9.0 GROUNDWATER CHARACTERIZATION ACTIVITIES

9.1 Actinide Migration

9.1.1 Introduction

During CY 2001, work continued on the Actinide Migration Evaluation (AME) pathway analysis with the evaluation and interpretation of data from actinide transport pathways (air, biological, surface water, and groundwater) at RFETS. In April 2002, two final documents were issued: the Actinide Migration Evaluation Pathway Analysis Summary Report (K-H, 2002a) and the Actinide Migration Evaluation Pathway Analysis Report Technical Appendix (K-H, 2002b). This section summarizes the portion of the AME project that pertains to the groundwater transport pathway.

9.1.2 Background

The effects of the potential for the migration of plutonium and americium from surface soils to groundwater have been considered by DOE, the K-H Team, and the AME group in the long-term remedial strategy for Site closure. Existing data on actinide migration at RFETS was summarized for the development of a conceptual model designed to gain an understanding of active actinide transport pathways at the Site (DOE, 1997a). Over 30 monitoring wells at RFETS have had groundwater Pu-239/240 and Am-241 activity-concentrations that exceeded RFCA Tier II action levels (0.15 pCi/L and 0.145 pCi/L, respectively) for these contaminants (DOE, 1997a). Groundwater interactions with surface water at RFETS are inevitable as virtually all shallow groundwater flows toward the major drainages and is eventually discharged to surface water via seeps, streams, and reservoirs. Consequently, groundwater was characterized as representing a potential long-term threat to surface water based on a preliminary review of the available data.

The presence of Pu-239/240 and Am-241 in groundwater samples at RFETS has been the subject of much speculation and study (EG&G, 1995e; CDPHE, 1996; DOE, 1997a; Harnish et al, 1994 and 1996; and Litaor et al, 1996). These contaminants are usually considered to be relatively immobile in the soil and groundwater environment because of their low aqueous solubility and tendency to strongly sorb on soil media (Cleveland et al, 1976; and Honeyman and Santschi, 1997). Most wells with exceedances of these actinides are located near potential source areas, such as the 903 Pad, but some are located at great distances from sources, including monitoring wells located at the east Site boundary along Walnut Creek. Colloid facilitated transport of radionuclides in groundwater has been reported in the literature as being a potentially important mechanism for radionuclide mobility in the subsurface. Alternatively, it has been speculated that well completion zones may have been cross contaminated when drilling through radionuclide bearing surface soils or sediments found near source areas. In addition, sample handling in the field and laboratory contamination have been raised as possible mechanisms of cross contamination.

Because a significant disparity exists between observed versus expected Pu-239/240 and Am-241 groundwater contaminant distributions, further evaluation of historical groundwater Pu-239/240 and Am-241 data and potential transport pathways was undertaken in 1998 to assess the significance of groundwater action level exceedances reported for RFETS monitoring wells (RMRS, 1998f). This analysis concluded that much, if not all, of the Pu-239/240 and Am-241 contamination detected in groundwater probably occurs from residual surface soil contamination introduced to the borehole during drilling and well installation operations (drilling-artifact contamination). Groundwater samples collected from these wells using historical RFETS sampling techniques (i.e., bailing) have the unavoidable effect of suspending contaminated drilling-artifact soil materials, thus creating artificially high contaminant levels. Under these circumstances, existing groundwater sampling results are unreliable indicators of groundwater contaminant concentration and transport.

Well drilling and installation using special surface isolation casing (aseptic) techniques offer a means to minimize drilling-artifact contamination as a source for Pu-239/240 and Am-241 detections in groundwater samples. When paired with existing monitoring wells containing Pu-239/240 and Am-241 contamination, monitoring wells installed with aseptic surface casing techniques can 1) provide a basis for assessing the effects, if any, of drilling-artifact contamination on groundwater sample quality, and 2) allow for the collection of groundwater samples that more accurately represent contaminant concentrations and transport conditions. Aseptic monitoring wells were installed in 1994 to evaluate elevated Pu-239/240 and Am-241 activity-concentrations in the lower Walnut Creek drainage and to upgrade boundary monitoring well integrity in other RFETS drainages (EG&G, 1995e). No Pu-239/240 and Am-241 contamination above Tier II groundwater action levels was detected in any of the wells installed under this program. Until 1999, monitoring wells installed with aseptic surface casing techniques were not paired with existing monitoring wells to validate or invalidate radionuclide detections found in the original well.

Four monitoring well locations (50099, 50199, 50299, and 50399) were chosen to evaluate actinide groundwater quality associated with Pu-239/240 and Am-241 surface soil contamination areas. These locations are adjacent to existing wells 1587, 06991, 11791, and P313489, respectively, all of which have a history of elevated groundwater Pu-239/240 and Am-241 activity-concentrations. Three of these wells (1587, 06991, and 11791) are associated with wind-blown soil contamination from the 903 Pad and Lip Area. The fourth well is associated with surface soil contamination in the IHSS 160 area (Building 444 parking lot). A detailed description of drilling techniques, well installation activities, and sampling results can be found in the 2000 Annual RFCA Groundwater Monitoring Report (SSOC, 2001a) and additional details on project approach and sampling strategy and methodology were presented in the Actinide Drilling-Artifact Contamination Project Sampling and Analysis Plan (RMRS, 1999c).

9.1.3 Methodology for Quantifying Actinide Transport

Calculating actinide quantities transported offsite each year in shallow groundwater requires quantifying 1) the volume of shallow groundwater flowing offsite, and 2) the concentrations of different actinides in the shallow

groundwater. The volume of shallow groundwater flowing offsite, or shallow groundwater flux, was calculated using the Site-wide Water Balance (see Section 9.2) model that utilizes the "MIKE SHE" computer code. This hydrologic model simulates all of the significant integrated hydrologic flow processes including overland flow, channel flow, and subsurface flow in the saturated and vadose zones. Lateral offsite shallow groundwater flow was computed for saturated conditions within the unconsolidated alluvial and weathered bedrock lithologies. For actinide transport analysis, offsite shallow groundwater flux volumes were estimated for water year 2000 (October 1999 through September 2000) for the Walnut Creek and Woman Creek groundwater basins. In addition to using model results for a normal precipitation year, shallow groundwater flux was estimated using precipitation data from the first half of 1995 when approximately twice the normal amount of precipitation fell. The model results using the 1995 data provide insight into shallow groundwater flows during wet conditions.

Shallow groundwater actinide measurements, collected from alluvial wells near Walnut Creek and Woman Creek at the eastern boundary of RFETS, were used to determine the concentration of actinides in shallow groundwater leaving the Site. The estimated annual shallow groundwater flux volumes for the Walnut and Woman Creek basins were multiplied by the average actinide concentrations within each basin to estimate the actinide loads transported offsite in shallow groundwater.

9.1.4 Plutonium and Americium in Shallow Groundwater

Soil samples collected near the soil surface (3 to 4 inches below original grade) at locations 50099 through 50399 confirm that shallow soils were contaminated with actinides (2.8632 to 489.2946 pCi/g Pu-239/240 and 0.6885 to 104.5068 pCi/g Am-241). Soil activity-concentrations at the base of the aseptic casing were below the target activity-concentration of 1 pCi/g in Wells 50199, 50299, and 50399, but exceeded the criteria at Well 50099 (6.0409 pCi/g Pu-239/240 and 1.0666 pCi/g Am-241). The presence of above target Pu-239/240 and Am-241 concentrations in this sample indicate that some shallow soil contamination was present when drilling was initiated through the aseptic casing. For this reason, the deeper soil samples collected from soil cores in this borehole were subsequently submitted for analysis. These cores represented undisturbed subsurface soils more closely than borehole wall or soil cutting materials. In all of the deeper soil samples, Pu-239/240 was not detected. While these core data imply that relatively clean drilling conditions were maintained below the base of the aseptic casing, there remains a potential for contaminated cuttings to have been brought downhole by the auger bit and/or flights. Therefore, although the Pu-239/240 or Am-241 contamination detected in groundwater samples collected from these wells may be the result of contamination by natural processes, the drilling and well installation processes continue to be potential contributors to contamination, as well as sample handling and laboratory procedures.

The results of 3rd/4th quarter 1999 groundwater sampling for all paired wells and 903 Pad Hillside wells are summarized below. Pu-239/240 activity-concentrations in groundwater ranged from below detection to 0.0601 pCi/L in the new wells and from below detection to 0.1067 pCi/L in the existing wells. Am-241 activity-

concentrations were lower than Pu-239/240 in all wells except well 06991. Generally, Pu-239/240 and Am-241 activity-concentrations were lower for the new wells compared to the existing wells. From these results, it is clear that the actinide activity-concentrations at these locations are significantly lower than found in previous years, as reported in DOE (1997d). The results of groundwater sampling for the 2nd quarter 2000 event indicate that, generally, the data for bailed samples are consistent with the results of the 3rd/4th quarter 1999 bailed sample data. However, Pu-239/240 and Am-241 activity-concentrations detected in the new wells compared with the existing wells are more similar. Of the bailed samples, Pu-239/240 activity-concentrations in groundwater ranged from below detection to 0.148 pCi/L in the new wells and from 0.0217 pCi/L to 0.176 pCi/L in the existing wells. The difference in initial sample (0.148 pCi/L) versus duplicate sample (0.0179 pCi/L) Pu-239/240 values reported for well 50099 indicates that a potential for sample heterogeneity or analytical error or sample contamination (field or laboratory) exists in the data. Am-241 activity-concentrations were lower than Pu-239/240 in only a few bailed samples; the majority had either equivalent or slightly higher values with a maximum result of 0.126 pCi/L reported for well 1587.

9.1.5 Uranium in Shallow Groundwater

Samples collected at Site wells from July 1999 to August 2000 were analyzed using ICP/MS. Most samples indicated that uranium that was detected was from natural sources. However, alluvial groundwater samples collected near the Site boundary in both the Walnut and Woman Creek groundwater basins had U-235/U-238 mass ratios slightly less than the 0.0072 ratio found naturally. In addition, the same Walnut Creek boundary location had detectable levels of U-236, an isotope that only comes from a man-made uranium source. The presence of U-236 and the small variation from the natural ratio, though potentially related to analytical uncertainty, indicates that the shallow groundwater found in these basins may have a small fraction of man-made (depleted) uranium as part of the total uranium concentration.

9.1.6 Summary of Groundwater Pathway Analysis

Pu-239/240 and Am-241 are relatively immobile in unsaturated soils. Soil profile data collected at the 903 Pad over the past three decades demonstrate that movement is limited mainly to the uppermost 20 cm of soil. Small amounts of these actinides have penetrated deeper into soil presumably via macropores, which occur to a depth of about 100 cm below ground surface. Considering that over three decades have passed since these actinides were first released to 903 Pad area soils, the low activity-concentrations (<1 pCi/g) in soil and groundwater at and below 70 cm indicate that the actinide flux to shallow groundwater is expected to be greatly attenuated and therefore very small.

Pu-239/240 and Am-241 are found in low activity-concentrations (<0.15 pCi/L) in UHSU wells associated with surface and near-surface soil contamination areas. Pu-239/240 and Am-241 groundwater contamination is not generally found in areas outside of surface soil contamination areas, including the RFETS IA. This situation indicates that contamination from potential underground IA actinide sources, such as process waste lines and

buildings, is not present in the UHSU. The only contamination found that was not attributable to surface soil contamination occurs at the Present Sanitary Landfill, where low level radioactive wastes were buried soon after landfilling operations began (see Section 6.0). Additional areas of localized contamination may still be discovered as environmental remediation activities and D&D monitoring programs for individual building closures are implemented during Site closure.

Recent sampling results from the actinide drilling-artifact contamination investigation indicate that trace activity-concentrations of these actinides found in UHSU groundwater are associated with locations of surface-contaminated soils. However, the Pu to Am ratios and presence of contamination in old and new wells does not totally tie the contamination to drilling artifacts. These results are generally below Tier II action levels and are significantly lower than activity-concentrations previously reported for older, paired, monitoring wells. The significance of these detections is still subject to uncertainty until analytical and/or sampling variations are better quantified and understood. Consequently, further investigation may be necessary to refine analytical and sampling techniques for the reliable measurement of low activity-concentrations of these actinides.

On the basis of uranium isotope high resolution ICP/MS analyses, anthropogenic uranium isotope contamination associated with Site activities has been detected in UHSU groundwater at various areas in the IA. However, much of the high uranium isotope activity concentrations observed are natural and not associated with contamination. Naturally occurring uranium isotope activity concentrations are observed to increase by approximately an order of magnitude from the west Site boundary to the east Site boundary. This trend indicates that a natural concentration gradient exists across RFETS, which must be considered when evaluating groundwater uranium isotope data. Other than anthropogenic uranium isotope levels in the SPP, the highest uranium isotope activity concentrations at the Site occur in background areas. Except for a few locations in the IA, anthropogenic groundwater uranium isotope contamination has not been detected in the UHSU.

9.2 Site-Wide Water Balance

9.2.1 Introduction and Objectives

During CY 2001, work continued on the SWWB project and culminated in spring 2002 with the completion of The Site-wide Water Balance Model Report for the Rocky Flats Environmental Technology Site (K-H, 2002c).

The RFETS is being closed and will eventually be converted into a National Wildlife Refuge. Anticipated closure activities will involve reconfiguring portions of the existing Site. These modifications will impact the current Site surface and subsurface hydrology. A comprehensive approach, incorporating mechanisms that govern the current Site hydrology, was required to understand and predict the potential hydrologic changes caused by anticipated closure activities. The hydrologic system is strongly influenced by surface water-groundwater interactions because

of the semiarid climate that exists in the Front Range of Colorado. This complex regional hydrologic system is complicated locally by man-made modifications within the IA that impact both surface and subsurface flows.

The primary objective of the SWWB study was to create a decision tool to quantitatively assess the integrated hydrologic conditions at the RFETS. This section of the Annual Report summarizes the development and application of a fully integrated hydrologic model that was developed as a management tool. Specifically, this integrated model was used to: (1) comprehend and simulate current Site hydrologic conditions; and (2) assess the hydrologic impacts caused by hypothetical modifications to the current Site configuration during closure activities.

The integrated model was designed to simulate important drainage-basin scale processes that control RFETS hydrology. It was not designed to simulate localized flows in features such as individual pipes or culverts, nor to model contaminant transport or evaluate engineering designs. However, the model was developed so that its input and output could be used to facilitate contaminant transport evaluations or engineering design calculations.

9.2.2 General Approach and Conceptual Flow Model

To achieve the SWWB objectives, the following tasks were identified and conducted:

- Site-specific data were collected to support development of the conceptual and numerical hydrologic models (data included hydrologic, surface and subsurface IA, structural, topographic, geologic, soil, and vegetative);
- The conceptual hydrologic model was developed based on existing and collected Site knowledge;
- The modeling approach appropriate for the Site (including code selection and verification) was developed;
- The numerical model was developed based on a selected computer code;
- Model performance (including calibration, validation and sensitivity analysis) was evaluated;
- The model was applied to two hypothetical Site closure scenarios; and
- The model results were assessed for implications to Site closure.

In order to develop the numerical model framework, a conceptual model was developed for the flow system at the Site. The RFETS conceptual model considered the relevant surface and subsurface flow processes and their interactions, and Site features affecting flows. Separate conceptual flow models were developed for the IA and Buffer Zone. This was necessary to assess the different observed flow responses in each area. The fully integrated hydrologic model simulates the combined flow characteristics of both areas. Analyzing available Site information, including (1) past studies; (2) hydrologic and geologic data; and (3) engineering plans and details supported the conceptual model development.

9.2.3 Numerical Model Approach and Design

The complex surface water-groundwater interactions within the RFETS hydrologic flow system required using a fully integrated computer code to create a flexible, yet comprehensive, management tool. After a detailed comparison of available integrated models, the MIKE SHE computer code was selected for the SWWB modeling. Details of the code selection process are presented in the Model Code and Scenario Selection Report (K-H, 2001c).

Semiarid conditions also compound the complexity of the Site hydrology, which requires using a transient modeling approach within this fully integrated system. Steady state models cannot reliably replicate the observed conditions at the Site, nor could a combination of non-integrated, media-specific transient model codes. Subregional scale models of hydrologic processes were developed to understand basic flow processes prior to simulating the fully integrated site-wide model. Model code verification results showed MIKE SHE was the most appropriate code for this application, capable of simulating the important RFETS hydrologic processes and their complex interactions.

Specific parameters and targets were identified and prioritized for the model calibration. Specific focus areas were specified where key decisions or Site hydrology would likely change in response to the hypothetical Site reclamation scenarios. Focus areas included: (1) the regional flow system; (2) major surface water drainages; (3) detention ponds; (4) specific contamination areas including the 903 Pad and Lip Area, the Original Landfill, and the Present Sanitary Landfill; (5) in situ groundwater treatment/collection systems; and (6) vegetation and animal habitat areas. Within the focus areas, additional effort was made to minimize the difference between model-simulated results and field measurements of the hydrologic system. The highest priority was given to accurately simulating surface water discharge from the IA to Woman and Walnut Creeks and from those drainages to the eastern Site boundary.

The integrated numerical model consisted of surface flow, vadose zone, and saturated zone components at discrete points on a grid. A 200 x 200-foot (approximately 61 x 61-meter) regularly spaced model grid was selected as the most suitable compromise between numerical efficiency and the solution accuracy required to meet the project objectives. In addition, time step ranges were used in the model to capture the rapid dynamics of the surface hydrologic system (0.5 minute time step) and slower response of the groundwater flow system (six hour maximum time step). Spatial precipitation distributions were specified from ten Site gauging stations every fifteen minutes, while potential evapotranspiration (PET) was specified every two hours based on a calculation from observed Site meteorological data.

The surface flow model simulates two-dimensional overland flow and one-dimensional channel flow. The channel flow network included both Walnut and Woman Creeks and most tributary branches. The A, B, and C series ponds and the East Landfill Pond were also incorporated into the channel network. Both channel flow and pond water interact directly with saturated zone flow. Drainage basin boundaries were used to define overland flow areas within the model, and detailed cross sections defined the channel flow network.

The subsurface model simulates one-dimensional unsaturated zone flow and three-dimensional saturated zone flow. The unsaturated zone model accounted for the spatial distribution of soil types. Effects of the time varying, spatially distributed vegetation were simulated through the unsaturated zone as ET. The saturated zone model uses four model layers to describe flow within unconsolidated material and weathered bedrock units. The top two layers simulate the unconsolidated material, allowing for separate specification of building basements and subsurface utilities. The bottom two layers simulate the weathered bedrock material, allowing for separate specification of Arapahoe Sandstone features. Average hydraulic characteristics and properties of subsurface remediation systems, utility trenches and drains, water supply lines, and building basements in the IA were incorporated into the saturated zone model.

9.2.4 Model Performance and Scenario Evaluations

After completing the numerical model design, the fully integrated model was calibrated. Calibration was achieved by adjusting model parameters (within reasonable natural ranges) until the simulated model results compared well with observed data. The calibration data set period was water year 2000 (October 1999 through September 2000). Observed site-wide flow conditions at RFETS were well simulated by model results. Key findings of the calibrated model included:

- For the current Site configuration, the water balance differs greatly in the IA as compared to the Buffer Zone. For the water year 2000 climate, roughly 90 percent of the Buffer Zone precipitation was lost through ET, with less than 1 percent running off to streams. In contrast, for the IA, roughly 60 percent of the precipitation was lost to ET, with 15 percent running off to streams;
- ET dominated groundwater levels adjacent to streams, which in turn strongly affected streamflows. During high ET, groundwater levels declined near Walnut and Woman Creeks at the eastern Site boundary. In Woman Creek, this effectively eliminated stream flow in late spring and summer. During times of the year with low ET, groundwater levels increased. This causes increased baseflow contributions to Woman Creek with resulting increases in the total flow and peak flow rates in that drainage;
- In Walnut Creek, flows were dominated by pond releases. However, during periods with no pond discharges, precipitation events rarely caused streamflow in Walnut Creek because of high soil infiltration rates and low groundwater levels adjacent to streams;
- Groundwater level changes were affected most by vertical processes, such as ET and direct recharge from precipitation, and to a lesser extent by lateral groundwater flow. Groundwater flow directions were strongly influenced by local topographic and bedrock surfaces; and
- IA surface flows were comprised of fast runoff, baseflow, and drain inflows. The fast runoff causes rapid hydrograph peaks, while baseflow and drain inflows produced continuous low flow rates exiting the IA as surface water.

The performance of the calibrated model was further assessed through a sensitivity analysis and model validation. The purpose of the sensitivity analysis was to identify key parameters to which the model was most responsive. The most sensitive modeling parameter was saturated hydraulic conductivity. The largest component of the water balance was ET. The model validation performance was demonstrated using pre- and post-calibration climatic

conditions. These simulations showed that the model performed well in simulating the hydrologic conditions of spring 1995 and water year 2001.

Model simulations were conducted for two hypothetical Site scenarios to evaluate changes based on water year 2000 hydrologic conditions. In the first scenario, the No Imported Water Scenario, imported water from offsite was discontinued. The Site normally purchases an average of approximately 420,000 cubic meters (110 million gallons or 340 acre-feet) of water annually from the Denver Water Board. The second scenario, the Land Configuration Scenario, also discontinued imported water and included the hypothetical regrading of topography in the IA, the Present Sanitary Landfill, and the Original Landfill. In the second scenario, IA changes included removal of all paved surfaces and foundation drains. Basement walls and slabs were left in place, with the exception of Building 771. Subsurface utilities were simulated as grouted, leaving backfill material in place; however, backfill material was simulated as removed for a subset of the process waste lines identified as having failed pressure tests.

For each hypothetical scenario, three climate conditions were applied to develop a range of simulated hydrologic responses. The three climate conditions represent average, wet, and dry years of precipitation for the Site. Finally, a Monte Carlo type of uncertainty analysis was conducted on the second scenario to assess the range of uncertainty in predicted output given uncertainty in sensitive model input parameters.

Several key findings about the change in hydrologic conditions from the present to the hypothetical Land Configuration Scenario were identified. These are summarized as follows:

- Regionally, most of the hydrologic system changes occurred within the regraded IA, the two modified landfill areas (Original and Present Sanitary Landfills) and to Walnut Creek, east of the IA;
- Surface discharge in Walnut Creek was substantially reduced, while flows in Woman Creek were largely unaffected;
- Walnut Creek discharges decreased for the following three reasons: (1) Waste Water Treatment Plant contributions to Walnut Creek were eliminated; (2) impervious surfaces in the IA were removed, thereby eliminating fast runoff; and (3) drain discharges to IA streams were eliminated;
- The number of required terminal pond discharges decreased in the hypothetical Land Configuration Scenario because of decreased flow from the IA;
- Average groundwater levels in the IA rose. Removing drain discharges and impervious areas caused groundwater to rise, whereas removing leaky water supply lines caused groundwater levels to decrease. The net effect of these changes was to increase IA groundwater levels; and
- Simulated discharges from groundwater remediation systems slightly decreased.

9.2.5 Implications to Site Closure and Potential Applications

Modeling results suggested that significant impacts to Site hydrology will occur for the hypothetical scenarios tested. These modeling results provide valuable insight into Site hydrology that will influence the RFETS closure

strategy and long-term stewardship. Implications based on the simulated scenario results are summarized as follows:

- Surface and subsurface flows in Woman Creek will be largely unaffected. Therefore, vegetation along Woman Creek will generally not be affected by the Site reconfiguration. (Note: the SID was not altered or removed in the scenarios.) An exception to this may occur in the area south of the Original Landfill. This area may experience some localized diminished flows from hypothetical covers and cutoff walls. A more detailed analysis of this area should be performed; and
- Surface and subsurface flows in Walnut Creek will be substantially reduced. As a result of the diminished surface flows, future hydrologic conditions in Walnut Creek downstream of the IA will be dominated by pond operating protocols and any pond discharge routing or structural modifications. An additional effect of reduced flows in Walnut Creek is the possible impact to vegetation downstream of the ponds caused by lower groundwater levels along the stream channel.

Additional applications of the fully integrated hydrologic model developed for RFETS may include evaluating additional Site configuration scenarios. Other model uses could involve local scale modeling, contaminant transport evaluations or more detailed assessments of potential hydrologic impacts to vegetation and wildlife habitat (K-H, 2002c).

9.3 Current Solar Ponds Plume Investigation

In early 2002, Water Programs supported an investigation of the groundwater plume at the Solar Ponds. The objective of this investigation was to determine the current configuration of the uranium and nitrate plume in that area, and to collect additional data on metals.

The 2001 IMP includes several routinely sampled monitoring wells in the general area of the Solar Ponds, but because of their geographic separation, data from these wells are insufficient to determine the plume configuration. Therefore, to support the upcoming closure of the Solar Ponds, a more detailed survey of groundwater contamination was desired that would allow a “snapshot” of groundwater conditions, including an up-to-date plume map.

This section describes the investigation and summarizes its results. Because the topic of nitrates in groundwater is addressed in Section 8.3 (which includes Solar Ponds groundwater data), it will not be repeated here.

9.3.1 Description of Investigation

The Water Programs group supported the needs of the Environmental Remediation (ER) group to perform this study. Those needs were driven by data needs supporting decisions on Solar Ponds remediation and closure.

A list of wells to sample was developed that comprised a selection of wells from the immediate vicinity of the Solar Ponds, the nearby surroundings, and more distal portions of the known groundwater plume. The ER group determined the analytical suite and the priority of the various analytes within the suite, based on their closure decision needs.

Table 9-1 lists the wells that were selected for sampling and summarizes the results of sample collection efforts. The analytical suite was as follows, with the sampling priority in the order listed:

1. Filtered Uranium;
2. Filtered Metals;
3. Nitrate/Nitrite;
4. Unfiltered Uranium ; and
5. Unfiltered Metals.

Table 9-1 Solar Ponds Investigation Sample Collection Summary

Well	VOA 524.2	Filtered Metals	Unfiltered Metals	Nitrate/ Nitrite	Filtered Uranium Isotopes	Unfiltered Uranium Isotopes
54494	X	X	X	X	X	X
P208989	X	X	X	X	X	X
3086	X	X	X	X	X	X
3186	X	X	X	X	X	X
3887	X	X	X	X	X	X
P207589	X	X	X	X	X	X
P210189	X	X	X	X	X	X
P209089	X	X	X	X	X	X
41693	X	X	X	X	X	X
42993	X	X	X	X	X	X
41993	X	X	X	X	X	X
05093	X	X	X	X	X	X
05193	X	X	X	X	X	X
P209689	X	X	X	X	X	X
P209589	X	X	X	X	X	X
22298	--	X	X	X	X	X
45693	X	X	X	X	X	X
P210089	--	X	X	X	X	X
B210389	--	X	X	X	X	X
B208689	--	X	X	X	X	X
B210489	--	X	X	X	X	X
1886	--	X	X	X	X	X
B208189	X	X	X	X	X	X
02691	X	X	X	X	X	X

X Sample requested but there was insufficient water to collect it.
X Sample requested and successfully collected.
-- Sample not requested.

The list of wells sampled for the current investigation purposely omitted wells in the current sampling program as well as some that had been more recently sampled (e.g., since 2000), instead focusing on wells that had not been sampled in years. Analytical results from this study were then grouped with data from those recently sampled wells to provide a more complete data set for the plume.

The focus of this section is on uranium, one of the main components of the SPP. Due to its much more complete data coverage, as explained below, only filtered uranium samples will be addressed. Metals results are discussed briefly at the end of this section. Nitrate and VOC data generated through this Solar Ponds investigation are part of the discussion in Section 8.3.

9.3.2 Data Handling

Uranium

Uranium data for wells in the area of the Solar Ponds were retrieved from the SWD. Only data from 1997 and later were retrieved. This is because an extensive nitrate/uranium sampling effort at the Solar Ponds was conducted in 1997 and 1998, including as many wells and well points as was then feasible. The current investigation was much more limited in scope. Therefore, in order to maximize the data coverage, results from this earlier sampling effort were included in the current evaluation.

Similarly, because samples for the analysis of uranium and metals are typically field-filtered, more data are available for filtered samples than for unfiltered samples. Current data from unfiltered samples typically do not exist for routinely sampled wells, except those few that are sampled using micropurging techniques. Therefore, to make the most of the available (and comparable) data, this section focuses on data from filtered samples. (The reason for filtering these samples is to generate data that more accurately represent groundwater conditions. Analytical results for unfiltered samples collected using bailer methods can be strongly affected by sediments contained within the sample, which are not actually part of the groundwater regime. The effect of sediments can be especially important in a high background-uranium environment such as RFETS, or for areas such as the Solar Ponds that may exhibit metals contamination in soils. Using such unfiltered sample data for groundwater evaluations can lead to an incorrect understanding of groundwater conditions and to erroneous conclusions.)

For a given well, uranium isotopic data were managed as follows. Any rejected data were deleted from the data set. At wells reporting both filtered and unfiltered data for a particular date, the unfiltered data were deleted. At wells from which multiple results were available for each isotope on a given date (e.g., both “Real” and “Duplicate” samples were collected and analyzed), the highest value for each isotope was retained in the data set, the others for that date were deleted.

Following these procedures, the data set contained a single result for each routinely analyzed isotope (U-233/234, U-235, and U-238), on each sampling date after 1/1/1997, at each well for which data exist over that time frame. The remaining data were then grouped into two data sets: 1997 through 2000, and 2001 to the most recent 2002 data available. Within each group, and for a given well, the results from each individual sampling event for U-233/234, U-235, and U-238 were summed. All the date-specific sums for that well were then averaged. This process gave an estimate of the average total uranium at the given well for the given time period. (This is only an estimate because the listed isotopes are not the only uranium isotopes that exist. However, these isotopes are by far the most predominant uranium isotopes, and therefore the averaged value is essentially equal to the total uranium.)

These average total uranium values were posted and contoured (Figure 4-3b) for each time period so that any major trends that might exist could be detected. Contour intervals were selected to reflect RFCA and background levels: the 2.847 pCi/L and 284.7 pCi/L values correspond, respectively, to a sum of the Tier II and Tier I activity-concentrations for the isotopes analyzed in groundwater (as listed above). The 50 pCi/L contour is used for display. The 104.29 pCi/L contour represents a sum of the background activity concentrations for these isotopes.

Metals

Because the most prominent groundwater contamination at the Solar Ponds consists of uranium and nitrate, other analytes have received less scrutiny in recent years. Sampling around the Solar Ponds for metals in groundwater has not taken place except at the few routine program wells in the area, and the 1997-1998 investigation omitted metals from the analytical suite. As a result, the amount of data available for metals at the Solar Ponds is greatly reduced compared to that for uranium and nitrate.

Further reducing the data set, available groundwater data for metals of interest from the early to mid-1990s, when the Solar Ponds still contained sludge, are of questionable relevance to current groundwater conditions. These older data were therefore removed from the data set. (To review those older metals data, see the RCRA Reports issued in the 1990s: DOE 1990, 1991a, 1992d, 1993c, 1994c, 1995, 1996a.)

After evaluating available data, those predating 2001 were eliminated and only 2001 through early 2002 data exceeding Tier II for metals were posted. These metals data are not conducive to contouring. Instead, these data are presented as a box-plot map rather than a contour map. Both filtered and unfiltered samples are represented in box plots. Where both forms of sample data exceeded Tier II at a well, the highest value was selected for inclusion on the map.

9.3.3 Results and Discussion

Uranium

Lack of data for the vast majority of groundwater monitoring locations in this area (Figure 4-3b) hampers a thorough, detailed understanding of uranium groundwater contamination in the vicinity of the Solar Ponds. Regardless, some general conclusions may be drawn.

As shown on Figure 4-3b, the uranium content of groundwater at the Solar Ponds has changed somewhat between the two time periods depicted on the figure. However, many of these changes are slight and are not readily apparent on the figure. Table 9-2 presents a summary of data from wells that are represented by averaged "total" uranium results (sum of filtered U-233/234, U-235, and U-238) for both periods of time.

The highest activity concentrations of uranium in groundwater continue to exist at and immediately adjacent to the Solar Ponds. Isotopic signatures indicate an anthropogenic source for this contamination (see Section 8.1). Levels of uranium are also elevated downgradient of the Solar Ponds, particularly in the area of the SPPTS discharge and the now obsolete pump house that received ITS waters, but these locations show natural uranium isotopic signatures. These downgradient levels may start to decrease due to modifications made to the SPPTS in late 2002. (The modifications are designed to minimize the potential for contaminated groundwater to bypass the treatment system, said bypass being one possible explanation for the elevated uranium activity concentrations in this downgradient area).

Table 9-2 Comparison of Averaged Total Uranium Results in Groundwater

Well	Location	1997-2000		2001-early 2002	
		Average Total Uranium (pCi/L)	Standard Deviation / Number of Sample Events	Average Total Uranium (pCi/L)	Standard Deviation / Number of Sample Events
05093	Source area	657.38	0 / 1	190.29	0 / 1
05193	Source area	241.72	0 / 1	206.48	0 / 1
41693	Source area	1157.90	0 / 1	572.20	0 / 1
43993	Source area	35.71	0 / 1	28.32	0 / 1
P209089	Source area	40.42	0 / 1	38.24	0 / 1
P209489	Source area	40.36	12.96 / 8	57.43	7.21 / 3
P210189	Source area	3.08	0 / 1	2.35	0 / 1
02691	Downgradient	5.62	0 / 1	13.51	0 / 1
1386	Downgradient	14.48	2.85 / 7	17.94	6.51 / 3
1786	Downgradient	62.27	5.75 / 5	62.38	2.93 / 2
3086	Downgradient*	171.05	0 / 1	136.37	0 / 1
45693	Downgradient*	103.74	0 / 1	239.35	0 / 1
B208689	Downgradient	139.95	0 / 1	111.67	0 / 1
B208789	Downgradient	18.90	5.44 / 6	14.96	2.83 / 3

Well	Location	1997-2000		2001-early 2002	
		Average Total Uranium (pCi/L)	Standard Deviation / Number of Sample Events	Average Total Uranium (pCi/L)	Standard Deviation / Number of Sample Events
B210389	Downgradient	104.73	0 / 1	114.24	0 / 1
B210489	Downgradient	53.67	0 / 1	44.56	0 / 1
P208989	Downgradient*	62.05	0 / 1	98.40	0 / 1
P209589	Downgradient*	368.96	0 / 1	392.90	0 / 1
P210089	Downgradient	6.54	0 / 1	7.50	0 / 1
P218389	Downgradient	2.88	1.46 / 2	1.03	0 / 1
P219489	Downgradient	9.58	0.53 / 2	8.03	1.46 / 2
P219089	Downgradient**	15.76	0 / 1	13.87	3.82 / 5
P219189	Downgradient**	104.10	4.42 / 4	95.41	4.37 / 2
00100	Upgradient	1.71	0 / 1	2.86	1.17 / 4
00500	Upgradient	0.34	0 / 1	1.31	1.58 / 3
00600	Upgradient	0.39	0 / 1	0.65	0.33 / 3
02397	Upgradient	1.27	0 / 1	1.56	0 / 1
02497	Upgradient	2.93	0.74 / 3	1.49	0 / 1
02500	Upgradient	6.40	0 / 1	9.82	0.59 / 3
P209289	Upgradient	2.23	0.12 / 2	1.23	0.30 / 2
P209389	Upgradient	1.46	0.37 / 8	1.70	0.20 / 3

* These wells are both downgradient of and near the source area (i.e., within about 250 feet). Other downgradient wells are farther from the source area.
**These locations are not strictly downgradient, but are grouped with downgradient wells for convenience.

Total uranium activity concentrations have decreased significantly in many wells in the source area (i.e., installed within the berms or immediately adjacent to the Solar Ponds) that were monitored for both time periods of interest. For example, the highest uranium activity concentrations in both the 1997-2000 and 2001-early 2002 data sets are from well 41693, located in the berm between Pond 207A and Pond 207B-North. In the earlier data set, the average total uranium was 1157.9 pCi/L; in the later data, it is 572.2 pCi/L. (Well 42993 showed average total uranium of 1011 pCi/L in the later time period, but is not represented by data in the earlier time period.)

Conversely, many wells that are downgradient of the source area, especially those closest to it, show an increase in average total uranium. Perhaps the best example of this is from well 45693, which is north of Pond 207C and near a small seep area. The average total uranium over the 1997-2000 time period at this well was 103.74 pCi/L. This increased more than two-fold to 239.35 pCi/L in the 2001-early 2002 data set.

The simplest explanation for the decreasing activity concentrations in the source area and increasing activity concentrations a short distance downgradient is that now that the source (the Solar Ponds fluids and sludge) has been removed, uranium is being flushed from the area. Under this scenario, a slug of water with elevated uranium activity concentrations is moving downgradient and the downgradient wells nearest the source are reflecting this.

Uranium is relatively mobile in groundwater, especially compared to other actinides found at RFETS (in particular, plutonium and americium), so this would be expected. However, more data and a more thorough evaluation are

required before such an explanation can be definitively concluded. One problem with this conclusion is the paucity of data upon which it is based; because most of the wells in this area are not routinely sampled, many wells – including those used as examples above – are represented by only one or two sample events in either data set. In addition, the standard deviations for locations represented by several samples (Table 9-2) generally show there is significant overlap in the averaged values from the two time periods. Finally, wells located farther downgradient from the source area vary in an apparently random fashion. Data gaps also exist here; for example, well 10594 is only represented by data during the early (1997-2000) time period.

Metals

Given the small data set representing current metals concentrations in groundwater, as discussed above, few conclusions can be derived and most of those that are evident are to be expected. However, some aspects of the data, as presented on Figure 9-1, warrant discussion.

The most notable feature of Figure 9-1 is the frequency with which thallium is reported above its Tier II concentration (2 µg/L). An increase in thallium concentrations has been reported for a large number of wells in the routine monitoring program, and does not seem to relate to any source. The Water Programs group is currently investigating the large increase in results reported above Tier II. Possible explanations include recent changes in laboratories analyzing metals samples; a detection limit of 4 µg/L, well above the Tier II action level; and the fact that the background concentration of thallium is reported as 4.9 µg/L (EG&G, 1993a).

Aside from thallium, selenium, lithium, and cadmium appear to exceed Tier II concentrations most frequently. Samples from wells in the vicinity of the Solar Ponds generally contain more Tier II concentrations of metals than those from distal wells.

Well 41693 appears most affected by elevated metals in groundwater. This well is located in one of the berms, and as noted in the preceding discussion on uranium, it also consistently contains the most elevated uranium activity concentrations. A sample collected in early 2002 from well 41693 shows Tier II levels are exceeded here for aluminum, beryllium, cadmium, lead, lithium, manganese, and nickel. None of these are present at Tier I concentrations.

Distal wells – those in the North Walnut Creek drainage – also have produced samples with metals concentrations above Tier II. Aside from thallium, elevated concentrations of lithium and selenium are each present in groundwater in this area.

9.3.4 Recommendations

Further examination of uranium activity concentrations is warranted for the Solar Ponds area to determine whether contamination inventory or mobile contaminant levels are truly decreasing at the source area, with a slug of groundwater containing elevated uranium activity concentrations moving downgradient. This has implications for the SPPTS, given the difficulties reported for that system (K-H, 2002d), and remedial actions for the Solar Ponds.

The quality of the groundwater at the Solar Ponds with respect to metals remains poorly understood. Similar to recommendations in Section 8.3, additional sampling is necessary from UHSU wells around the Solar Ponds in order to address uranium and metals questions. Samples should be collected even from wells represented by plentiful data, especially for evaluation of contamination and migration of uranium. If possible, sampling should be scheduled to occur during a period of higher water levels so that as many data gaps as possible may be filled. Attempting to sample during periods of lower water levels has met with minimal sampling success in the past, so it may not be worth repeating these attempts.

Finally, it should be noted that many of the "wells" mapped around the Solar Ponds are actually 0.25-inch diameter tubing installed in a small diameter borehole and used in the early 1990s for potentiometric data. While attempts to collect samples from these may be made, the probability that they will be able to supply sufficient volume to satisfy all sample needs is low. Sample needs may include a 1-liter bottle each for metals and uranium, several 40-ml vials for the analysis of VOCs, and potentially other analytical samples. A backup plan may need to be implemented to either accept the existing monitoring well coverage as sufficient (which may be warranted, especially given the additional wells installed in 2002 downgradient of the Solar Ponds) or install a number of temporary wells to collect the required analytical samples where well coverage and/or design is determined to be insufficient to meet the objectives of the study.

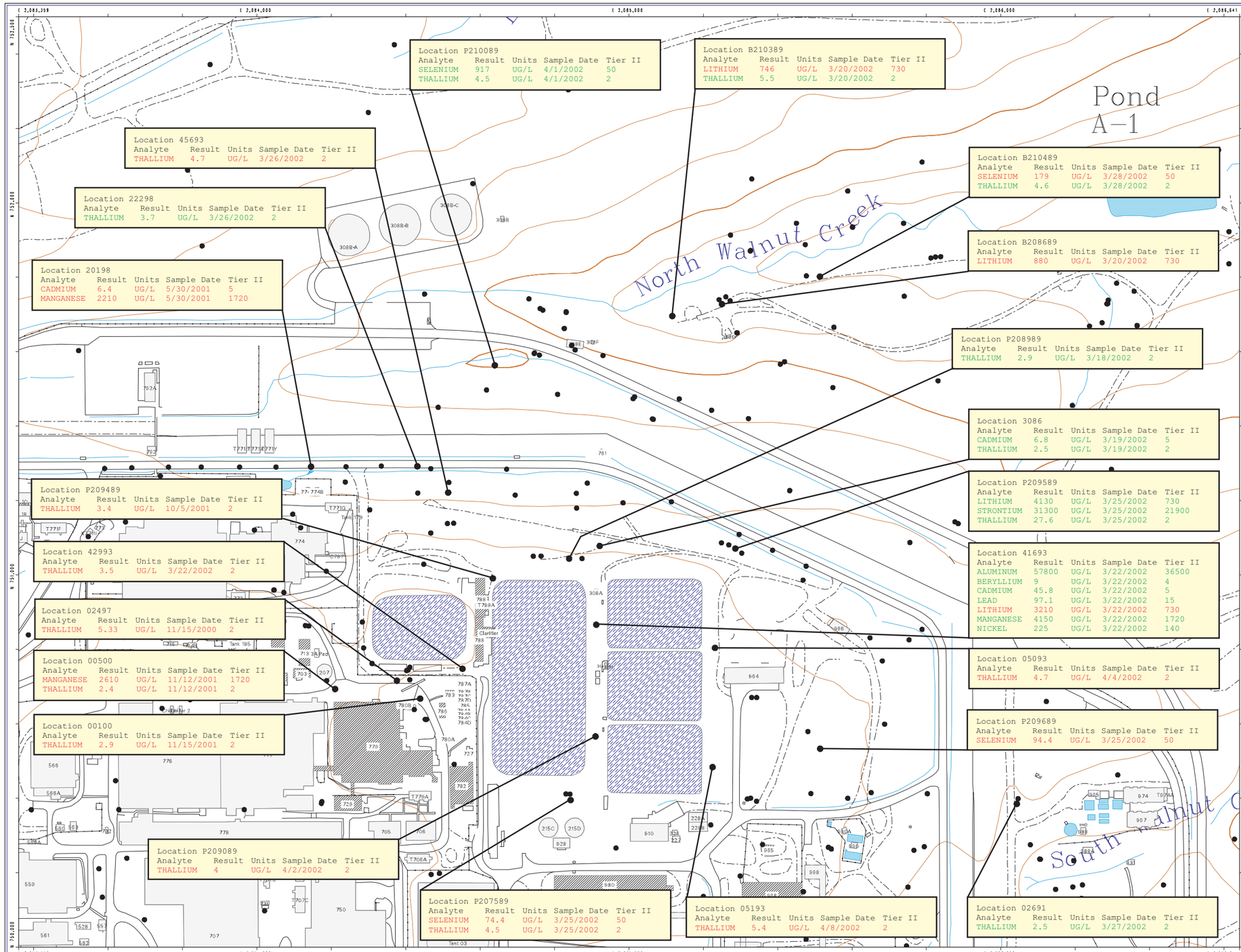

Figure 9-1

Metals Above Tier II Concentrations in Groundwater at the Solar Evaporation Ponds

EXPLANATION

- Wells (For sampled wells: Red = filtered, Green = unfiltered)

Standard Map Features

- Buildings and other structures
- Demolished buildings
- Solar Evaporation Ponds (SEPs)
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences and other barriers
- Topographic Contour (20-Foot)
- Rocky Flats Environmental Technology Site boundary
- Paved roads
- Dirt roads

DATA SOURCE BASE FEATURES:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas, Digitized from the orthophotographs, 1/95
Topographic contours were derived from digital elevation model (DEM) data by Morrison Knudson (MK) using ESRI Arc TIN and LATTICE to process the DEM data to create 5-foot contours. The DEM data was captured by the Remote Sensing Lab, Las Vegas, NV, 1994 Aerial Flyover at ~ 10 meter resolution. DEM post processing performed by MK, Winter 1997.

Scale = 1 : 3230
1 inch represents approximately 269 feet

50 0 100 200 ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

GIS Dept. 303-966-7707

Prepared by: DynCorp THE ART OF TECHNOLOGY

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