14, T34N, R74W, and SW¼ SW¼, Section 26, T34N, R73W, respectively. These facilities are designed to provide chemical makeup of recovery solutions, recovery of uranium by ion exchange, resin loading/unloading and groundwater restoration capabilities.

Figure 3-1 shows the proposed project area plan. The total surface area to be affected by the proposed operation is completely within the proposed project area. Estimated surface area to be disturbed is approximately 813 acres. Seven wellfields, three Satellite facilities, six deep disposal wells and six surge ponds compose the significant proposed surface features to be associated with the uranium ISR recovery operations. Construction of the three Satellite facilities, associated structures and wellfield header houses will encompass approximately 160 acres. Road disturbance acreage has been calculated assuming approximately seven miles of 25-foot-wide main road and approximately 18 miles of 8-foot wide, two-tracks for field roads. Each proposed Satellite facilities is anticipated to consist of an 80- x 160-foot building, two surge ponds, and other infrastructure within the enclosed security fencing.

The total proposed wellfield area to be used for the injection and recovery of solution over the eleven-year mine life will be approximately 763 acres. Individual wellfield areas will be fenced to limit access by livestock during production and restoration activities. The fenced wellfield area will be slightly greater than that encompassed by the areas to be mined.

As shown on Figure 3-1, other mineralized trends within the current proposed project area, particularly those in the northern portion of the site, are known to exist but have not been extensively delineated. As a result, additional development areas may be determined as exploration and delineation activities continue.

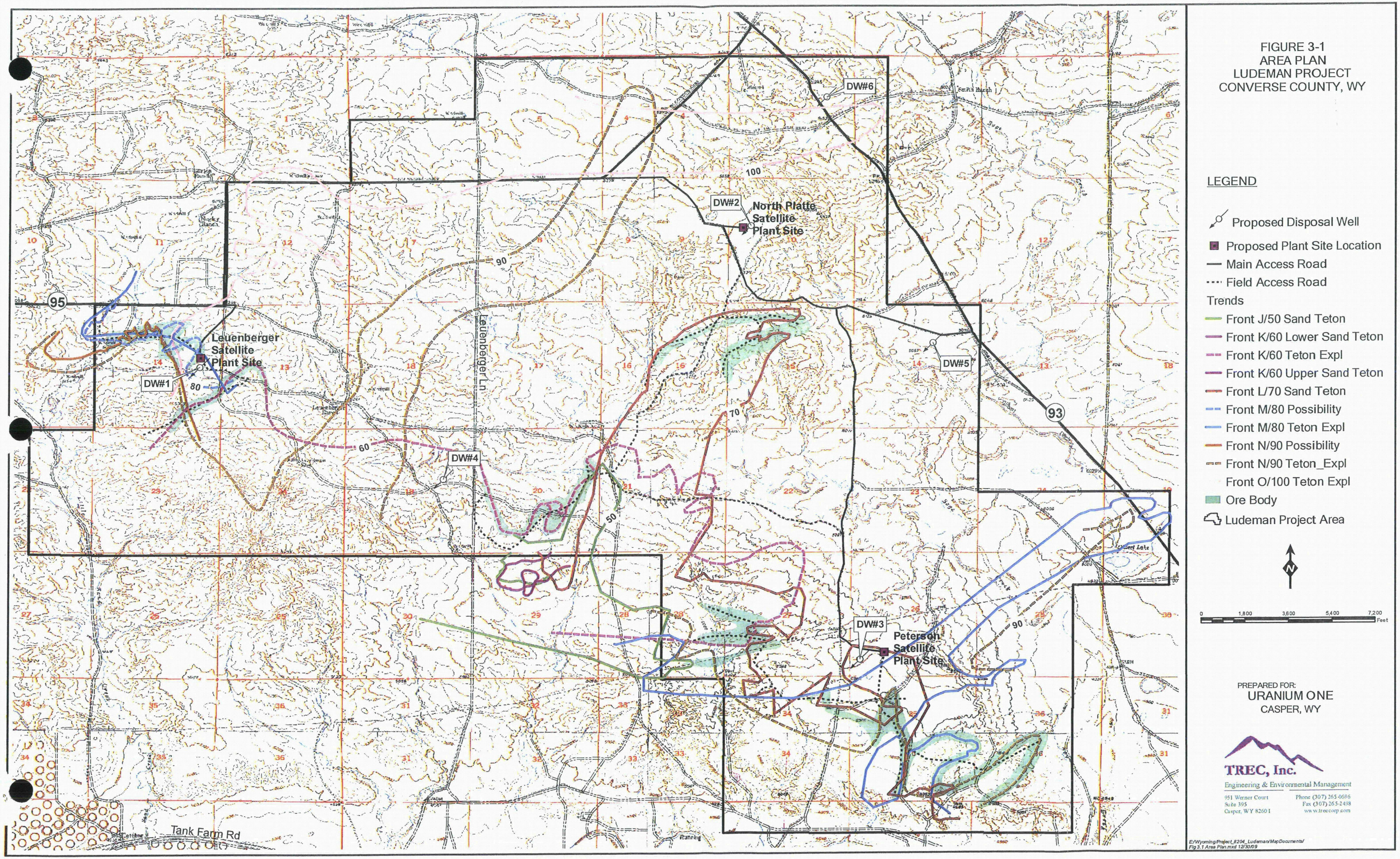


FIGURE 3-1
AREA PLAN
LUDEMAN PROJECT
CONVERSE COUNTY, WY

3.1 ISR PROCESS AND EQUIPMENT

3.1.1 Proposed Ludeman Project Area Ore Bodies

Uranium ore within the proposed project area occurs in typical roll-front deposits. Uranium One exploration nomenclature designates the sands in the project area by decreasing numbers with increasing depth. The Production Zone aquifers in the proposed project area are the 70, 80 and 90 Sands of the Lebo member of the Paleocene Fort Union formation. The sand thickness is variable and ranges in thickness from 13 to 164 feet in the 70 Sand, zero to 161 feet in the 80 Sand and 19 to 299 feet in the 90 Sand. The 70 Sand is continuous across the planned wellfields as is the 90 Sand. The 80 Sand is not continuous across the area as it pinches out in the south-east and east-central portions of the proposed project area. Confinement exists between the 70, 80 and 90 Sand Production Zones and the overlying and underlying sands throughout the proposed project area.

The mineralization in the 90 Sand in the western portion of the project area varies from 189 to 292 feet deep from surface level and averages 219 feet in depth. The mineralization in the 80 Sand varies from 303 to 441 feet deep from surface level and averages 352 feet in depth. Mineralization in this area is primarily contained within the 60, 80, 90 and 100 Sands; only the 80 and 90 Sands are planned to be mined. The thickness of the mineralization in the 90 Sand averages 8.3 feet with an average grade of 0.090 percent U_3O_8. The thickness of the mineralization in the 80 Sand averages 9.5 feet with an average grade of 0.130 percent U_3O_8.

The mineralization in the central part of the proposed project area varies from 465 to 690 feet deep averaging 557 feet in depth from surface. Mineralization is primarily contained within the 50, 60 and 70 Sands; only the 70 Sand is planned to be mined. Mineralization thickness in this portion of the project area averages 10.6 feet with an average grade of 0.074 percent U_3O_8.

The south-eastern portion of the proposed project area has depths to mineralization ranging from 19 to 366 feet, averaging 191 feet. The 70, 80 and 90 Sands contain the primary mineralization in the area, averaging 4.6 feet in thickness with an average grade of 0.093 percent U_3O_8.

Typical stratigraphic intervals to be mined are shown in the geologic cross sections and generalized stratigraphic column in Section 2.6 of this application. For ISR wellfields, the Production Zone is the geological sandstone unit where the recovery solutions are injected and produced. However, the ore thickness and corresponding Production Zone at any location is a fraction of the total thickness of the host sand and rarely exceeds 20 feet.

3.1.2 Delineation Drilling

The irregular shape, distribution and grade of uranium deposits requires several phases of drilling to determine ore reserves, injection, production and groundwater monitoring well locations and to allow for sufficient time to develop wellfield engineering and design plans. Geophysical logging is performed in all drill holes. The most common logs used are resistivity, spontaneous potential (SP), and natural gamma. The resistivity and SP logs are used to determine the lithology of the hole, and the natural gamma log is used to estimate the depth and location of the uranium. Additionally, deviation logs are commonly used to determine the amount of borehole drift between ground surface and bottom of the completed hole. Drilling methodology will be primarily performed with standard truck-mounted, mud rotary drilling rigs.

Preliminary ore reserve estimates and project feasibility analyses are typically completed after a substantial portion of a deposit has been drilled on centers as close as 100 feet (i.e., one hole per 10,000 square feet). The information provided by this phase of drilling permits the development of preliminary wellfield design plans and delineation of groundwater monitoring well locations.

To determine the lateral extent of the economically recoverable uranium ore, additional drilling on centers as close as 50 feet (i.e., one hole per 2,500 square feet) is typically required. The information obtained from this phase of drilling is used to map the ore body both in plan and cross-section and to locate potential injection and production wells. This data is also used to finalize the locations of groundwater monitoring wells which are typically installed prior to installation of mine unit patterns.

The final phase of ore body delineation consists of drilling pilot holes for injection and production wells. Prior to installation of casing, the geophysical logs of each pilot hole in a pattern are reviewed to determine the screen interval of the well and confirm that the pattern contains sufficient reserves to recover uranium economically. If it is determined that a pilot hole (or holes) does not contain enough mineral reserves to provide for economic production, the hole will not be cased, but will be plugged and abandoned in accordance with the procedures outlined in Section 6 of this application.

Delineation drilling will occur throughout each year, depending on production and development needs. Typically, 200 to 500 delineation drill holes will be completed each year, as necessary, to adequately define future wellfield pattern areas.

3.1.3 Well Construction and Integrity Testing

Well construction materials, methods, development, and integrity testing are described below. All work will be performed under the direction and supervision of qualified Uranium One personnel.

3.1.3.1 Well Construction Materials

During the life of the proposed project, Uranium One will install production and monitor wells. The production wells will consist of injection and recovery wells. The injection wells will be used to convey the barren lixiviant to the Production Zone, while the recovery wells will be used to recover the pregnant lixiviant after contact with the uranium ore. These wells will be installed using the same completion method so that the wells can be used for either injection or recovery. The ability to change the well function allows for improved uranium recovery and more efficient groundwater restoration as well as an improved ability to respond to potential excursions of lixiviant. Typical well completion schematics for recovery wells, injection wells, and monitor wells are shown on Figure 3-2.

All production wells are planned to be constructed of Standard Diameter Ratio (SDR) 17 polyvinyl chloride (PVC) with a sufficient pressure rating to withstand the maximum anticipated injection pressure and the maximum resistance to hydraulic collapse pressure anticipated during cementing of the well. Additionally, the wells will be constructed in accordance with Section 6, Chapter 11, "Non Coal In Situ Mining", of the WDEQ Land Quality Division (LQD) Rules and Regulations. The specifications embodied in Chapter 11 have been previously proposed by Uranium One for Moore Ranch, Uranerz for Nichols Ranch and Hank, and Ur-Energy for Lost Creek, and have had such specifications accepted by NRC in their license approvals. The wells are planned to be installed using 4.5, 5.0 or 6.0 inch SDR17 well casing. PVC casing is typically supplied in 20 ft. lengths, and the lengths will be mechanically joined with either threaded connections and/or a water tight O-ring seal, secured in place by a high strength nylon spline.

In accordance with Section 6 of Chapter 11, Uranium One plans to use an annular seal consisting of a cement slurry or a cement bentonite mixture approved by the LQD Administrator. A cement bentonite mixture was approved by the LQD Administrator for the installation of Uranium One's regional baseline monitor wells. The purpose of sealing the annular space is to assure structural integrity of the casing, stabilize the upper formations, protect against contamination of the well from the surface, and to prevent migration of ground water from one aquifer or water-bearing stratum to another.

The interior monitor wells will be screened in the Overlying and Underlying Aquifers, while the perimeter monitor wells will be screened in the Production Zone. The completion intervals for these wells will be predetermined and will use the same materials of construction as the production wells.

3.1.3.2 Well Construction Methods

The recovery and injection wells will be installed with identical completion methods to allow the ability to change the well function for improved uranium recovery, more efficient restoration, and improved ability to respond to potential excursions. Monitor wells will also utilize the same completion methods of the recovery and injection wells and is described below:

- <u>Construction Method (see Figure 3-2)</u>

  1. A 5 to 6.5 inch diameter pilot hole will be drilled through the projected mineralized zone within the Production Zone aquifer. The pilot hole may penetrate the upper portion of the Underlying Aquitard to obtain an accurate geophysical log, however the pilot hole will not fully penetrate the Underlying Aquitard that separates the Production Zone from the Underlying Aquifer. The pilot hole will be logged using a geophysical tool which will provide a suite of logs consisting of gamma, single point resistance, spontaneous potential, neutron and deviation. The grade and depth of each mineralized intercept will be provided by the log;

  2. To complete the well, the pilot hole will be reamed to a diameter of 7 7/8 to 9 7/8 inches (a minimum of 3 inches greater than the nominal OD of the casing) to a maximum depth of 15 feet below the bottom of the mineralized zone. The pilot hole below the bottom of the reamed hole will be filled with drill cuttings during the reaming process. In some cases, the ream hole may be drilled and logged without a pilot hole being drilled first. PVC casing with a nominal OD of 5 to 6.6 inches will be placed in the reamed hole to a depth approximately 10 feet below the mineralization. Centralizers will be placed on the casing string at a maximum spacing of one per 40 feet. Also, a wooden dowel or bolt will be placed through the casing approximately 3 feet from the bottom to act as a stop;

  3. A specified volume of cement slurry calculated to fill the annular volume and mixed to approved specifications will be pumped inside the casing through a cementing head. Once the cement is in place, a cement wiper plug will be placed in the top of the casing. A volume of displacement water will then be pumped into the casing forcing the cement slurry out of the bottom of the casing and up the annulus between the casing and the reamed hole. Once the wiper plug reaches the wooden dowel or bolt in the bottom of the casing displacement of the cement will

end and the valve on the cementing head will be closed which will hold the cement in place while the cement cures. The use of a wiper plug cleans the cement slurry from the inside of the casing and assures that the cement will not be over displaced by providing a surface indication (increased pressure reading) of when the cement job is complete. The well annulus will be topped off with cement to the surface prior to reentry by the drill rig;

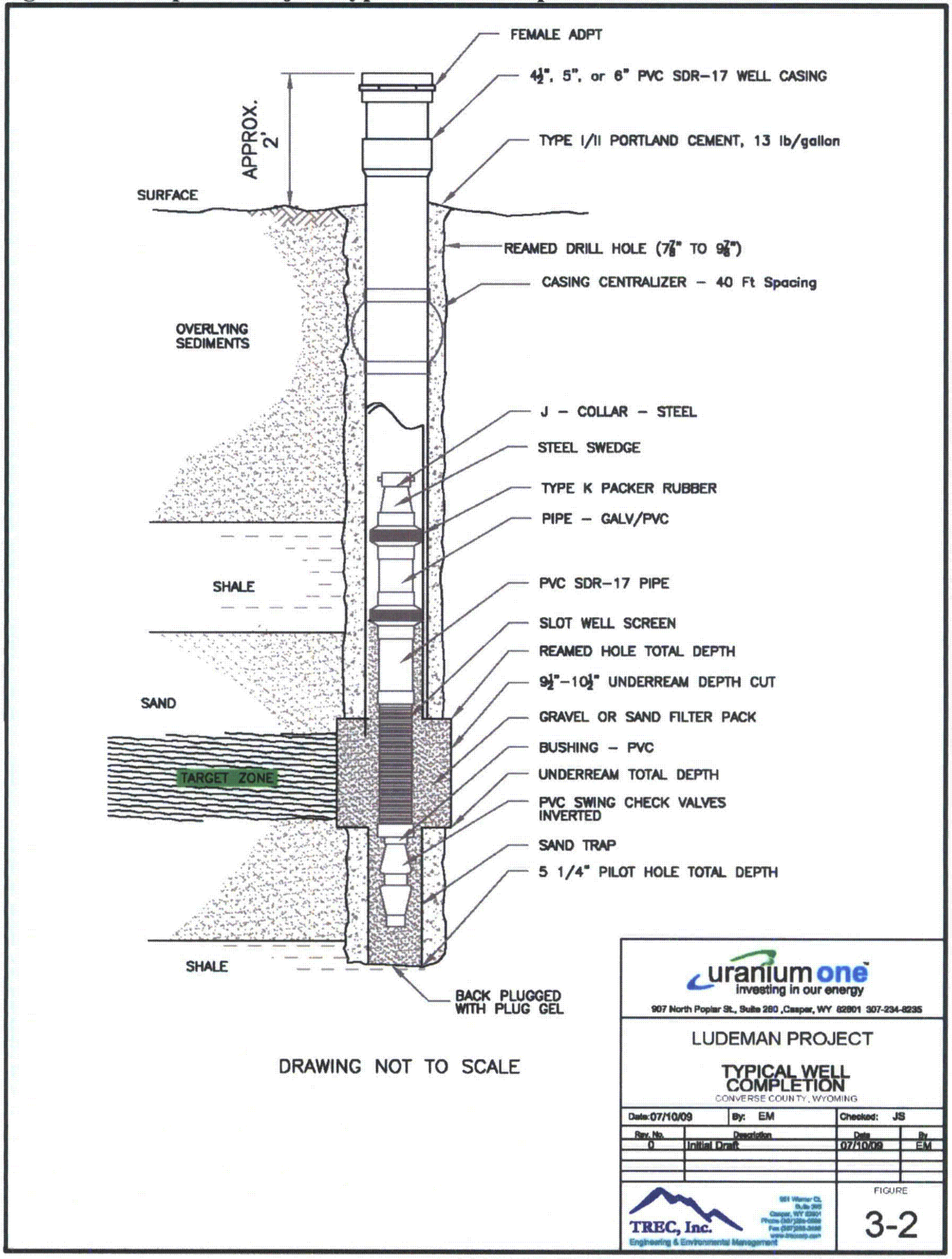
4. After the cement is allowed to cure for a minimum of 72 hours, the well will be under-reamed through the mineralized zones to a diameter of 9 $^{1/2}$ to 10 $^{1/2}$ inches, depending on the OD of the casing. The under-reaming will be completed by a specialized tool utilizing retractable blades. The blades are closed for the trip down the well and are opened by pressure from the rig mud pump. After under-reaming the designated zone through the casing and cement, the blades are again retracted for the trip out of the well. The well may be caliper logged as necessary to verify the correct interval has been opened. If deemed necessary, to support sand zones that are not competent, a well screen will be telescoped into the casing covering the under-reamed zone. The uppermost screen openings will be placed below the top of the under-reamed interval and below the bottom of the annular seal. A PVC riser pipe will be attached to the top of the screen and will be held in place by one or more k-packer(s). Gravel pack sand may be placed between the screen and the under-reamed hole;

5. The well will be developed to remove contaminants and fines from the drilling and completion process and maximize the flow rate. A well completion form will be completed documenting all of the details on drilling, completion materials, casing depth, completion interval, and the cement mix;

6. After drying, the drill cuttings contained in the pits will be covered with subsoil and the stockpiled topsoil. The ground surface will then re-contoured and reseeded; and

7. The well will then be integrity tested as discussed in Section 3.1.3.4 below.

Figure 3-2: Proposed Project Typical Well Completion



3.1.3.3 Well Development

Following well installation, but before baseline water quality samples are taken for groundwater restoration and water quality monitoring, the wells will be developed to restore the natural hydraulic conductivity and geochemical equilibrium of the screened aquifer. All wells will be developed initially immediately after construction using air lifting, swabbing or other accepted development techniques. Well development removes water and drilling fluids from the casing, by flushing it with water from the screened interval. The purpose of well development is to allow representative formation water to enter the well screen and casing. This process is necessary to allow representative samples of groundwater to be collected for monitor wells, and to ensure efficient injection and recovery operations from the production wells.

Final development of monitor wells will be performed by pumping the well, or swabbing for the amount of time necessary, to ensure that stable formation water is present. pH and conductivity measurements will be taken on the development water during this process to ensure that development activities have been effective. The field parameters must be stable at representative formation values before baseline sampling will begin.

3.1.3.4 Well Mechanical Integrity Testing

Prior to being placed into operation and after well completion, the integrity of the wells will be verified by a pressure based Mechanical Integrity Test (MIT) as required by State and Federal UIC Programs.

The MIT is conducted by placing inflatable packers near the top of the casing and directly above the riser pipe connected to the screen interval. The packers are inflated and the interval between the packers is filled with water and pressurized to the test pressure (maximum allowable injection pressure plus a safety factor of 20 percent). This pressure must be maintained within 10 percent for 10 minutes to pass the MIT. An alternative to using a top inflatable packer may be utilized. Instead of an inflatable packer, the top of the casing may be sealed by a specially designed flange top. A well integrity record will be completed for each tested well. If a well shows an unacceptable pressure drop during the integrity test, the packers may be reset and the equipment checked for leaks. If in successive tests the well passes the integrity requirements, the well will be deemed acceptable for use as injection, recovery, or monitor well.

If there are obvious leaks, or the pressure drops by more than ten percent during the ten-minute period, the seals and fittings on the packer system will be reset and/or checked and another test is conducted. If the pressure drops less than ten percent the well casing is considered to have acceptable mechanical integrity.

The maximum allowable injection pressure will be based on the formation fracture pressure. At these depths, Uranium calculates that the maximum allowable injection pressures will range from 90 to 145 psi across the extent of the property.

If a well casing does not meet the MIT criteria, the well will be taken out of service and the casing may be repaired and the well re-tested. If this is not done the well is plugged and abandoned. The WDEQ-LQD will be notified of any well that fails the MIT. If a repaired well passes the MIT, it will be employed in its intended service following approval from the LQD Administrator that the well has demonstrated mechanical integrity. If the well defect resulting in a failed MIT occurs at depth, the well may be plugged back and re-completed for use in a shallower zone, provided it passes the subsequent MIT. If an acceptable test cannot be obtained after repairs, the well will be plugged and abandoned.

In addition to the initial testing after well construction, a MIT will be conducted on any well after any repair where a downhole drill bit or underreaming tool is used. Any production well with evidence of suspected subsurface damage will require a new MIT prior to the well being returned to service. In accordance with WDEQ requirements, MITs will be repeated once every five years for all production and injection wells wells.

The MIT of a well will be documented to include the well designation, date of the test, test duration, beginning and ending pressures, and the signature of the individual responsible for conducting the test. Results of the MITs are maintained on site and are available for inspection. In accordance with WDEQ requirements, the results of MITs are reported to the WDEQ on a quarterly basis.

3.1.4 ISR Process

Production of uranium at the proposed project will utilize ISR methodologies involving two separate, but related processes. These processes include an ISR process and a recovery process. The ISR process will be accomplished by installing a series of injection and recovery wells. Utilizing those injection wells, a carbonate-leaching, or barren lixiviant will be injected into the ore body. To promote flow across the mineralized areas, corresponding recovery wells will be used to pump water from the ore body, and allow for the collection of the uranium-bearing carbonate leach, or pregnant lixiviant, which will be then pumped to the proposed Satellite facilities.

During any operation where these injection fluids are utilized, excursions can be a concern. Extraction fluids are normally maintained in the production aquifer within the immediate vicinity of the wellfield. A ring of encircling monitor wells will be used to detect any production fluids migrating from the production area due to fluid pressure imbalance. Such a system has been proven to function satisfactorily over many years of operating experience with uranium in situ uranium recovery operations. More specific details regarding the proposed project monitor well rings and excursions are discussed in Section 3.1.5.3.

Once the pregnant lixiviant reaches the proposed Satellite facility, the uranium will be removed from the lixiviant through the use of pressurized downflow ion exchange columns utilizing resin having an affinity for the uranium complex. After the lixiviant has passed through the ion exchange system, the solution will be re-fortified with a concentrated carbonate solution, making barren lixiviant, which will be then recycled to the injection wells for further production. Once the ion exchange resin in an ion exchange column is loaded to capacity with uranium complexes, the column will be taken out of service. The resin loaded with uranium will be transferred from one of the Satellite facilities to the Willow Creek Central Processing Plant via tanker truck. Once the resin has been stripped of the uranium by the process of elution, the resin will be returned to the Ludeman satellite facilities for reuse in the ion exchange circuit..

The second process is the further refinement of the uranium-rich solution to create a marketable yellowcake product. The resin will be shipped via trucks to the Willow Creek where the uranium will be removed from the resin by elution. This will be accomplished by precipitating the dissolved uranium out of the eluent solution, dewatering the uranium solids then vacuum drying the uranium slurry. The dried uranium product, yellowcake, is then packaged to allow safe transportation utilizing NRC-approved carriers.

SUA-1341 allows yellowcake production up to 2.5 million pounds of throughput per year. The License Renewal Application (LRA) for SUA-1341 (Cogema, 2007) estimated that during peak periods of production, the Willow Creek Satellite could produce up to one million pounds per year of uranium product which will be dried at the Willow Creek CPP and stated that Uranium One may wish to dry up to an additional 1.5 million pounds per year of yellowcake product from other uranium licensees. The LRA also noted that MILDOS modeling has been performed at the 2.5 million pound throughput and no significant increases in exposures to the general public were indicated as a result of this level of drying.

With NRC approval of this amendment request for SUA-1341, Uranium One will begin construction and operation of the proposed Ludeman project. Shipments of loaded IX resin from the proposed project will supfacility the "toll" shipments from other Uranium One projects and other licensees allowed by SUA-1341 up to the licensed production capacity for Willow Creek.

3.1.4.1 ISR Reactions

The lixiviant is the recovery solution which is used to solubilize the uranium from the ore deposit. The composition of the recovery solution is designed to reverse the natural geochemical conditions which led to the original uranium deposition. The project will use oxygen, and carbon dioxide (CO_2) added to the native groundwater to promote the dissolution of uranium as a uranyl carbonate complex. Sodium carbonate (Na_2CO_3) or sodium bicarbonate ($NaHCO_3$) may be added if necessary to boost the carbonate in the lixiviant if carbon dioxide addition alone is not adequate. The lixiviant is typically made up on a batch basis in the facility and added continuously to the injection stream. The expected or typical lixiviant concentration and composition is shown in Table 3-1.

Table 3-1: Typical Lixiviant Concentrations

SPECIES	RANGE (mg/L)	
	Low	High
Na	≤ 400	6000
Ca	≤ 20	500
Mg	≤ 3	100
K	≤ 15	300
CO_3	≤ 0.5	2500
HCO_3	≤ 400	5000
Cl	≤ 200	5000
SO_4	≤ 400	5000
U_3O_8	≤ 0.01	500
V_2O_5	≤ 0.01	100
TDS	≤ 1650	12000
pH	< 6.0	8.0

* All values in mg/l except pH (units).

NOTE: The above values represent the concentration ranges that could be found in barren lixiviant or pregnant lixiviant and would include the concentration normally found in "injection fluid".

The chemistry of ISR recovery involves an oxidation step to convert the uranium in the solid state to a form that is easily dissolved by the recovery solution. The reactions representing these steps at a neutral or slightly alkaline pH are:

Oxidation: $UO_{2\,(solid)} + O_{2\,(in\ solution)} + 2H^+ \rightarrow UO_{3\,(at\ solid\ surface)} + H_2O$

Dissolution: $UO_3 + 2\,HCO_3^{-1} \rightarrow UO_2(CO_3)_2^{-2} + H_2O$

$UO_3 + CO_3^{-2} + 2HCO_3^{-1} \rightarrow UO_2(CO_3)_3^{-4} + H_2O$

The principal uranyl carbonate ions formed as shown above are uranyl dicarbonate, $UO_2(CO_3)_2^{-2}$, (UDC), and uranyl tricarbonate $UO_2(CO_3)_3^{-4}$, (UTC). The relative abundance of each is a function of pH and total carbonate strength.

3.1.4.2 Uranium Extraction

The process flow sheet depicting the uranium extraction process as planned for the proposed Satellite facilities is shown in Figure 3-8. The recovery of uranium from the pregnant lixiviant at the proposed Satellite facilities will take place in the ion exchange columns. The uranium bearing recovery solution enters the pressurized downflow ion exchange column and passes through the resin bed. A uranium-specific ion exchange resin, such as Dowex 21K, or equivalent, is used. The uranium complexes in solution are loaded onto the ion exchange resin in the column in either bicarbonate or chloride form. This loading process is represented by the following chemical reaction:

$$2\,R\,HCO_3 + UO_2(CO_3)_2^{-2} \longrightarrow R_2UO_2(CO_3)_2 + 2HCO_3^{-1}$$
$$2\,RCl + UO_2(CO_3)_2^{-2} \longrightarrow R_2UO_2(CO_3)_2 + 2Cl^-$$

As shown in the reaction, loading of the uranium complex results in simultaneous displacement of chloride and bicarbonate ions from the resin to the barren lixiviant.

The now-barren lixiviant passes from the ion exchange columns to be reinjected into the Production Zone. The solution is refortified with carbon dioxide and oxygen as required, and pumped to the wellfield for reinjection into the formation.

3.1.5 Wellfield Design and Operation

The proposed project wellfield area maps are shown in Figures 3-3 and 3-4. As described in Section 3.1.2, current wellfield delineation is preliminary, based on Uranium One's current knowledge of the area. The final wellfield footprints will be developed after wellfield delineation is completed. The final wellfield design will be submitted to WDEQ-LQD in the wellfield package information described in Section 5.

The wellfield injection/recovery pattern employed is based on the conventional square five spot pattern which is modified as needed to fit the characteristics of the orebody (see Figure 3-5). The standard five-spot pattern contains four injection wells surrounding a centrally located recovery well. The pattern dimensions vary depending on the formation and the characteristics of the orebody. The injection wells in a normal pattern are expected to be between 75 feet and 150 feet apart. All wells will be completed so they can be used as either injection or recovery wells, so that wellfield flow patterns can be changed as needed to improve uranium recovery and restore groundwater quality in the most efficient manner. Other wellfield designs include alternating or single line drives.

Each injection well and recovery well is connected to the respective injection or recovery manifold in a wellfield header house building. The manifolds deliver the injection and recovery solutions to the pipelines carrying the solutions to and from the ion exchange facilities. Flow meters and control valves are installed in the individual header houses to monitor and control the individual well flow rates and pressures. Header houses will be used to distribute injection fluid to injection wells and collect production solution from recovery wells. Each header house will be connected to two trunk lines, one for receiving injection fluid from the Satellite facility and one for conveying recovery fluids to the Satellite facility. Header houses will include manifolds, valves, flow meters, pressure meters, booster pumps and oxygen for addition to the injection lixiviant. Each header house will service approximately 40 to 60 wells (injection and recovery). Typically header houses are made of steel construction and are approximately 10 feet wide by 20 feet in length and an approximate height of 10 feet. Currently, approximately 14 header houses are planned to be constructed for the Leuenberger Wellfield 1 in Section 14, 14 header houses for Leuenberger Wellfield 2 in Sections 13/14 and one header house for Leuenberger Wellfield 3 in the NW quarter of Section 14. Sixteen header houses are planned for the North Platte Wellfield 1 in Sections 15/16, and 13 header houses for the North Platte Wellfield 2 in Section 20. In addition, 14 header houses are planned for the Peterson Wellfield 1 in Section 27 and 14 header houses for Peterson Wellfield in Section 35.

Wellfield piping is primarily constructed of high density polyethylene (HDPE), with some PVC, and/or steel. The wellfield piping will be operated at pressures equal to or less than the rated operating pressure of the pipe and other in-line equipment. The typical pressure rating, for both the PVC and HDPE piping is between 160 and 300 psig. If a higher design pressure is needed, the pressure rating of the materials will be evaluated and, if necessary, materials with a higher pressure rating will be used.

The individual well lines and the trunk lines to the Satellite facility(s) are buried to prevent freezing and destruction from vehicle traffic. The use of wellfield header houses and buried lines is a proven method for protecting pipelines.

3.1.6 Wellfield Operational Monitoring

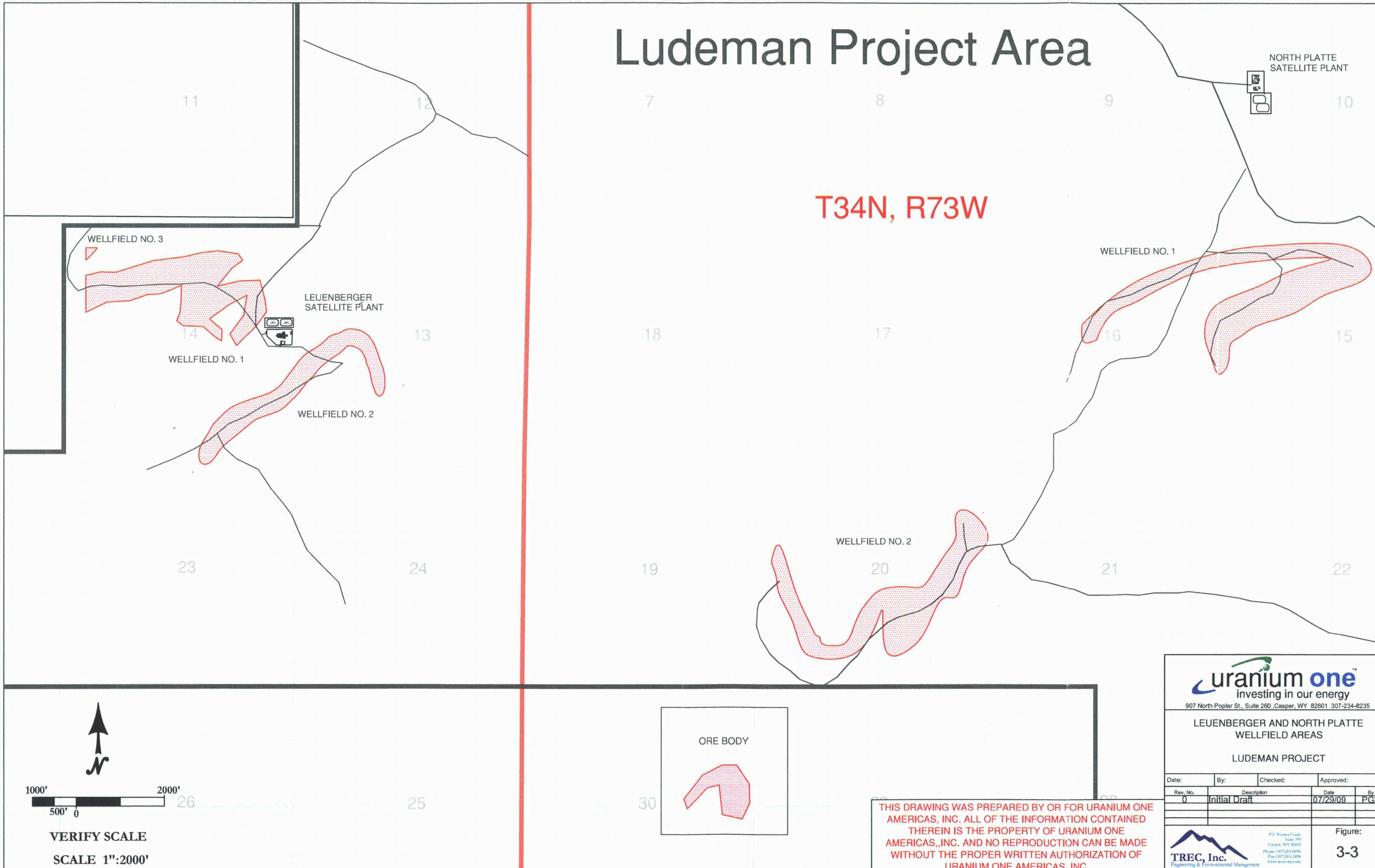
An extensive groundwater sampling program will be conducted prior to, during and following ISR recovery operations at the proposed project to identify any potential impacts to water resources in the area. The groundwater monitoring program is designed to establish baseline groundwater quality prior to ISR operations; detect any potential excursions of lixiviant either horizontally or vertically outside of the Production Zone during active ISR; and determine when the Production Zone Aquifer has been restored adequately following ISR.

Injection and recovery well flow rates will be monitored at each header house so that injection and recovery can be balanced for each pattern and each wellfield. The flow rates of each injection and recovery well will be monitored continuously through the use of individual electronic flow meters in each wellfield header house. Also, pressure gauges will be installed to measure pressures for each of the injection and recovery wells. The pressure of the injection and recovery manifold will be monitored at each header house with electronic pressure transducers. The flow meters and pressure transducers will be electronically connected to the header house control panel, which will be in constant communication with the process monitoring and control systems in the proposed Satellite facilities' control room.

High and low pressure along with flow rate alarms will be in place to alert wellfield and facility operators if pressures or flow rates in a particular header house are operating outside of acceptable operating parameters. In conjunction with the alarm system, the pumps in each recovery well will be automatically shut off and automatic valves on the injection and recovery manifolds will be directed to close to stop the flow of injection and recovery solutions to and from the wells if significant changes in flow or pressure occur. Also, the oxygen system in each header house will have a solenoid valve that will close and shut off the flow of oxygen to the injection wells in the event of injection flow shutdown. This action will isolate the header house from the rest of the production circuit to prevent or limit a possible spill in the wellfield.

The groundwater monitoring program at the proposed Ludeman Project will be designed to detect excursions of lixiviant outside the wellfield under production and into the overlying and underlying water bearing strata. After baseline water quality is established for the monitor wells for a particular production unit, UCLs are set for chemical constituents which would be indicative of a migration of lixiviant from the well field. The constituents chosen for indicators of lixiviant migration and for which UCLs will be set are chloride, conductivity, and total alkalinity. These constituents are used as excursion indicators for nearly all currently licensed and operating ISR facilities, including Willow Creek..

Chloride is chosen due to its low natural levels in the native groundwater and because chloride is introduced into the lixiviant from the ion exchange process. Chloride also is a very mobile constituent in the groundwater and will show up very quickly in the case of a lixiviant migration to a monitor well. Conductivity is chosen because it is an excellent general indicator of overall groundwater quality. Total alkalinity concentrations should be affected during an excursion as bicarbonate is the major constituent added to the lixiviant during ISR operations. UCLs will be set by analyzing the data for each excursion indicator.
The currently proposed excursion indicator parameters will be adequate to identify that the groundwater quality at a monitor well may have been affected from ISR operations. During routine sampling, if two of the three UCL values are exceeded in a monitor well, an excursion is deemed to have occurred. According to NUREG-1569, Sec. 5.7.8.3 (Criterion 5), a series of sampling events must occur to verify the excursion event.


Ludeman Project Area
T34N, R73W
NORTH PLATTE SATELLITE PLANT
WELLFIELD NO. 3
LEUENBERGER SATELLITE PLANT
WELLFIELD NO. 1
WELLFIELD NO. 2
WELLFIELD NO. 1
WELLFIELD NO. 2
ORE BODY
11
12
7
8
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LEUENBERGER AND NORTH PLATTE WELLFIELD AREAS
LUDEMAN PROJECT
Date:
By:
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Initial Draft
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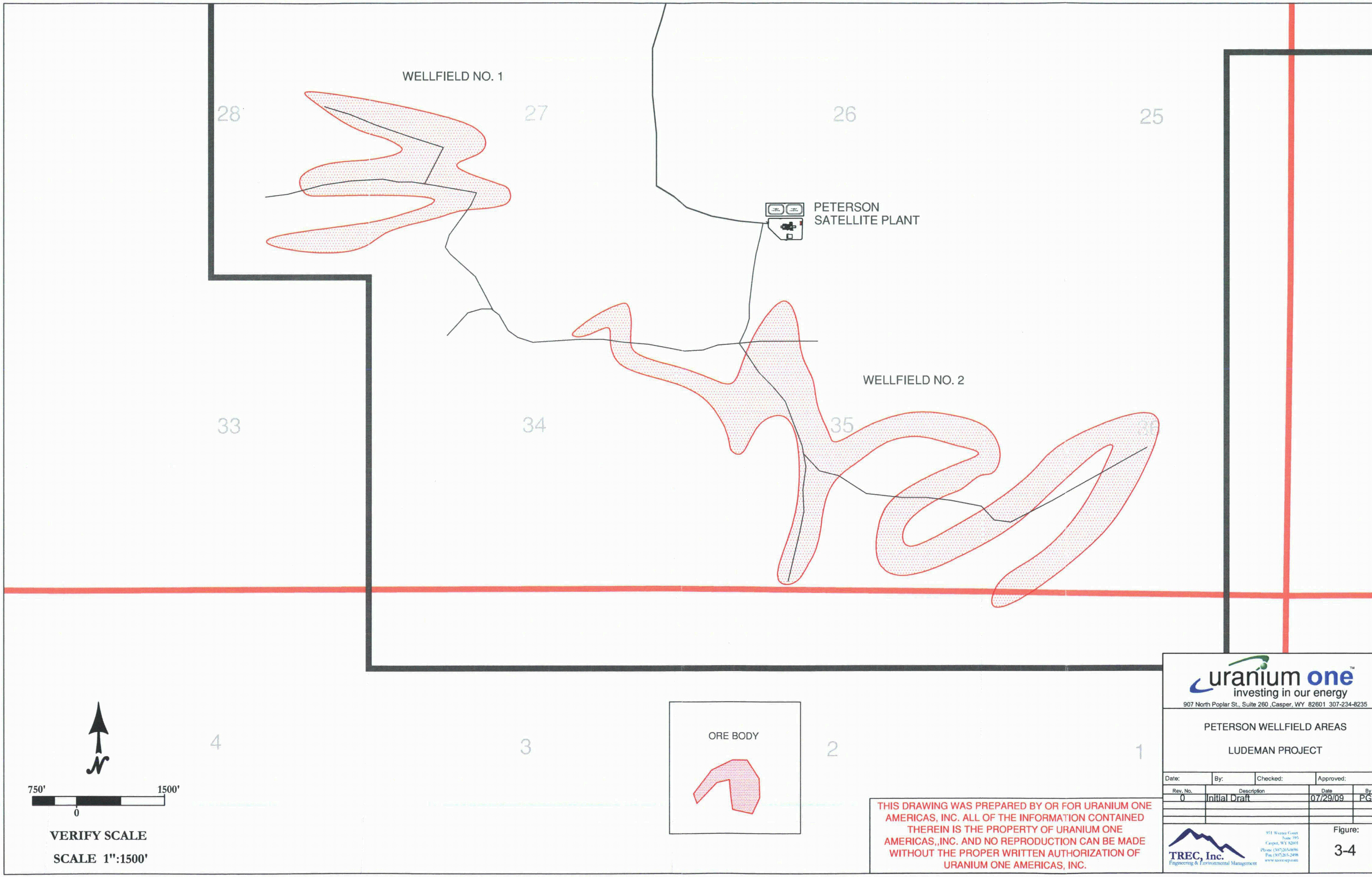
PGL
TREC, Inc.
Engineering & Environmental Management
Figure:
3-3



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PETERSON WELLFIELD AREAS

LUDEMAN PROJECT

Date:	By:	Checked:	Approved:

Rev. No.	Description	Date	By
0	Initial Draft	07/29/09	PGL

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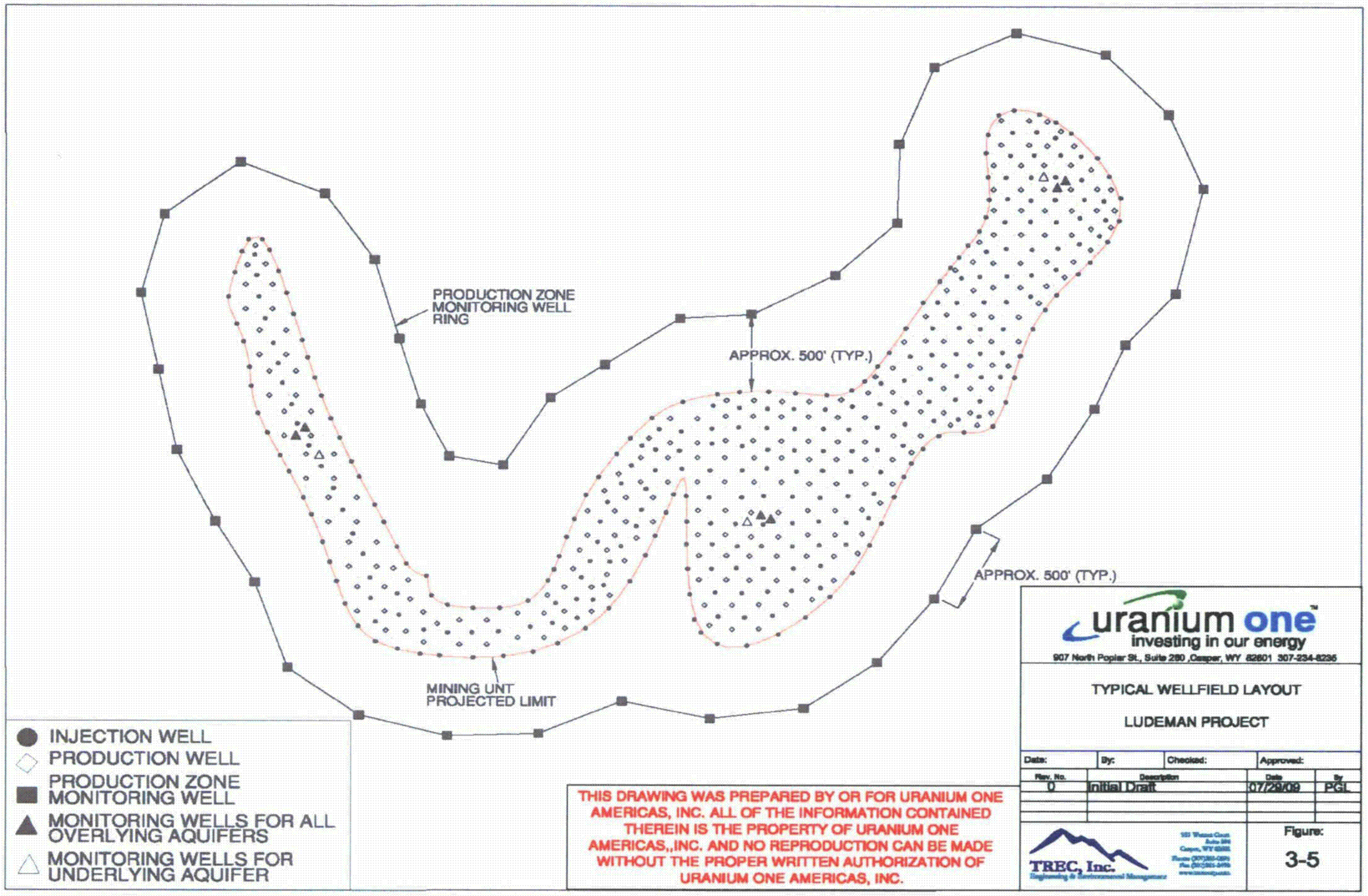
Engineering & Environmental Management

Figure:
3-4

Figure 3-5: Typical Wellfield Layout



3.1.6.1 Water Balance

During operations, more groundwater is produced from each wellfield than injected to create an overall hydraulic cone of depression in the Production Zone. Under this pressure gradient, the natural groundwater movement from the surrounding area is toward the wellfield providing additional control of the recovery solution movement. The difference between the amount of water produced and injected is the wellfield "bleed."

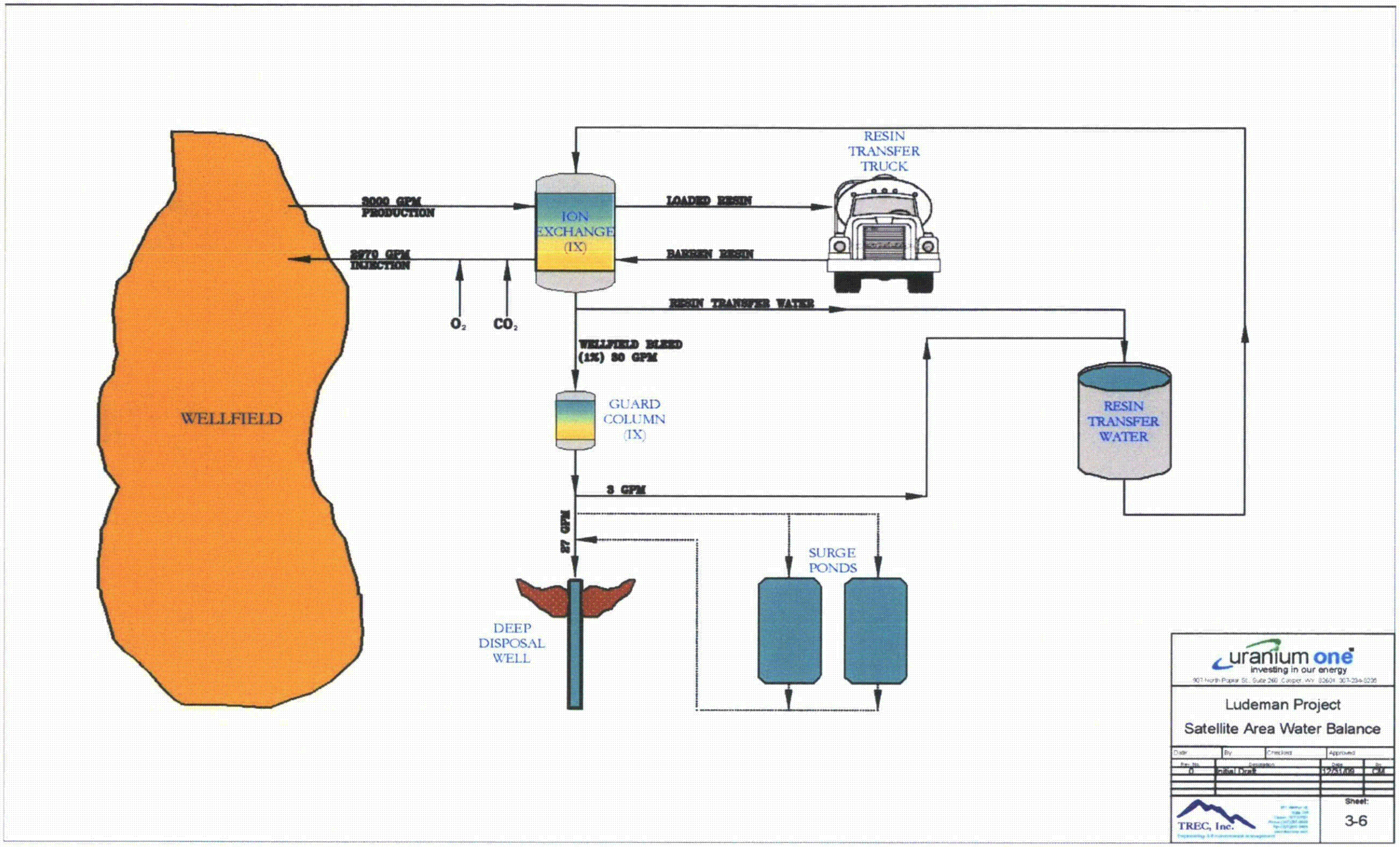
The minimum bleed rate (also called over-production) will be a nominal 0.5 percent of the total wellfield production rate and the maximum bleed rate typically approaches 1.5 percent. Bleed rates will be adjusted as necessary to ensure that the wellfield cone of depression is maintained. Based on a bleed of 0.5 to 1.5 percent, which has been successfully applied during mining at other ISR operations, the potential impact from consumptive use of groundwater is expected to be minimal. In this regard, the vast majority (e.g., on the order of 99 percent) of groundwater used in the mining process will be treated and re-injected. Potential impacts on groundwater due to consumptive use outside the proposed project area are expected to be negligible.

As demonstrated from the limited drawdown during the regional aquifer testing (maximum radius of influence seen during testing was 750 feet for 70 Sand, 500 feet for 80 Sand and 550 feet for 90 Sand), this amount of consumptive use will generate negligible drawdown outside of the project boundaries. As a result, no impact to other users of groundwater is expected, since there is no groundwater use from the Production Zone aquifer allowed within ¼ mile of any wellfield, and since the aquitards between the production sands have been determined to be effective barriers to vertical flow from the results of aquifer testing performed on the Ludeman site. For the same reasons, no impacts to groundwater users outside and downgradient of the proposed project boundary are expected. Impacts to groundwater from consumptive use are also discussed in detail in Section 7.2.

All groundwater monitoring wells will be completed using the well construction and testing methods previously discussed and developed prior to recovery solution injection. Injection of solutions for mining will be at a rate of approximately 3,000 gpm for each Satellite facility. Groundwater balance for the Satellite facility is shown on Figure 3-6. The liquid waste generated at the Satellite facilities will be primarily the production bleed, which is estimated to range from 0.5 percent to 1.5 percent of the total flow or 15 to 45 gpm, and may average one percent (30 gpm) of the production flow. Uranium One proposes to dispose of the liquid waste through deep disposal well injection. Each Satellite has two surge ponds to temporarily store liquid waste if the well becomes inoperable or is down for maintenance as discussed in Section 4.

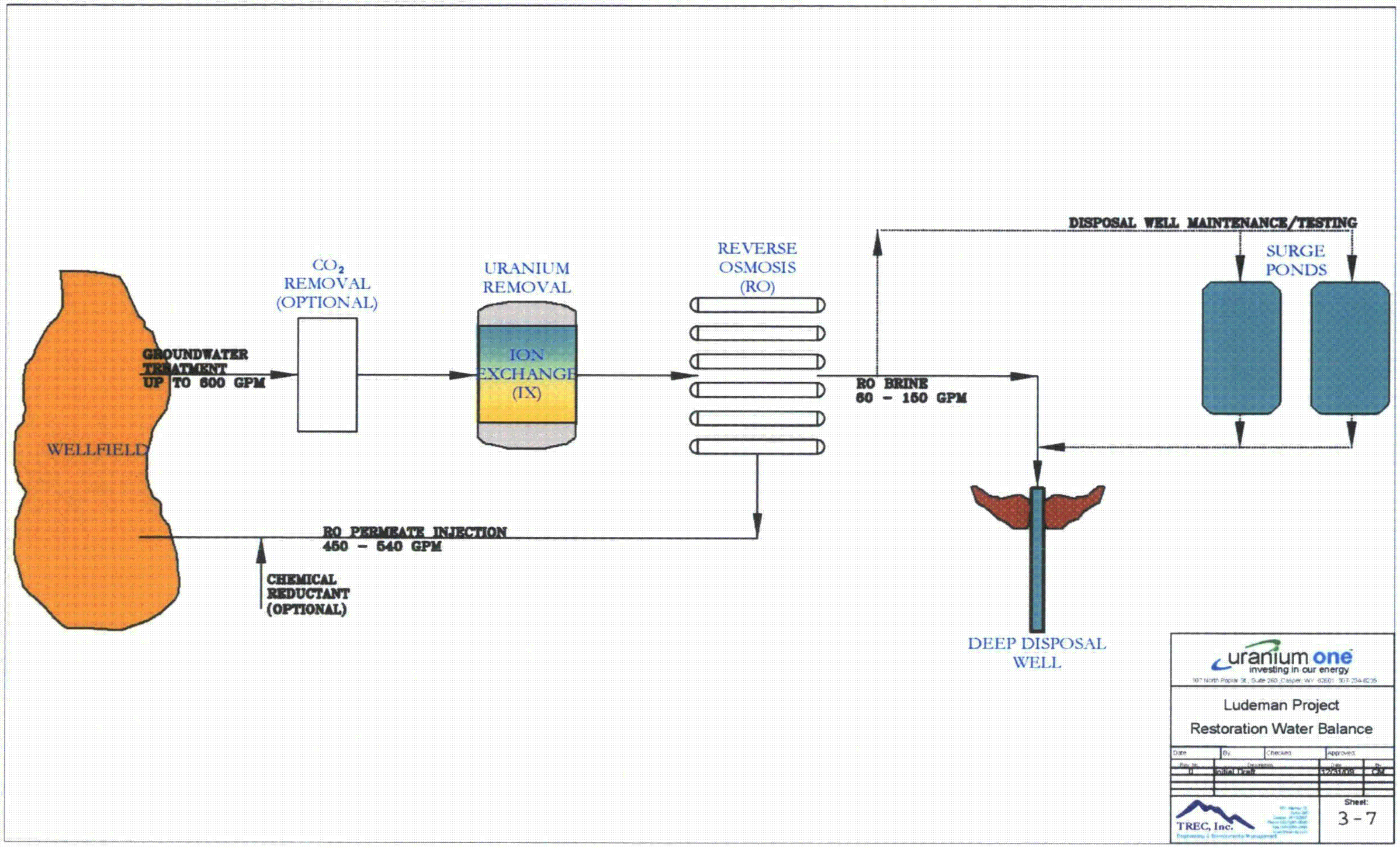
Restoration flow capacity (reverse osmosis treatment) will be approximately 600 gpm. The typical rate for brine waste water produced during restoration averages approximately 20 percent. This results in an RO brine rate of approximately 60 gpm to 150 gpm during restoration at full capacity. Restoration water balance is shown on Figure 3-7. Additional bleed will be encountered if groundwater sweep is utilized as a first stage of restoration. However, as described in Section 6.1, Uranium One does not anticipate utilizing groundwater sweep in significant amounts due to the limited success groundwater sweep has shown at other ISR operations.

Figure 3-6: Ludeman Project Satellite Area Water Balance*



*All numbers are approximate

Figure 3-7: Ludeman Project Restoration Water Balance*



* All numbers are approximate

3.2 SATELLITE FACILITY, PROCESSING, AND CHEMICAL STORAGE

The proposed Satellite ion exchange facilities are shown on Figures 3-3 and 3-4, including associated structures and wellfields. Each of the proposed Satellite facilities will be designed to operate at a throughput of 3,000 gpm. The Satellite facilities will include the ion exchange, resin loading, and transfer areas. These areas will also contain chemical storage, storage yards, a temporary byproduct storage area, and employee parking. The Satellite facilities will each be approximately 80 feet in width by 140 feet in length and will be entirely contained within a concrete curb designed to contain the volume of the largest tank in the facility. Figure 3-8 shows the general layout of the process equipment in the Satellite facility.

3.2.1 Satellite Facility Equipment

The Satellite facility includes the following systems:

- Ion exchange circuit;
- Resin transfer;
- Chemical addition;
- Filtration;
- Liquid waste stream circuit; and
- Groundwater restoration circuit.

The following sections will provide a description of each processing system and the equipment and materials used. A complete process flow diagram which shows process flows and equipment is shown in Figure 3-9.

3.2.1.1 Ion Exchange Circuit

In accordance with data presented in the NRC NUREG-1910 (NRC, 2009), Section 2.7.1, Uranium One will utilize pressurized down-flow ion exchange (IX) columns. The uranium-bearing solution, or pregnant lixiviant, recovered from the wellfield will be piped to the pressurized down-flow ion exchange systems in the Satellite facility for extraction of the uranium using specialized ion exchange resin. With this ion exchange system the radon present in the lixiviant is forced back underground in the re-fortified groundwater which thereby provides for significantly reduced potential for occupational and/or public exposure to radon and its progeny. More specific emission details are discussed in Sections 4 and 7 of this TR.

NUREG-1910 notes the pressurized downflow ion exchange systems contain most of the ^{222}Rn present in the lixiviant. Thus, the use of this type of ion exchange system allows for more effective control of ^{222}Rn. ^{222}Rn is only released during resin transfer and routine maintenance. Use of a pressurized, downflow ion exchange system enables Uranium One to control where the ^{222}Rn can go during maintenance and resin transfer, in turn allowing for a reduction in ^{222}Rn emissions relative to other available ion exchange technologies. The use of this type of system also represents a specific emission control method which reduces emissions to levels that are as low as reasonably achievable (ALARA) and complies with the requirements of 10 CFR Part 40, Appendix A, Criterion 8. The use of engineering controls, such as pressurized, downflow ion exchange columns, along with independent tank and area ventilation systems will ensure that exposures to ^{222}Rn and its progeny are maintained ALARA. Vents on the individual ion exchange vessels are connected to a manifold which is exhausted outside the Satellite facility in the event ^{222}Rn is released.

These columns will be operated in series as pairs to allow one column to be in the lead position and one in the tail position. This will allow the column in the tail position to be placed in the lead position once the original lead column is taken off-line for resin transfer. Resin will be transferred to an elution tank, where the resin will be stripped, and then transferred back to a pressurized down-flow ion exchange column.

An additional set of ion exchange columns will be used for restoration purposes only. As the pregnant lixiviant passes through the ion exchange system, the uranyldicarbonate and uranyltricarbonate ions will be removed preferentially from the lixiviant. The barren lixiviant leaving the ion exchange systems will normally contain less than 2 mg/l of uranium. After the barren lixiviant leaves the ion exchange system, CO_2 and/or carbonate/bicarbonate will be added as necessary to refortify the barren lixiviant with the carbonate/bicarbonate concentration desired for recovery operations. The barren lixiviant will then be pumped back to the wellfields, with an oxidant (O_2 gas) added before the solution is re-injected into the Production Zone.

3.2.1.1.1 Ion Exchange Circuit Equipment

Materials of construction and general specifications for the ion exchange circuit equipment are listed below. Detailed specifications and dimensions will be addressed during detailed engineering.

- Ion Exchange Columns: The ion exchange columns are pressurized downward-flow vessels constructed of mild steel with an epoxy internal coating. Internal distribution headers are constructed of 316SS steel; and
- Booster Pumps: Booster pumps are standard pumps of steel construction.

3.2.1.2 Restoration Circuit

Uranium One will use RO treatment during groundwater restoration to maximize permeate and minimize brine production. The interference from groundwater restoration with ongoing uranium recovery operations will be kept to a minimum by maximizing the quantity of permeate re-injected into wellfields undergoing RO treatment and will hasten the clean-up of the affected groundwater. Restoration equipment will be housed in the Satellite facility facility.

3.2.1.2.1 Restoration Circuit Equipment

Materials of construction and general specifications for the restoration circuit equipment are listed below. Detailed specifications and dimensions will be addressed during detailed engineering.

- RO Systems: The RO unit and related pumps will be will be constructed of chemically compatible material; and
- Restoration IX Columns: The restoration IX columns will be constructed of mild steel with an epoxy internal coating. Internal distribution headers are constructed of 316SS steel.

3.2.1.3 Bleed Treatment Circuit

To control the movement of lixiviant within the Production Zone, a small percentage of barren lixiviant will continuously be diverted away from the volume being pumped back to the injection wells, resulting in more lixiviant being pumped from the Production Zone than injected. This bleed will create a negative pressure gradient within the Production Zone, causing groundwater from the surrounding area to be drawn toward the wellfield. The negative-pressure gradient will contain the lixiviant within the ore-bearing region of the Production Zone, preventing the lixiviant from migrating away from the wellfield, and minimize the dilution of lixiviant by uncontrolled fluid movement.

It is anticipated that the bleed rates will range from approximately 0.5 percent to 1.5 percent of the recovery flow rate, and average approximately 1.0 percent. As discussed in Section 3.1.6.1, Water Balance, the wellfield bleed will be removed by processing a portion of the lixiviant through the production RO unit. The resulting brine from this RO unit will be piped either to the surge ponds or to the deep disposal wells.

3.2.1.4 Resin Transfer and Elution

Once the ion exchange resin in an ion exchange column is loaded to capacity with uranium complexes, the column will be taken out of service. The resin loaded with uranium will be transferred from one of the proposed Satellite facilities to the Willow Creek CPP via tanker truck. Once the resin has been stripped of the uranium by the process of elution, the resin will be returned to the Ludeman Satellite for reuse in the ion exchange circuit. In the elution circuit the loaded resin will be stripped of uranium by a process based on the following chemical reaction:

$$R_2UO_2(CO_3)_2 + 2Cl^- + CO_3^{-2} \longrightarrow 2\ RCl + UO_2(CO_3)_3^{-2}$$

After the uranium has been stripped from the resin, the resin may be rinsed with a sodium bicarbonate solution. This rinse removes the high chloride eluant physically entrained in the resin and partially converts the resin to bicarbonate form. In this way, chloride ion buildup in the lixiviant can be controlled.

3.2.2 Satellite Facility Chemical Storage

Chemical storage facilities at the proposed Satellite facilities will be designed to store and contain each specific material used. Materials storage areas will be constructed and maintained according to best practices. Proper signage will be installed in the storage areas. Appropriate handling procedures will be instituted and observed, and a hazard communication program in accordance with OSHA standards will be in place to deal with potential hazards associated with all materials stored at the site.

3.2.2.1 Process Related Chemicals

Process-related chemicals will be stored in bulk at the proposed Satellite facilities will potentially include carbon dioxide, sodium carbonate/bicarbonate, oxygen, and sodium sulfide, and hydrogen peroxide. Risk assessments completed by the NRC in NUREG-6733 for ISR facilities identified anhydrous ammonia and bulk acid (sulfuric and hydrochloric) storage as the most hazardous chemicals with the greatest potential for impacts to chemical and radiological safety.

3.2.2.1.1 Oxygen Storage and Delivery System

Oxygen will be added to the injection stream either upstream of the injection manifolds within the header house buildings or to individual injection well meter runs. Oxygen storage will be placarded and located near the Satellite facilities or at centralized position(s) in the wellfield. Each vessel will be equipped with safety relief devices and will be located at least 25 feet from buildings or as required by applicable NFPA and OSHA standards. The storage facility will be designed to meet industry standards in NFPA-502F and OSHA standards for the installation of bulk oxygen systems on industrial premises (29 CFR 1910.104).

Oxygen service pipelines and components must be clean of oil and grease since gaseous oxygen will cause these substances to burn much more rapidly if ignited, as it will any other combustible material. All components intended for use with the oxygen distribution system will be properly cleaned using recommended methods in CGA G-4.1. The design and installation of oxygen distribution systems will be based on CGA-4.4.

3.2.2.1.2 Carbon Dioxide Storage and Delivery System

The carbon dioxide storage and delivery system will be stored adjacent to the Satellite facility where it may be added to the lixiviant prior to leaving the facility, and for the make-up of sodium bicarbonate for addition to the lixiviant stream. It will be used to dissolve carbon dioxide into the pregnant lixiviant to improve recovery of uranium.

3.2.2.1.3 Chemical Reductants

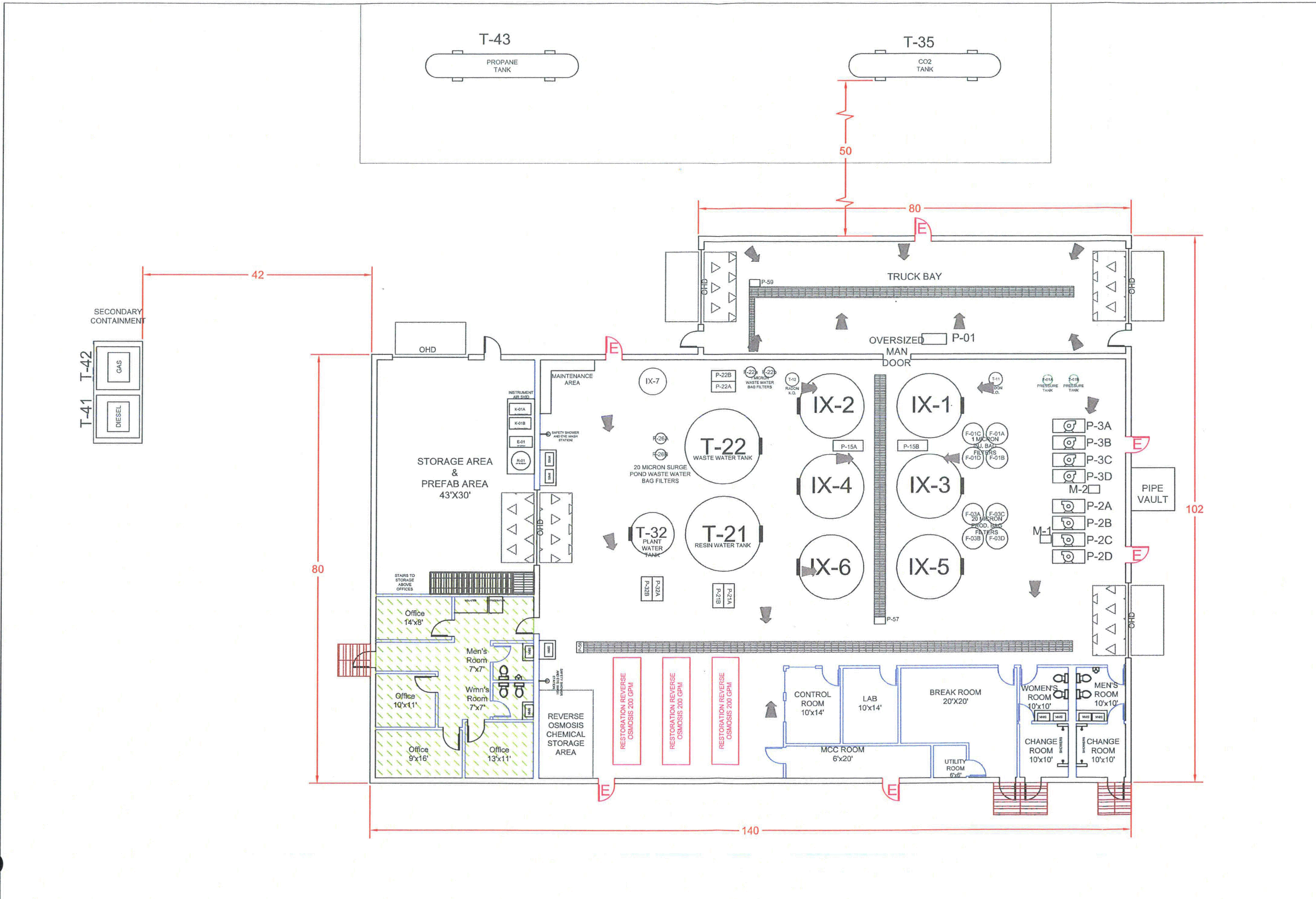
Hazardous materials typically used during groundwater restoration activities include the addition of a chemical reductant (i.e., sodium sulfide or hydrogen sulfide gas). To minimize the potential for accidents involving process chemicals to impact areas where licensed material is handled, these materials are stored outside of process areas. Sodium sulfide may be used as a chemical reductant during groundwater restoration. The material consists of a dry flaked product and is typically purchased on pallets of 55-pound bags or super sacks of 1,000 pounds. The bulk inventory will be stored outside of process areas in a cool, dry, clean environment to prevent contact with any acid, oxidizer, or other material that may react with the product. There are no current plans to use hydrogen sulfide gas at the proposed project. However, in the event that Uranium One determines that use of hydrogen sulfide as a chemical reductant is necessary, proper chemical safety precautions will be taken.

3.2.2.2 Non-Process Related Chemicals

Non-process related chemicals that may be stored at the proposed project site include petroleum products (gasoline, diesel) and propane. Due to the flammable and/or combustible properties of these materials, all bulk quantities will be stored outside of process areas at the Satellite facility. All gasoline and diesel storage tanks will be located above ground and within secondary containment structures designed to accommodate at least 110 percent of the volume of the largest tank in the containment structure. If the aboveground hydrocarbon storage capacity exceeds 1,320 gallons, Uranium One will prepare a Spill Prevention, Control, and Countermeasure (SPCC) plan in accordance with EPA requirements in 40 CFR Part 112.

3.2.2.3 Facility Areas Where Fumes or Gases May Be Generated

The potential exists for buildup of carbon dioxide or oxygen gases may also occur in confined spaces such as header houses if carbon dioxide and oxygen lines are present. Procedures will require monitoring for these gases in confined spaces or basements where these gases may be present prior to employees conducting work in these areas.



LEGEND

- Emergency Exit
- Slab Slope Direction
- Subgrade Sump
- Reverse Osmosis
- Entry Windbreak (Roof, Walls and Concrete Apron)
- Second Level

NOTE: THE IX VESSELS ARE PAIRED AS FOLLOWS:
IX-1 & IX-2
IX-3 & IX-4
IX-5 & IX-6

VERIFY SCALE

SCALE: 1"=8'

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Ludeman Satellite Project
Satellite Plant Layout

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0	Initial Draft	10/12/09	CM
1	Internal Review Comments	10/15/09	CM

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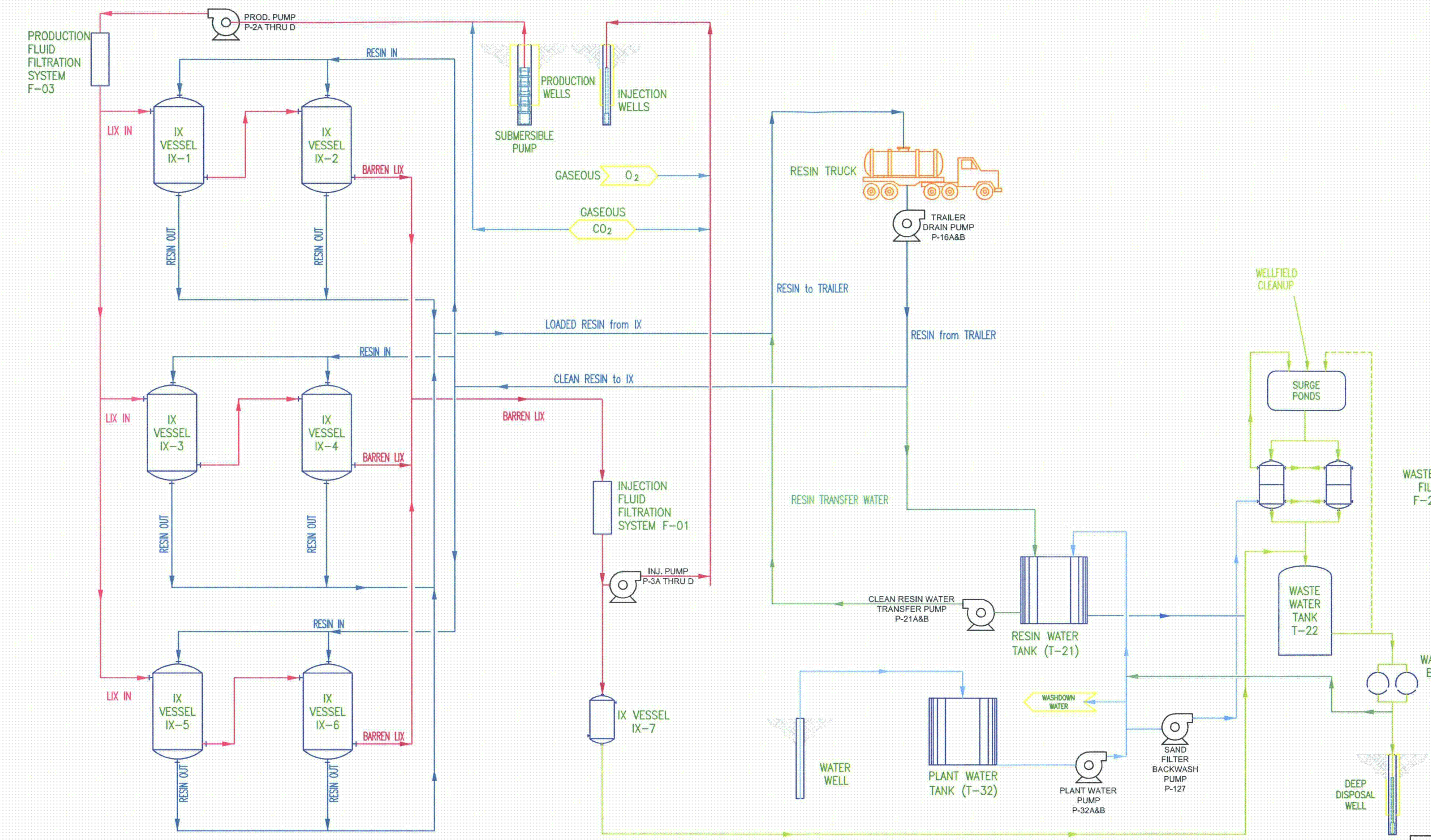
Figure: 3-8



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LUDEMAN PROJECT
SATELLITE PROCESSING
PLANT FLOW DIAGRAM

Date:	By:	Checked:	Approved:

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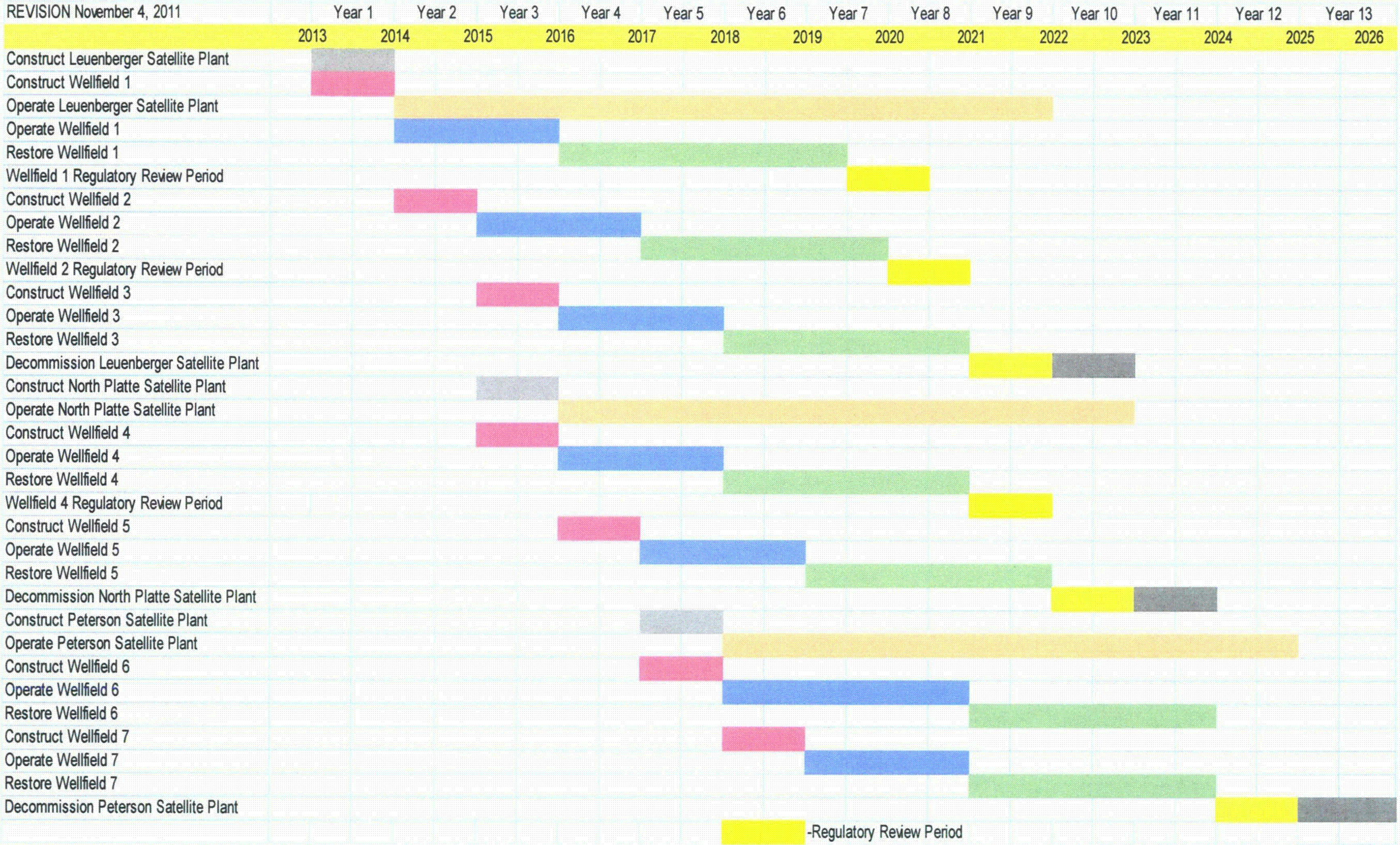
FIGURE: 3-9

3.2.3 Proposed Operating Schedule

Following NRC approval of the amendment of Materials License SUA-1341, construction of the first wellfield and ancillary Satellite facility are planned to begin in the second quarter of 2013. Completion of the first Satellite facility, wellfield and deep disposal well is expected to be completed in the second quarter of 2014 and startup of operations will commence. Construction of subsequent wellfields will follow, approximately one every year. It is anticipated that there will be a seamless transition from production to restoration of wellfields. It is anticipated that depleted wellfields will be inactive for less than 30 days, unless immediately adjacent to another active wellfield, in which case restoration could pull mining solutions into the area of restoration. Development of the three Satellite facilities and associated wellfields will begin in sequential order.

Additional wellfield plans will be developed approximately one year prior to the planned commencement of new mining operations in that wellfield. The layout of the planned wellfields and Satellite facilities are shown in Figure 2.1-1 in Section 2.1of this TR. It is currently anticipated that ISR operations and wellfield restoration will continue for approximately twelve years. At that time, decommissioning of wellfields including well abandonment, removal of related piping and equipment, wellfield building removal, surface soil radiological surveys and reclamation will commence. Projected production and restoration schedules for the proposed project are shown in Figure 3-10.

Figure 3-10: Proposed Project Operations Schedule



3.3 INSTRUMENTATION AND CONTROL

3.3.1 Wellfield Operations/Ion Exchange Circuit

The wellfield and ion exchange circuits operate at steady state conditions, and deviations from the normal operating flow rates and pressure profiles (e.g., 10 percent or greater) are indicative of operating upsets. An automatic emergency shutdown system consisting of pressure and flow rate switches will be provided for these circuits when normal operating parameters are exceeded. Instrumentation and control related to these circuits to accommodate emergency shutdown systems and alarms are listed below:

- Instrumentation will be provided to measure total production and injection flow and pressure on the main trunk lines at the Satellite facilities. Flows and pressures will be monitored continuously and will be displayed locally on the metering instrumentation and displayed at the facility control room. Automatic shutdown and alarms will be provided for deviations outside of established operating parameters; and
- The individual well flows will be adjusted and controlled within the header houses. Manifold pressures inside the header houses will be maintained below the maximum operating pressure. Instrumentation will be provided to measure individual well recovery and injection flow rates, as well as the manifold pressures coming into and going out of the individual header houses. Flows and pressures will be monitored continuously and will be displayed locally in the header house. These values will also be displayed in the facility control room. Total recovery and injection flows will be derived from the sum of the individual flows. Flows will also be continuously monitored to trigger and log an alarm in the event set parameters are exceeded. Wellfield header houses will also be equipped with sensors to detect the presence of liquids in the basement and initiate alarms. Automatic shutoff valves and alarms will be provided for deviations outside of established operating parameters for the systems controlled within the header house.

In the event of an automatic shutdown, an alarm will notify the operator. Once the upset (broken piping, leaking vessels, etc.) is identified and corrective action taken, only then can the circuit be manually restarted. This type of control system provides the best protection against fluid spills to the environment by limiting the amount of fluid released and by providing immediate notification to facility operators and enhancing response to any upset conditions. Backup for the automatic emergency shutdown systems are provided by local displays and controls for the metering instrumentation or header house displays if systems controls or displays in the Satellite facility should become temporarily unavailable.

3.3.2 Process Areas

In the process areas, tank levels are measured in chemical storage tanks as well as process tanks. Instrumentation will be installed to provide continuous monitoring of chemical and process tank levels. Other instrumentation may also be provided in process areas to provide continuous monitoring for rates and pressures of process fluids and chemicals and other in-line instrumentation used for process measurements. Readout from process area instrumentation will be displayed on the facility control room monitors and will be displayed locally on the metering instrumentation providing backup monitoring.

Alarms and automatic shutdown of systems (where needed) will be provided for deviations outside of established operating parameters. The alarms and automatic shutdown systems will provide the best protection against upset conditions of process fluids or chemicals by limiting the amount of fluids or chemicals released and immediate notification to facility operators, enhancing response to any upset conditions. The continuous monitoring will also be used operate the facility process at maximum efficiency.

3.3.3 Process Waste Water Disposal

Process waste water will be disposed of through deep disposal wells as described in Section 4. These wells will be equipped with a high-level shutoff switch on the injection tubing to prevent operation of the pumps at pressures greater than the limiting surface injection pressure. In addition, the wells will be equipped with a low-pressure shutoff switch on the surface injection line that will deactivate the injection pump in the event of a surface leak. Finally, the wells will include a high/low pressure shutoff switch with a pressure sensor on the tubing/casing annulus. This switch will stop the injection pump in the event of either (1) a tubing leak or (2) a casing, packer, or wellhead leak.

This type of instrumentation and control system provides the best protection against process waste water spills to the environment by limiting the amount of fluid released and providing immediate notification to facility operators enhancing response to any upset conditions. Pressure monitoring in the tubing/casing annulus also provides immediate indicators of potential well integrity issues. Backup for the automatic emergency shutdown systems are provided by local displays and controls for the metering instrumentation in the Satellite facilities and at the wellhead if systems controls or displays in the Satellite facility control room should become temporarily unavailable. In addition, inspections of the disposal wells will be conducted once per shift.

If a deep disposal well is to become temporarily unavailable, due to routine maintenance etc., there are surge ponds at each Satellite location to temporarily store the accumulated waste water until the deep disposal well has returned to operation.

3.3.4 Radiological Monitoring Instrumentation

Handheld radiation detection instruments and portable samplers will be used to monitor radiological conditions at the Satellite facilities. Specifications for this equipment are discussed in further detail in Section 5. The location of monitoring points and monitoring frequency for in-facility radiation safety is also discussed in Section 5.

3.3.5 Byproduct Material Disposal

Byproduct material will be collected and stored within the Satellite facilities in appropriate containers (e.g., 55-gallon drums with drum liners). When these containers are full, they will be closed and stored within the Satellite facilities or will be moved to a byproduct storage area and stored in a strong tight container as defined by DOT regulations. The strong tight containers will be capable of preventing the spread of contamination and contact with precipitation. Uranium One plans to use covered roll-off containers with an approximate capacity of 20 cubic yards. Once full, these containers will be shipped for disposal to a licensed disposal facility. During storage, the containers will be located within a restricted area. Access to the byproduct storage facility will be controlled through the use of security fencing, locked gates, and proper posting as a restricted area.

Larger items such as contaminated equipment that cannot be stored in a roll-off container will be stored in the Satellite facilities or covered/sealed in manner that will prevent the spread of contamination in the byproduct storage area.

3.4 ACCESS ROADS CONSTRUCTION AND MAINTENANCE

3.4.1 Main Access Roads

State Highway 95 provides access to the proposed project area from the towns of Glenrock and Rolling Hills to the west and State Highway 93 provides access from Douglas to the southeast. Interstate 25 provides access to both of these state highways from the south of the proposed project area. There will be two access points for the roads to the Satellite facilities and wellfields. The access to the proposed North Platte Satellite facility and Peterson Satellite facility facilities will be located off of Highway 93 in Section 14 (T34N R73W) and Section 9 (T34N R73W). The access to the proposed Leuenberger Satellite facility site will be from Highway 95 in Section 12 (T34N R74W). The access roads will provide the main access to the Satellite facility facilities. Field access roads for wellfield access will fork off of the main access roads. Existing road locations will be used where possible for both the main access roads and the field access roads. Section 2.1 of this Technical Report provides a description of the site and facilities layout for the proposed project. Figure 3-1 shows the proposed project boundaries, facility locations, access roads, and wellfield and mineralized areas.

Design and construction of the main site access roads will be done in accordance with general road construction requirements. The proposed main access roads will be approximately 24 feet wide and will be graded, drained, surfaced, and capable of carrying highway loads. Professional engineering design and construction oversight will be utilized as needed.

Design, field survey, and plans requirements for general road construction include the following.

3.4.1.1 Design Requirements

- Design speed is generally 15 to 50 miles per hour;
- Travelway minimum is 14 feet (single lane) and 24 feet (double lane) with intervisible turnouts, as may be required;
- Recommended minimum horizontal curve radius is 220 feet. Where terrain will not allow 220-foot curve radii, curve widening is necessary;
- Vertical curves should be designed with an appropriate "k" value (rate of vertical curvature length per percent of "A", the algebraic difference in grade) based on design speed;
- Maximum grades should not exceed 8 percent. Pitch grades for lengths not to exceed 300 feet may be allowed to exceed 8 percent in some cases;
- All culverts will be sized in accordance with accepted engineering practices and any special environmental concerns. The minimum size culvert in any installation is 18 inches. Drainage crossings and culverts should be designed for a 25-year or greater storm frequency and allow fish passage in perennial streams where fish are present;
- Turnouts are required on all single-lane roads. Turnouts must be located at 1000-foot intervals or be intervisible, whichever is less. The length should not be less than 100 feet, with additional 50-foot transitional tapers at each end; and
- Surfacing will be required to provide all-weather access. Aggregate size, type, amount, and application method will be specified in road plans.

3.4.2 Field Access Roads

Field access roads will be constructed to access header houses within wellfield areas and other ancillary facilities. Field access roads will be constructed in a manner to provide adequate drainage and utilize best management practices when applicable to minimize the potential for erosion. The top 3 to 6 inches of topsoil (A and E Horizons) will be stripped and stockpiled for the road width and drainage ditches. Field access road surface will be approximately twelve feet wide with drainage ditches cut on each side as needed. Approximately 3 inches of gravel, scoria, or other suitable road base will be applied to the road surface to provide access during all weather conditions. Properly sized culverts will be used for field access roads crossing across small drainages. Efforts will be made to construct field access roads to avoid crossing major drainages. However, if crossing a major drainage is required, then adequately sized culverts will be utilized and embankments will be protected from erosion using adequate best management practices (rip rap, rock, etc.). Culverts across significant drainages will be designed to pass the 25-year peak runoff event using head available at the entrance. The minimum culvert size of 18" will be utilized to divert drainage from roads or for crossing small drainages or swales. Crossings for major drainages will be constructed at or near right angles. Locations of constructed access roads and culverts will also be reported in the annual report. Field access roads will be reclaimed in accordance with the Reclamation Plan in Section 6.

Temporary two-track roads may be developed during facility construction activities. No topsoil will be stripped, road base applied, or drainage structures constructed for these two-track trails and they will be reclaimed once they are no longer in use. Two-track roads may also be utilized during operations to access areas with less frequency including monitor wells and other monitoring locations.

3.4.3 Construction, Drainage, Maintenance

3.4.3.1 Construction

The roads will be designed and constructed to allow for successful interim and eventual final reclamation. Revegetation of road ditches and cut and fill slopes will help stabilize exposed soils and reduce sediment loss, reduce the growth of noxious weeds, reduce maintenance costs, maintain scenic quality and forage, and protect habitat. To ensure successful growth of facilities and forbs, topsoil must be salvaged where available during road construction and re-spread to the greatest degree practical on cut slopes, fill slopes, and borrow ditches prior to seeding. To ensure the stability of freshly topsoiled slopes during revegetation, the application of mulch or other sediment control measures may be appropriate.

Construction with saturated or frozen soils results in unstable roads and will be avoided. Vehicular travel under wet conditions can produce significant rutting of unsurfaced roads resulting in soil loss and safety concerns. Therefore, excessive use of unsurfaced roads will be avoided to the extent possible during saturated soil conditions.

3.4.3.2 Road Drainage Design

The proper design and construction of structures for the drainage of water from or through the roadway often contributes the most to the long-term success of the structure and minimizes the maintenance and adverse environmental effects, such as erosion and sediment production.

The most economical control measure will be designed to meet resource and road management objectives and constraints. The economic considerations will include construction and maintenance costs. The need for drainage structures can be minimized by proper road location. However, adequate drainage is essential for a stable road. A proper drainage system will be the best combination of various design elements, such as ditches, culverts, drainage, dips, crown, in-slope or out-slope, low-water crossings, subsurface drains, and bridges.

3.4.3.2.1 Surface Drainage

Surface drainage provides for the interception, collection, and removal of water from the surface of roads and slope areas. The design may need to allow for debris passage, mud flows, and water heavily laden with silt, sand, and gravel.

3.4.3.2.2 Drainage Structures

Proper location and design can provide economical and efficient drainage in many cases. However, structural measures are often required to ensure proper and adequate drainage. Some of the most common structures are drainage dips, ditches, culverts, and bridges.

<u>Drainage Dips</u> - The primary purpose of a drainage dip is to intercept and remove surface water from the traveled way and shoulders before the combination of water volume and velocity begins to erode the surface materials. Drainage dips should not be confused with water bars which are normally used for drainage and erosion protection of closed or blocked roads. Spacing of drainage dips depends upon local conditions such as soil material, grade, and topography.
<u>Ditches</u> - The geometric design of ditches must consider there source objectives for soil, water, and visual quality, maintenance capabilities and associated costs, and construction

costs. Ditch grades should be no less than 0.5 percent to provide positive drainage and to avoid siltation. The types of ditches normally used are: drainage, trap, interception, and outlet.

Road Crowning - Roads which use crowning and ditching are common and can be used with all road classes. This design provides good drainage of water from the surface of the road. Drainage of the inside ditch and side hill runoff is essential if the traveled way is to be kept dry and passable during wet weather. Snow removal becomes a simple task for common road maintenance equipment. Because the roadbed is raised, wind often blows the snow off the travel way.

Culverts - Culverts are used in two applications on access roads; (1) in streams and gullies crossed by an access to allow normal drainage to flow under the traveled way, and (2) to drain inside road ditches. The latter may not be required if drainage dips are used. All culverts should be laid on natural ground or at the original elevation of any drainage crossed. Culverts should be placed on a three percent minimum grade; reverse camber is not allowed.

Uranium One is planning to build six culverts for road construction based on a 10-year storm occurrence. The Leuenberger facility site will have one 18-inch culvert to prevent ponding near the access road. The North Platte Site will have one 24-inch culvert for its south access road. The Peterson Site access road will have two separate 18-inch culverts to prevent ponding in section 15, a 36-inch culvert in section 22 and two 36-inch culverts side by side in section 22. If additional culverts are needed to prevent shallow ponding 18-inch culverts will be used. The culvert locations are shown on Figure 2.1-1 of this TR.

The outlet of all culverts will extend at least one foot beyond the toe of any slope. All culverts used in construction of access roads will be concrete or corrugated metal pipe (CMP) made of steel or aluminum. Only undamaged culverts will be used, and any culvert will be inspected for damage prior to installation. All spots on the pipes where the zinc coating has been injured should be painted with two coats of zinc-rich paint or otherwise repaired. Excavation, bedding and backfilling of culverts will be conducted according to standard engineering practices.

Ditch Relief Culverts - Ditch relief culverts are installed to periodically relieve the ditch line flow by piping water to the opposite side of the road where the flow can be dispersed away from the roadway. The spacing of ditch relief culverts is dependent on the road gradient, topography, soil types, and runoff characteristics. A culvert with an 18-inch diameter is the minimum size to be used for ditch relief to prevent failure from debris blockage. The depth of culvert burial must be sufficient to ensure protection of the culvert barrel for the design life of the culvert given anticipated road and traffic conditions. This requires anticipating the amount of material that may be lost due to road use and erosion. Ditch relief culverts can provide better flow when skewed 15 to 30 degrees downgrade from a line perpendicular to the centerline of the road. This improves the flow hydraulics and reduces siltation and debris plugging the culvert inlet. Culverts placed in natural drainages can also be utilized for ditch relief. The design of culverts for later removal may be beneficial for intermittent use roads that will be closed for extended periods of time.

Bridges and Major Culverts - Uranium One does not anticipate any multiple culvert or bridge installations will be needed for constructed access roads. If needed, they will be designed and installed in accordance with appropriate Converse County requirements.

Low-Water Crossings – Where roads cross small drainages and intermittent streams, culverts and bridges are often unnecessary. The crossing can be effectively accomplished by dipping the road down to the bed of the drainage. Material moved from the banks of the crossing should be stockpiled near the right-of-way. Gravel, riprap, or concrete bottoms may be required in some situations. In no case will the drainage be filled during road construction or maintenance so that water will be impounded.

3.4.3.3 Road Maintenance

Uranium One will carry out maintenance activities on all main and field access roads as necessary. The activities normally required include blading, surface replacement, dust abatement, spot repairs, slide removal, ditch cleaning, culvert cleaning, brush removal, litter cleanup, weed control, and snow removal.

3.5 REFERENCES

Center for Nuclear Waste Regulatory Analyses, NUREG/CR–6733, *A Baseline Risk-Informed, Performance-Based Approach for In Situ Leach Uranium Extraction Licenses*, 2001.

National Fire Protection Association, NFPA-50, *Standard for Bulk Oxygen Systems at Consumer Sites*, (NFPA, 1996)

Compressed Gas Association, CGA G-4.1, *Cleaning Equipment for Oxygen Service*, (CGA, 2000)\

Compressed Gas Association, CGA G-4.1, *Cleaning Equipment for Oxygen Service*, (CGA, 2000)

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4.0 EFFLUENT CONTROL SYSTEMS

This section describes the effluent control systems to be used at the proposed Ludeman Project (proposed project). The effluents of concern at ISR operations include the release or potential release of radon gas (radon-222), solid and liquid waste. The proposed monitoring and control systems have been located to optimize their intended function and are appropriate for the types of effluent generated during ISR construction, operation aquifer restoration and decommissioning. SOPs and spill prevention plans will address contingencies for all reasonably expected system failures and include appropriate personnel to be notified, measures to efficiently detect and mitigate a release to the environment.

4.1 GASEOUS AND AIRBORNE PARTICULATES

4.1.1 Non-Radioactive Emissions and Control Measures

Fugitive dust will be generated during all phases of the proposed project from activities such as transport vehicles traveling on unpaved roads and disturbance of soil materials by heavy equipment. Uranium One will mitigate fugitive dust emissions with the use of selection of road surface materials that will minimize dust, prompt revegetation of disturbed areas, and speed limits.

Emissions from internal combustion engines will be the primary source of non-radioactive gaseous effluent. Minimal releases from drilling rigs, drilling support equipment, employee and supply transport vehicles, and wellfield utility trucks. These emissions will likely include SO_2, CO, CO_2, NO_x, and PM_{10} and total hydrocarbon.

Potential emissions from process chemicals that will be used at the facilities are described in Section 7.

4.1.2 Radioactive Gaseous Emissions and Control Measures

The primary radioactive airborne effluent at the proposed project will be radon-222 gas. Radon-222 is found in the pregnant lixiviant that comes from the wellfield into the.Satellite Facility. The uranium is separated from the groundwater by passing the solution through fixed bed ion exchange columns operated in a pressurized downflow mode. NUREG-1910 (NRC, 2009) in Section 2.7.1 notes that pressurized ion exchange systems contain most of the radon gas present in the lixiviant and therefore it is retained within piping and is not normally released. In these systems, radon-222 may be released during venting and resin transfer operations. The alternative to pressurized downflow ion exchange columns typically employed for ISR recovery is upflow non-pressurized ion exchange columns. These columns release a significant amount of the radon-222 present in the lixiviant. The use of pressurized downflow ion exchange columns at at the Satellite facilities will reduce the radon-222 emissions relative to other available ion exchange technologies and represents an emission control method that reduces emissions to levels that are as low as reasonably achievable and complies with the requirements of 10 CFR Part 40, Appendix A, Criterion 8. Further, the use of these ion exchange systems coupled with tank and area ventilation systems ensures that worker exposure to radon-222 and its progeny is maintained As Low As Reasonably Achievable (ALARA) through the use of engineering controls.

Vessel vents from the individual ion exchange vessels will be directed to a manifold that is exhausted to atmosphere. Venting any released radon-222 gas to atmosphere outside the Satellite facility will minimize employee exposure. Small amounts of radon-222 may be released via solution spills, filter changes, ion exchange resin transfer, from the reverse osmosis (RO) system operation during groundwater restoration, and from maintenance activities. These situations result in minimal radon-222 releases on an infrequent basis. Routine monitoring of radon daughters within the Satellite facilities will identify exposure levels and initiate corrective actions, if necessary, to ensure exposures of workers are maintained ALARA. A more detailed discussion can be found in Section 5 of this TR.

This section describes the gaseous effluent control systems that will be installed in the proposed project facilities.

4.1.2.1 Gaseous Effluents-Tank and Process Vessel, and Work Area Ventilation Systems

A separate ventilation system will be installed for the ion exchange vessels or other vessels where radon-222 or process fumes would be expected. The system will consist of an air duct or piping system connected to the top of each of the vessel. The venting system from all tanks and sumps consists of four- to six-inch polyvinyl chloride (PVC) piping and function to vent radon-222 to the outside atmosphere. The design of the ventilation system will ensure that the system will be capable of limiting employee exposures with the failure of any single fan. Discharge stacks will be located away from building ventilation intakes to prevent introducing exhausted radon-222 into the facility as recommended in Regulatory Guide 8.31 (USNRC, 2002). Airflow through any openings in the vessels will be from the process area into the vessel and into the ventilation system, controlling any releases that occur inside the vessel. Separate ventilation systems may be used as needed for the functional areas within the Satellite facilities. Tank ventilation systems of this type have been successfully utilized at other

ISR facilities and have proven to be an effective method for minimizing employee exposure.
The work area ventilation systems will be designed to force air to circulate within the Satellite facilities. The ventilation system exhausts will be located on the leeward side of the buildings and will exhaust outside the building, drawing fresh air in from the upwind side of the building. During favorable weather conditions the exhaust fans will be turned off, open doorways and convection vents in the roof will provide satisfactory work area ventilation. The design of the ventilation system will be adequate to ensure that radon daughter concentrations in the facility are maintained below 25 percent of the derived air concentration (DAC) from 10 CFR Part 20 as follows:

- For the Satellite facilities, a minimum of two exhaust fans will operate at a minimum rate of 10,000 cubic feet per minute (cfm), at zero inches of water, each. Increased operation of these systems will provide adequate ventilation during unfavorable weather conditions. The system will have a design rate of three air exchanges per hour with a redundant system as a backup of three air exchanges per hour.

Radon-222 effluent monitoring will be conducted in the Satellite facilities as described in Section 5.7.7.

Minute amounts of radon-222 may be released outside of the Satellite facilities from the wellheads, header houses, and surge ponds. At the wellheads and surge ponds, radon-222 will be released directly to the atmosphere where it will rapidly disperse. Wellhead enclosures may be vented to reduce radon buildup which could otherwise expose wellfield personnel during inspection and maintenance activities. Header houses will have ventilation systems consisting of a roof- or wall-mounted fan as well as a separate radon-222 ventilation system with an intake located in the header house sump and exhaust point on the building roof.

Radon-222 that is discharged from the proposed Ludeman facilities will quickly disperse into the atmosphere, Although, Uranium One will conduct surveys for radon daughter concentrations in the operating areas of the Satellite facilities on a monthly basis as discussed in Section 5.7.3.2 of this TR.

Additionally, environmental release and their potential impact to the public has been modeled using the MILDOS-Area computer model. Results of the model are presented in Appendix C of this report.

4.1.3 Air Particulate Effluents

The proposed project consists of only wellfield and ion exchange operations, and no yellowcake processing occurs where airborne particles could be present. There is no potential hazard for air particulate effluents at the proposed Ludeman Project site.

4.1.4 Reporting Effluent Releases

10 CFR §40.65 requires licensees to submit a semiannual environmental and effluent report to the NRC. The report must specify the quantity of each of the principal radionuclides released to unrestricted areas in liquid and in gaseous effluents during the previous six months of operation.

The predominant radionuclide released to unrestricted areas from the proposed project will be airborne releases of radon-222 from non-point sources such as well fields and the Satellite facilities. Radon-222 releases in the wellfields will occur from material contained in mud pits during drilling, sample collection in header houses, and from wellhead venting activities. Radon-222 releases from the Satellite facilities will occur through tank ventilation systems during venting and backwashing operations and from the normal building ventilation system, which will exhaust building air at various points in the structure.

Table 4-1: Operational Parameters Used to Estimate Semiannual Radon-222 Emissions

Parameter	Projected Value	Unit
Mined Area	Determined based on actual mined area for reporting period	$m^2\ y^{-1}$
Average Lixiviant Flow	Determined based on actual lixiviant flow for the reporting period	$L\ m^{-1}$
Average Restoration Flow	Determined based on actual restoration flow for the reporting period	$L\ m^{-1}$
Operating days per year	Determined based on actual operating days for the reporting period	days
Number of mud pits generated per year	Determined based on actual number of mud pits generated for the reporting period	NA
Storage time in mud pits	Determined based on actual storage time for the reporting period	days
Number of Resin Transfers per day	Determined based on actual number of resin transfers for the reporting period	NA

Parameters listed in Table 7-4 of the Technical Report which are not included in Table 4-1 above and for which site specific parameters have not been measured are listed in Table 4-2. In these cases, default or typical parameters as described in Regulatory Guide 3.59 will be used.

Table 4-2: Default Based Parameters Used to Estimate Radon-222 Releases

Parameter	Value	Unit	Source
Ore radium-226 Concentration	282	$pCi\ g^{-1}$	Reg. Guide 3.59
Radon-222 emanating power	0.2	NA	Reg. Guide 3.59

The radium-226 concentration in ore assumes that radium-226 is in secular equilibrium with the average uranium-238 concentration for the proposed project listed in Table 7.3-1, which is consistent with the assumptions used in Regulatory Guide 3.59.

The radon-222 emanating power for the ore has not been measured. Table 8.1 of "Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil" (USDOE, 1993) presents a range of radon-222 emanating power for crushed uranium ore of 0.006 to 0.55 with an arithmetic mean of 0.28. Regulatory Guide 3.59 states to use a radon-222 emanating power of 0.2 when this parameter has not been measured. The use of 0.2 for radon-222 emanating power is consistent with methods described in Regulatory Guide 3.59 and is within the range of typical values for uranium ore.

4.2 WASTE MANAGEMENT

This section describes the proposed waste management system. Liquid and solid wastes are divided into two general categories: 11e.(2) waste and non-11e.(2) waste. The proposed waste management system is summarized below for each category of waste.

4.2.1 11e.(2) Liquid Waste

4.2.1.1 Brine

Brine will be generated from RO treatment of the production bleed and from RO treatment of the groundwater restoration water. Brine will be routed from the production and restoration RO units in the Satellite facilities to a wastewater collection system. RO brine will be discharged into the surge ponds or waste water tank for storage and eventual disposal in the deep disposal wells.

4.2.1.2 Excess Permeate

Permeate will also be generated from the treatment of both the process bleed and groundwater from aquifer restoration. Excess permeate which is not recycled back to operation or restoration activities will be used as plant makeup water. Permeate will be high quality water and will generally be put to beneficial use.

4.2.1.3 Other 11e.(2) Liquid Waste

Other 11e.(2) liquid wastes include spent eluate, resin transfer wash water, plant wash-down water, and fluids generated from wellfield release. Liquid wastes generated in the Satellite facilities will be discharged to the wastewater disposal system while water collected from wellfields will be collected in dedicated portable tanks or tanker trucks and transported to the wastewater disposal system. Any water captured from leaking pipelines or equipment will also be transported to the wastewater disposal system in dedicated portable tanks or tanker trucks.

These liquid wastes will be combined with brine and disposed of through the deep disposal well. The anticipated water chemistry of the waste stream that will be disposed of in the deep disposal well is presented in Table 4-3.

Table 4-1: Summary of Anticipated Waste Stream Water Quality

Chemical Parameter	Estimated Range Waste Stream Water Quality	
	Minimum (mg/L)	Maximum (mg/L)
pH	6	9
Sodium	150	3,000
Calcium	200	1,000
Potassium	10	1,000
Bicarbonate as HCO_3	1,500	4,000
Carbonate as CO_3	0	500
Sulfate	80	2,000
Chloride	200	4,000
Uranium as Unat	1	15
^{226}Radium (in pCi/L)	300	3,000
Total Dissolved	2500	15,000

4.2.2 Non 11e.(2) Liquid Waste

4.2.2.1 Stormwater Runoff

Stormwater management is controlled under National Pollutant Discharge Elimination System (NPDES) permits issued by the WDEQ-WQD. As part of the permit, a storm water pollution plan (SWPPP) will be prepared describing best management practices (BMPs) used to keep pollutants out of surface waters and storm drains. Facility drainage will be designed to route storm runoff water away from or around the Satellite facility, ancillary buildings and parking areas, and chemical storage. The design and controls of the proposed project facilities will be implemented such that runoff is not considered to be a potential source of pollution.

4.2.2.2 Domestic Liquid Waste

Domestic liquid wastes from the restrooms and lunchrooms will be disposed of in a septic system that meets the requirements of the WYDEQ-WQD and will likely include one or more septic tanks for primary treatment. Septic tank effluent will be disposed of in a gravity or pressure-dosed drain field. The septic system will be separate from other liquid waste lines to prevent 11e.(2) byproduct material discharge into the septic fluid. These systems are in common use throughout the United States and the effect of the system on the environment is known to be minimal.

4.2.2.3 Waste Petroleum Products and Chemicals

At the proposed project, small quantities of used oil will be generated from equipment and vehicles used on-site. The waste petroleum products will be temporarily stored on-site before being transported to a nearby recycling or disposal facility. These wastes will not have been affiliated with the processing or generation of 11e.(2) byproduct material and will not be classified as AEA-regulated waste.

Waste petroleum product fluids will be stored in an aboveground storage tank located in the maintenance shop. The storage tank will be cylindrical and constructed of steel with a locking cap and venting system. Secondary containment will be designed to contain 110 percent of the tank volume. Spills of waste petroleum will be contained, mitigated, cleaned up, and reported in accordance with WDEQ requirements.

The proposed project is anticipated to be classified as a conditionally exempt small quantity generator (CESQG) by WDEQ/SHWD. As such, the project will be required to generate less than 220 pounds (100 kg) of hazardous waste in any calendar month, generate less than 2.2 pounds (1 kg) of acutely hazardous waste, and store less than 2,200 pounds (1,000 kg) of hazardous waste at any one time.

4.2.3 Solid 11e.(2) Byproduct Material

All contaminated items that cannot be decontaminated to meet release criteria will be properly packaged, transported, and disposed of off-site at a licensed to 11e.(2) byproduct material disposal facility. Solid wastes generated by the proposed project that may become contaminated with radioactive isotopes consist of items such as rags, trash, packing material, worn or replaced parts from equipment, piping, filters, protective clothing, and solids removed from process pumps and vessels. Radioactive solid waste which has a contamination level precluding decontamination will be isolated in drums or equivalent DOT approved containers. Uranium One estimates that the proposed project will produce approximately 250 yd^3 of solid 11e.(2) byproduct material per year during operation. These materials will be stored on site inside the security controlled area until such time that a full shipment can be shipped to a waste disposal site or mill tailings facility licensed to accept 11e.(2) byproduct materials.

This 11e.(2) byproduct material will be collected and stored within the proposed project Satellite facilities in appropriate containers (e.g., 55 gallon drums with drum liners) approved by DOT, and will be appropriately labeled and placarded for the class of material being shipped. When these containers are full, they will be closed, sealed and stored within the byproduct storage area and stored in a strong, tight container as defined by DOT regulations. The strong, tight containers will be capable of preventing the spread of contamination and contact with precipitation. The proposed project plans to use covered roll-off containers with an approximate capacity of 15-30 cubic yards. Once full, these containers will be shipped for disposal to a byproduct licensed disposal facility. During storage, the containers will be located within a designated security controlled area. Access to the byproduct storage facility will be controlled through the use of security fencing, locked gates, and proper posting as a security controlled area.

Larger items such as contaminated equipment that cannot be stored in a roll-off container will be stored in the proposed project Satellite facilities or covered/sealed in manner that will prevent the spread of contamination in the byproduct storage area.

SUA-1341 currently has an agreement with Pathfinder Mine Corporation Shirley Basin Facility which will be modified to include shipment of 11e.(2) byproduct materials from the proposed Ludeman Project facilities.

4.2.4 Non-11e.(2) Solid Waste

4.2.4.1 Uncontaminated Solid Waste

Uranium One estimates that the proposed project will produce approximately 2,000 yd^3 of uncontaminated solid waste per year. Uncontaminated solid waste will be collected on the site on a regular basis and disposed of in the nearest approved sanitary landfill, compliant with the rules and regulations of WDEQ-SHWD.

4.2.4.2 Septic System Solid Waste

Domestic liquid wastes from the restrooms and lunchrooms will be disposed of in an approved septic system that meets the requirements of the WDEQ for Class V UIC wells. Occasionally, it will be necessary to dispose of sludge material collected in septic systems holding tanks. The disposal of these sludge materials must be performed in accordance with WDEQ-SHWD rules and regulations.

4.2.4.3 Hazardous Waste

Hazardous wastes are defined by WDEQ-SHWD's Hazardous Waste Management Chapter 2 or by USEPA in 40CFR Part 261. Generated materials defined by these regulations as hazardous waste will be consolidated in appropriate containers upon generation and shipped off-site for disposal at a facility licensed for the acceptance of hazardous wastes. Wastes that may be generated at the proposed project that may be classified as hazardous wastes include solvent rags, expired laboratory reagents, solvents, cleaners, or degreasers. It is also expected that the proposed project facilities will generate Universal Wastes such as batteries, fluorescent light bulbs and used oil.

It is anticipated that the proposed project facilities will be classified by WDEQ-SHWD as a Conditionally Exempt Small Quantity Generator (CESQG). As such, the project will be required to generate less than 220 pounds (100 kg) of hazardous waste in any calendar month, generate less than 2.2 pounds (1 kg) of acutely hazardous waste, and store less than 2,200 pounds (1,000 kg) of hazardous waste at any one time. This classification as a CESQG does not relieve Uranium One from complying with CESQG regulations and those requirements to dispose of classified hazardous wastes at a properly licensed hazardous waste facility. Uranium One will comply with the EPA and WDEQ-SHWD CESQG requirements and monitor the generation of hazardous waste to ensure compliance with the weight generation rules of those regulations.

4.2.4.4 Deep Disposal Well Permitting

The Wyoming DEQ is in the process of reviewing how it will implement the UIC regulations related to ISR operations, the permitting path for deep disposal wells is not entirely clear at this time. However, it is clear that an approach similar to that used by other ISR operations in the Powder River Basin is warranted. In this regard, Uranium One anticipates submittal of a Class I injection well permit during the second quarter of 2010. The target zones will be the Lance Formation through the Parkman Formation (depths ranging from 4,500 to 10,000 feet).

The Lance Formation has a total thickness in the area of approximately 2,500 feet. The Lance Formation includes approximately 900 feet of net sand with porosity greater than 8 percent and an average permeability of about 12 millidarcies. Individual sandstone lenses within the Lance Formation commonly have porosities around 20 percent. The Teckla-Parkman section in the area of the proposed project has a total thickness of about 2,000 feet. The section has on the order of 340 feet of net sand above 8 percent porosity with a permeability of approximately 3 millidarcies. Individual sands within the Teckla-Parkman seldom exceed porosity of 12 percent. Based on superior porosity-thickness, the primary target of Class I wells at the proposed project will be the Lance Formation.

The proposed project wastewater disposal requirements are expected to vary from 100 to 300 gpm, the total number of deep injection wells required may also vary from the proposed six wells, depending on whether injection to the Lance formation is approved. If the Lance formation is not approved for liquid waste disposal additional deep wells may be necessary in the Teckla-Parkman formation.

Although water quality in the Lance Formation is not anticipated to exceed TDS levels of 10,000 mg/l, it is likely that this unit will contain elevated concentrations of various constituents that exceed Wyoming Class I, II or III groundwater standards, such as TDS, chloride, ammonia, trace metals, organic compounds, or oil and grease. The Lance Formation is an established oil and gas producing section in the Powder River Basin. Additionally, the depth of this unit makes it unlikely to ever be a source of drinking water supply.

Data from wells in the area indicate that the Teckla Parkman water quality either exceeds the TDS level of 10,000 mg/l or contains levels of BTEX compounds that exceed drinking water standards. Oil and gas production occurs throughout the region in the Teckla-Parkman section and in deeper geologic units.

Uranium One believes that permanent deep disposal is preferable to evaporation in evaporation ponds or land application methods for the following reasons: (1) Liquid waste disposed through deep wells is secluded from human contact eliminating risk to human health; (2) large evaporation ponds have the potential for leaks and impacts to the environment and much larger volume of 11(e)(2) byproduct is created through use of evaporation ponds; (3) land application methods have the potential to impact surface media from prolonged discharge and would require extensive treatment to meet land application standards. All compatible liquid wastes at the proposed Satellite facilities will be disposed in the planned deep wells. Further discussion of the liquid waste disposal alternatives considered by Uranium One is contained in Section 8.3 of this TR.

4.2.4.5 Surge Ponds

Two surge ponds are planned as part of the waste storage infrastructure for the proposed Satellite facilities. The primary purpose of surge ponds is to manage permeate and brine inflows to optimize disposal techniques and provide for waste storage in the event of upset conditions. Lined retention ponds will be designed to meet the requirements of both NRC Regulatory Guide 3.11 for embankment retention systems and WQD Rules and Regulations, Chapter 11, for lined wastewater storage ponds. It should be noted that the NRC guidance and regulations were intended for tailings impoundments and some of the requirements for tailing ponds do not apply to the design of the surge ponds.

Details of preliminary pond designs are provided in Addendum 4-A of this TR. At the time of this application, a inclusive surge pond design has not been completed. Pond locations have been chosen for each Satellite site but geotechnical work is required to confirm the suitability of these locations and will be completed as the licensing process progresses. The information provided in Addendum 4-A provides a preliminary design based on the surge pond design plan for the Moore Ranch Project.

4.2.4.5.1 Pond Liner and Leak Detection Systems

Surge pond liners and leak detection systems will meet the requirements of Regulatory Guide 3.11. Each pond will be equipped with an impermeable chemically compatabile liner which will likely be high density polyethylene (HDPE) or polypropylene (PP) primary liner with a minimum thickness of 36 mils (0.036 inch). HDPE and PP liners are generally very resistant to chemicals and alkaline and acid agents, with the exception of oxidizing acids, and salt solutions (Renken et al 2005). Site preparation and liner installation will be in accordance with manufacturer's specifications.

The leak detection system will consist of a permeable drainage layer and a collection piping system. The permeable drainage layer will be located directly under the primary liner. This layer will provide support for the overlying liner, and will also transmit any leakage to collection pipes. The drainage layer will be constructed of suitable transport media (i.e. sand). Geocomposite fabric will be used on the side slopes to allow movement of the leakage to the collection pipes. The pond bottom will be sloped from the center outward. The perforated pipes will be installed along the same slope as the pond floors and will drain to riser pipes located in the embankment. The presence of liquid in these riser pipes will be detected during routine inspections to be followed by sampling for water quality to confirm a leak is the cause of the moisture. Water quality analysis will include electrical conductivity and other major ions required to evaluate and mitigate a liner integrity issue. A cross section of the ponds leak detection system is shown in Sheet 2 of Addendum 4-A.

Beneath the surge pond leak detection system will be a secondary geosynthetic liner, with a minimum thickness of 36 mils (0.036 inch). The liner will be installed on top of the underlying foundation material and will function to contain potential leakage. Geotechnical investigations of the underlying foundation material it may indicate that conditions favor installation of natural clay liner instead of the geosynthetic liner. This determination will be made after falling head permeability tests are conducted on bulk soil samples of the foundation material. If the permeability of foundation material is a minimum of two orders of magnitude less than either the graded sand or geocomposite drainage materials that make up the leak detection system, the permeability contrast ensures that any leakage through the primary synthetic liner will be detected before saturation of the foundation materials could occur. If the foundation materials do not have the required permeability, bentonite may be mixed with the foundation material to decrease its permeability. Use of a natural clay or soil-bentonite secondary liner is preferred over the use of synthetic materials due to the self-healing properties of these liners and the proximity of the proposed project to bentonite supplies.

The use of sand and geocomposite drainage material beneath the primary synthetic liner eliminates the need for air vents beneath the liner since gases produced under the liner would be vented through the sand and geocomposite drainage material.

4.2.4.5.2 Surge Pond Inspection Plan

The surge pond inspection plan is based on the routine weekly inspections currently required in SUA-1341 for the Willow Creek evaporation ponds. Weekly inspections will consist of checking the pond depth and visually inspecting the pond embankments for slumping, movement, or seepage. The pond depth measurements will be checked against the freeboard requirements. The liner system will be visually inspected to identify any damage. The perimeter game-proof fence, restricted area signs, and pond inlet piping will be checked.

Inspections under the NRC implementation of the National Dam Safety Program and its associated guidelines will not be required since the surge pond embankments will not be twenty-five feet or more in height and the surge pond impounding capacity will not exceed fifty acre-feet.

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