FINAL REVISED

Groundwater Conceptual Plan for the Rocky Flats Environmental Technology Site

Rocky Mountain Remediation Services, L.L.C.

Environmental Restoration/Waste Management

Sitewide Actions

September 1996

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FIGURES

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EXECUTIVE SUMMARY

The Groundwater Conceptual Plan provides a basis for cleanup and management of contaminated groundwater at the Rocky Flats Environmental Technology Site (RFETS) consistent with the Rocky Flats Cleanup Agreement (RFCA) Preamble, and the *Action Levels and Standards Framework for Surface Water, Ground Water and Soils*. This plan was originally issued in March 1996, but has been revised to reflect the final RFCA, and to include additional groundwater plume data. The Groundwater Conceptual Plan constitutes the source evaluation required for groundwater by RFCA.

Addressing groundwater on a sitewide basis allows for effective coordination of groundwater activities and provides consistency in addressing groundwater contamination. Domestic use of groundwater at RFETS will be prevented through institutional controls, therefore, the goal is to manage or cleanup groundwater to protect surface water quality for all agreed-upon uses. In addition, the Groundwater Conceptual Plan identifies, describes, and ranks the principal groundwater contaminant plumes to provide a planning basis for funding and implementation of groundwater actions.

The lateral extent and spread of contaminants in RFETS groundwater is limited by hydrogeologic conditions, therefore, the contaminant plumes are relatively stable. In addition, groundwater discharges to surface water before leaving RFETS, and there is a natural vertical barrier to downward migration of contaminated groundwater. Low-permeability claystones form a barrier at least 500-feet thick between contaminated groundwater at RFETS and the Laramie/Fox Hills Aquifer.

The volatile organic compound (VOC) contaminant plumes in groundwater are the most likely to impact surface water and are the primary focus of the Groundwater Conceptual Plan. Contaminant plumes with other inorganic constituents are addressed in this plan where surface water may be impacted above action levels. The plumes are defined based on the RFCA two-tiered groundwater action levels which are protective of surface water uses as well as ecological resources.

The groundwater Tier I action levels are used to identify highly contaminated areas as potential cleanup targets and are defined as 100 x Federal Drinking Water Maximum Contaminant Level (MCL) for VOCs. Tier II action levels are used to identify contaminated groundwater that may impact surface water and are defined as the MCL for individual constituents. Where MCLs are not available, the residential Programmatic Risk-Based Preliminary Remediation Goal (PPRG) value will apply.

The groundwater contaminant plumes with VOC concentrations exceeding Tier I action levels are: (1) 881 Hillside Drum Storage Area Plume, (2) Mound Plume, (3) 903 Pad and Ryan's Pit Plume, (4) Carbon Tetrachloride Spill Plume, (5) East Trenches Area Plume, and (6) Industrial Area Plume. Additional plumes discussed that do not exceed the Tier I action levels, but may have the potential to impact surface water, include those at the Present Landfill, Solar Ponds, and the Property Utilization and Disposal (PU&D) Yard.

Proposed cleanup actions consist of source removal or containment with capture and treatment or management of the contaminated groundwater. Using available information, potential actions were conceptually developed for each major groundwater contaminant plume. Based on capture and treatment effectiveness, installation and operating costs, and plant infrastructure requirements, passive captive and treatment methods were the preferred conceptual actions. Before each cleanup action can begin, analyses must be done to select the specific cleanup alternative, and to perform engineering design. Additional data may be needed to select the appropriate treatment systems and ensure the proper placement of cleanup systems.

The groundwater contaminant plumes were ranked based on the methodology previously developed to provide the basis for establishing the priority and sequence of proposed cleanup actions. However, a schedule for implementing groundwater cleanup will be dependent on funding, data sufficiency, resource availability, and the integration with other cleanup and RFETS activities.

1.0 INTRODUCTION

The Groundwater Conceptual Plan was originally developed as a joint effort between the Department of Energy, Rocky Flats Field Office (DOE/RFFO), Kaiser-Hill Company, L.L.C. (K-H), Rocky Mountain Remediation Services, L.L.C. (RMRS), the Environmental Protection Agency (EPA), and the Colorado Department of Public Health and Environment (CDPHE). This revised plan incorporates the final Rocky Flats Cleanup Agreement (RFCA) (July 19, 1996) and guidance from the Action Levels and Standards Framework for Surface Water, Ground Water, and Soils Working Group ("the Working Group"). This Working Group was formed to:

- Provide a basis for future decision making,
- Define the common expectations of all parties, and
- Incorporate land- and water-use controls into site cleanup.

The Groundwater Conceptual Plan was originally issued in March 1996 and has been revised to incorporate changes in RFCA and additional information on plumes.

1.1 ROCKY FLATS CLEANUP AGREEMENT AND ACCELERATED SITE ACTION PROJECT (ASAP)

RFCA is an agreement between DOE/RFFO, EPA, and CDPHE to ensure the effective and efficient cleanup of RFETS. The RFCA Preamble mandates that environmental cleanup will be implemented through an integrated and streamlined regulatory approach. The RFCA preamble also defines the approximate areal extent of the five future conceptual land uses: (1) capped areas underlain by waste disposal cells or contaminated materials closed in-place; (2) an industrial-use area; (3) restricted open space; (4) restricted open space because of low levels of plutonium contamination in surface soils; and (5) unrestricted open space.

The RFCA Preamble states that the goal of soil and groundwater management and cleanup is the protection of surface water quality for the designated uses. Proposed actions will be designed to protect ecological resources and the proposed appropriate industrial or open space uses. Groundwater will not be used for any purposes at RFETS, except as related to cleanup activities. ASAP was developed as an accelerated strategy to reduce risks and close RFETS. The ASAP strategy was used to develop the Integrated Site Baseline (ISB) and the 10 Year Plan, a proposal issued by the Secretary of Energy for RFETS cleanup in 10 years.

The Groundwater Conceptual Plan is based on the ASAP strategy, and incorporates the RFCA Preamble objectives and the *Action Levels and Standards Framework for the Surface Water, Ground Water, and Soils*. This plan provides a basis for cleanup and management of contaminated groundwater at RFETS to protect surface water quality and ecological resources, and is the basis for the groundwater cleanup in the ISB and the 10 Year Plan.

1.2 PURPOSE OF THE GROUNDWATER CONCEPTUAL PLAN AT RFETS

Groundwater at RFETS is present in the shallow, unconsolidated sediments and subcropping bedrock throughout the site. In the past, each Operable Unit (OU) investigated groundwater within its boundaries without addressing influences from upgradient sources. However, groundwater is not limited by OU or Individual Hazardous Substance Site (IHSS) boundaries. Several sources may contribute to a single groundwater plume, and groundwater plumes may cross several OUs and contribute to surface water contamination a great distance from the source location. Figure 1-1 shows the location of the principal areas discussed in the text.

The Groundwater Conceptual Plan addresses groundwater on a sitewide basis, to allow effective coordination of groundwater activities, and establish a consistent approach to addressing groundwater contamination. While remediation of groundwater contaminant plumes must consider both the source and the associated groundwater plume, groundwater plume remediation can be performed independently of source remediation. Because there is no exposure pathway to humans from contaminated groundwater, the programmatic goals are to protect surface water and the environment and limit potential contaminant migration (to the extent practicable).

The three specific goals of the Groundwater Conceptual Plan are to:

1) Identify and describe the principal contaminant plumes in groundwater;

2) Rank the contaminant plumes for the purpose of establishing the priority for cleanup actions, in accordance with the method outlined in the "Environmental Restoration (ER) Ranking" (RFCA Attachment 4); and

3) Provide an initial planning basis for funding and the related implementation schedule for groundwater cleanup.

To meet these goals, the Groundwater Conceptual Plan proposes cleanup and/or management of contaminated groundwater through source removal, source control, and/or treatment of dissolved-phase plumes. Contaminated seeps are also addressed, as these represent the distal ends of the contaminated groundwater plumes. The Groundwater Conceptual Plan recommends evaluating whether some areas of contaminated groundwater may remain in place, given that the programmatic goals can be met without active intervention.

1.3 DOCUMENT ORGANIZATION

The conceptual plan for groundwater restoration is presented in five sections: (1) Section 1.0 describes the goals and purpose of the groundwater strategy, and presents the organization of the report; (2) Section 2.0 provides a summary background on groundwater at RFETS; (3) Section 3.0 presents the action levels and standards developed by the Working Group and describes the groundwater monitoring requirements; (4) Section 4.0 describes the various groundwater contaminant plumes present at RFETS and provides an overview of the proposed cleanup actions that may be used; and (5) Section 5.0 summarizes the proposed next steps.

This document also contains two appendices: (1) Appendix A is a list of acronyms used in this text, and (2) Appendix B contains the executive summary of the White Paper - Analysis of Vertical Contaminant Migration Potential (RMRS 1996a)

2.0 HYDROGEOLOGY AT RFETS

A basic understanding of the hydrogeologic setting is important for evaluating the nature and distribution of contaminated groundwater at RFETS. The current reference documents for describing the sitewide geologic, hydrogeologic and groundwater geochemical data at RFETS are the "Geologic Characterization Report for the Rocky Flats Environmental Technology Site" (EG&G 1995a), the "Hydrogeologic Characterization Report for the Rocky Flats Environmental Technology Site" (EG&G 1995b), and the "Groundwater Geochemistry Report" (EG&G 1995c). Much of the following discussion was derived from these reports. Unpublished plume maps from the 1995 Well Evaluation Project were modified to generate the plume configuration maps in this report.

RFETS is located approximately 4 miles east of the Front Range on a nearly flat-lying pediment surface, unconformably overlying nearly flat-lying bedrock (Figure 2-1). A conceptual cross-section of the local hydrogeologic setting at RFETS (Figure 2-2) illustrates that at the site, the shallow groundwater flows through two separate water-bearing layers, known as hydrostratigraphic units. These units are defined based on observed differences in hydrologic and geochemical characteristics for each flow system. These units are generally referred to as the upper hydrostratigraphic unit (UHSU) and the lower hydrostratigraphic unit (LHSU). A third hydrostratigraphic unit - a permeable, deep regional artesian aquifer known as the Laramie-Fox Hills Aquifer - lies below the LHSU and is used extensively as a water supply in the greater Denver area. The RFETS hydrostratigraphic units are described in the greater detail in the Hydrogeologic Characterization Report for the Rocky Flats Environmental Technology Site (EG&G 1995b).

The UHSU is the predominant water-bearing unit of concern at RFETS and is considered to be equivalent to the "uppermost aquifer" as defined by the Resource Conservation and Recovery Act (RCRA). It consists of unconsolidated, sandy and gravely materials mixed with clay (i.e., alluvium, colluvium, and artificial fill), as well as weathered bedrock claystones and sandstones which are hydraulically connected to the alluvium. The LHSU consists of unweathered claystone with some interbedded siltstones and sandstones. There is a significant difference in the ability of each unit to transmit groundwater. For example, the geometric mean hydraulic conductivity value of 2×10^{-4} centimeters per second (cm/sec) for the Rocky Flats Alluvium (UHSU) is about three orders of magnitude greater than that for unweathered LHSU Laramie claystones (geometric mean of 3×10^{-7}

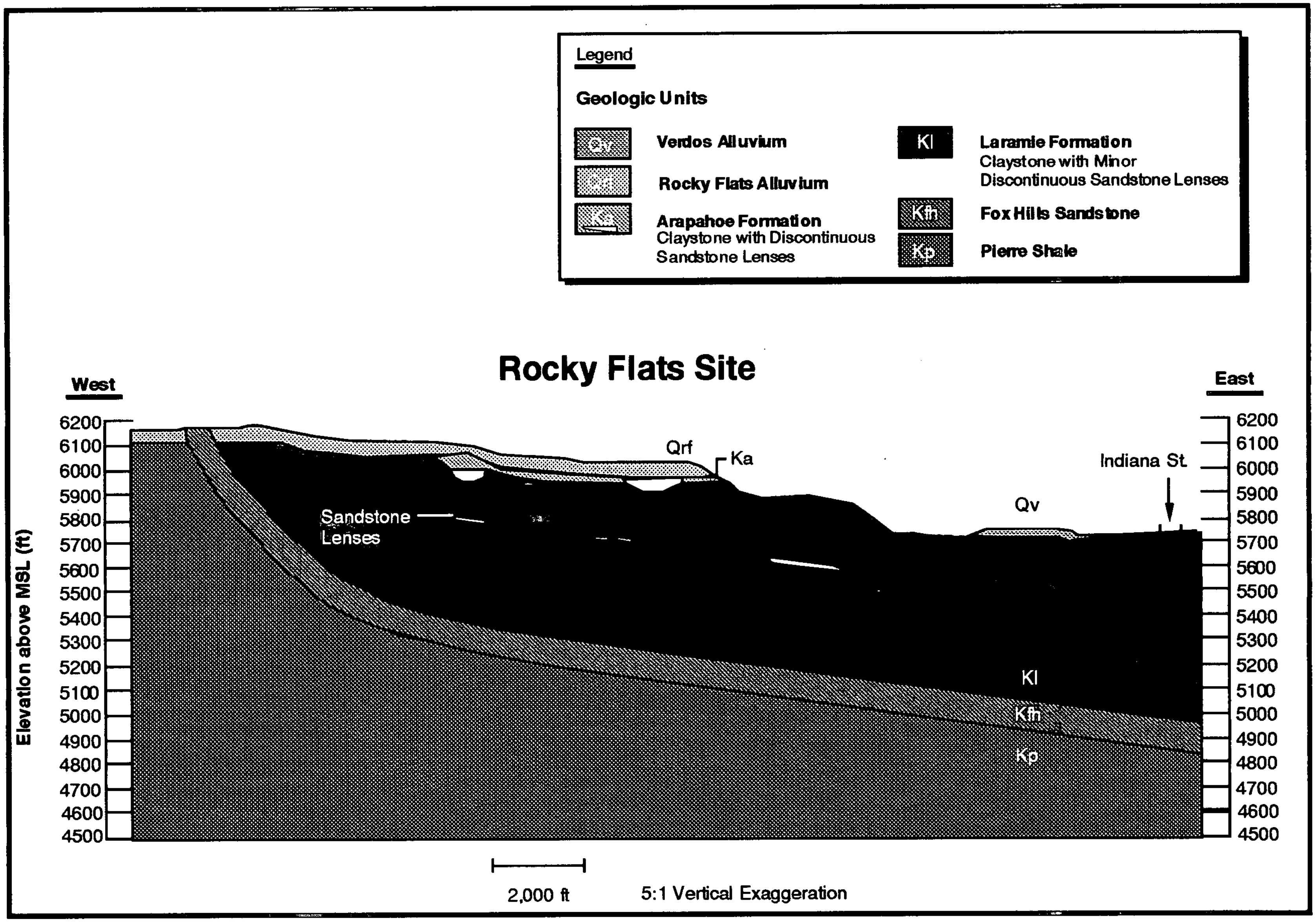
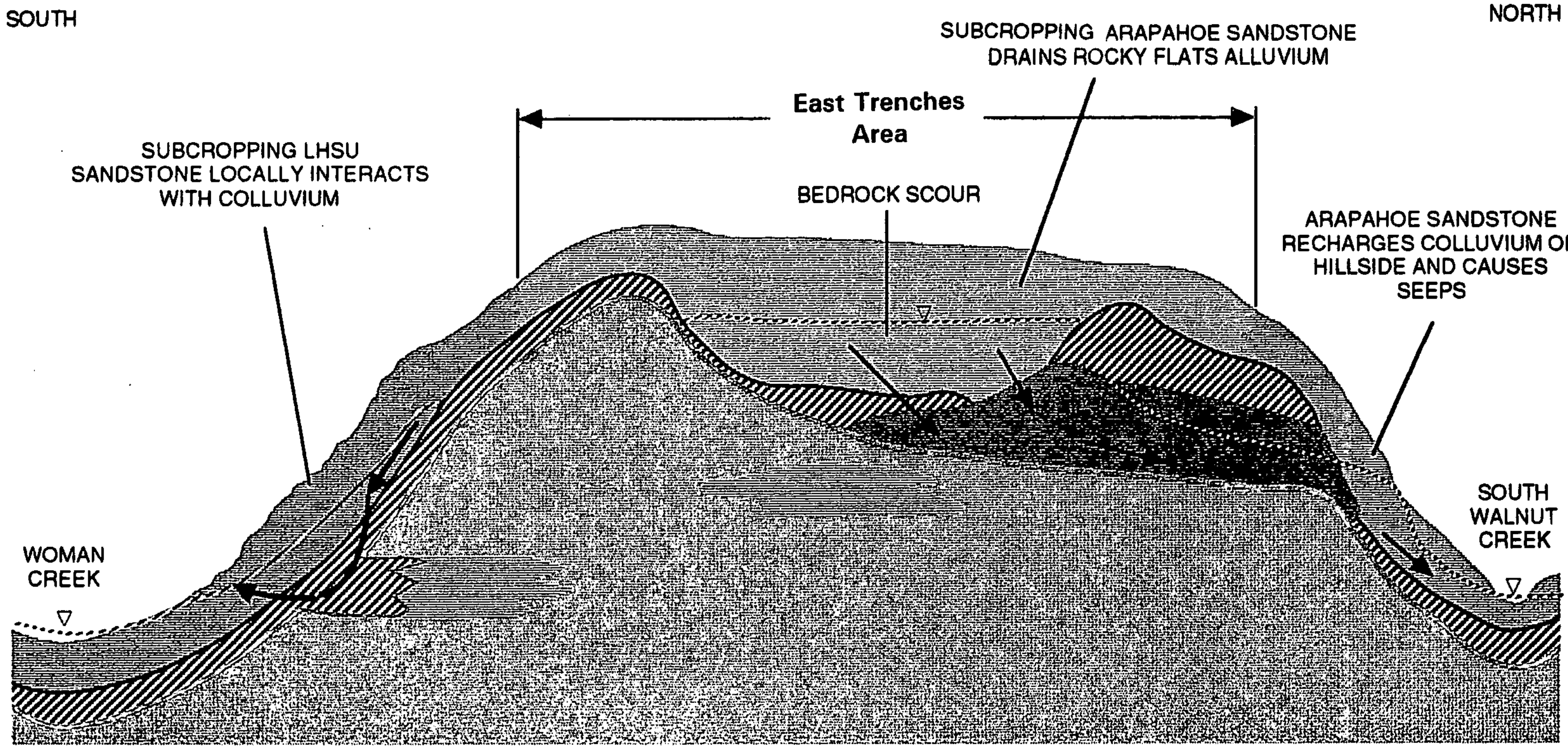


Figure 2-1 Generalized Geologic Cross-Section of the Rocky Flats Area



EXPLANATION

- (Qrf) ROCKY FLATS ALLUVIUM
- (Qc) COLLUVIUM
- UNWEATHERED CLAYSTONE/ SILTSTONE BEDROCK
- WEATHERED BEDROCK
- WEATHERED ARAPAHOE #1 SANDSTONE BEDROCK
- LHSU UNWEATHERED SANDSTONE BEDROCK
- GROUND WATER FLOW DIRECTION
- CONCEPTUAL UHSU/LHSU BOUNDARY
- WATER TABLE

Schematic Cross Section of Hydrostatigraphy at East Trenches Area

DRAFT OU2 PHASE II RFI/RI

April 1995

Figure 2-2

g95\ES\hydrodoc\hydrostat cross-sectn..cdw cm/sec) (EG&G 1995b). The hydraulic conductivities of LHSU materials are similar to that required for a landfill liner. Wells completed in the UHSU and LHSU generally have poor water-yielding characteristics that prevent their development as viable water sources for residential use, although a few isolated UHSU well locations (i.e., bedrock sandstones in OU 2 (EG&G 1992) and valley-fill alluvium in Walnut Creek near Indiana Street (EG&G 1995d) have sustainable well yields that could support limited household use.

The spread of individual groundwater contaminant plumes at RFETS is limited by natural hydrogeologic conditions, including: the magnitude and distribution of hydraulic conductivities and hydraulic gradients; limited aquifer extent and interception of plume fronts by hydrologic boundaries (i.e., interception of groundwater contaminant plumes by drainages); and other physical controls, such as bedrock topography and the presence of discontinuously saturated areas, that constrain and moderate groundwater and contaminant movement.

Generally, groundwater flows slowly at RFETS. For example, using Darcy's Law, the velocity of groundwater moving laterally through the Rocky Flats Alluvium in the East Trenches Area is estimated to be about 50 feet per year (assuming a hydraulic conductivity of 217.3 ft/yr, effective porosity of 0.1, and hydraulic gradient of 0.0213 ft/ft).

Because natural processes such as sorption and geochemical transformation reactions tend to attenuate the movement of organic contaminant plumes in groundwater, the velocity of contaminant movement is expected to be retarded relative to the groundwater flow velocity. Contaminants in the East Trenches Plume are expected to migrate at rates ranging from about 2.5 and 25 feet per year, based on a reasonable range of retardation factors and neglecting the effects of dispersion and diffusion. Other processes may further attenuate contaminant movement, such as diffusion of aqueous contaminants into clayey matrix materials. Therefore, in some cases, plume front movement appears to be imperceptibly slow. The apparent slow migration rate of some contaminant plumes at RFETS, although not fully understood, provides a level of confidence that temporary deferment of remedial actions at these plumes will not result in undue risks to the environment.

Groundwater in the surficial deposits of the UHSU generally flows to the east following bedrock and surface topography, and ultimately discharges to one of three stream drainages which are the main water pathways offsite. These drainages include Walnut and Woman Creeks, which receive groundwater flow from the IA, and Rock Creek, which receives groundwater flow from areas essentially unimpacted by RFETS activities. Surface water flow from the IA is controlled by a series of impoundments in the Walnut and Woman Creek drainages. These impoundments also intercept groundwater flow associated with the valley-fill alluvium and promote intermingling of surface water with groundwater prior to release offsite. As a result, there is no known direct hydraulic connection between impacted groundwater at RFETS and offsite domestic wells.

In partially saturated areas, alluvial UHSU groundwater has been shown to preferentially flow along predepositional channels cut into the underlying bedrock surface (see Figure 2-2). These channels are known to occur in the IA, Solar Ponds, 881 Hillside, 903 Pad, and East Trenches Areas. Groundwater flow is often concentrated within these channels, and hillside contact seeps result where these channels are cut by erosional surfaces. These channels restrict plume spreading and movement. Other hydrogeologic controls for groundwater flow and contaminant transport are hydraulic gradient, distribution of subcropping sandstones and claystones, and topography. In the IA, features such as interceptor drain systems, buried utility lines, and building foundation drains control groundwater flow.

The lithologic and hydraulic characteristics of the LHSU cause it to act as a regional confining layer for the underlying Laramie-Fox Hills Aquifer. The LHSU is a natural barrier to vertical groundwater flow and contaminant transport that effectively isolates impacted UHSU groundwater from deeper strata and the Laramie-Fox Hills Aquifer (RMRS 1996a). At RFETS, the LHSU is estimated to measure at least 600 feet in thickness as shown in Figure 2-1 (modified from EG&G 1995a). By comparison, the average RCRA landfill is lined with only a few feet of similar material. These stratigraphic relationships, combined with an observed downward vertical hydraulic gradient, result in a LHSU groundwater flow regime that is effectively separated from the UHSU, and is predominantly vertically downward rather than horizontal. The available data from groundwater monitoring in the LHSU indicates that it is uncontaminated.

The available hydrogeologic and geochemical data suggest that fractures and faults are not significant conduits for downward vertical groundwater flow at RFETS (RMRS 1996a). Evidence of limited shallow hydraulic communication between UHSU and LHSU groundwater was found to exist in some wells, but these occurrences do not present a pattern consistent with known fault locations.

Due to the thickness, lithology, and observed trend of decreasing hydraulic conductivity values with depth for the LHSU, it appears that the LHSU has sufficient hydrologic integrity to provide long term protection of the Laramie-Fox Hills Aquifer from shallow groundwater contamination (RMRS 1996a). The executive summary of the White Paper - Analysis of Vertical Contaminant Migration Potential - Final Report, RF/ER-96-0040.UN is presented in Appendix C and summarizes the hydrologic information used to reach the above conclusions.

3.0 ACTION LEVELS AND STANDARDS

The RFCA Preamble was used as the basis for development of the Action Levels and Standards Framework for Surface Water, Ground Water, and Soils. Protection of surface water quality is the primary basis for the cleanup and/or management of contaminated subsurface soil and groundwater at RFETS. Surface water, groundwater, and soil cleanup are interrelated, and all three media were considered in developing a sitewide strategy for RFETS.

Sections of the *Action Levels and Standards Framework for Surface Water, Ground Water, and Soils* (Attachment 5 of RFCA, July 19, 1996) were released for public comment beginning September 1, 1996 and ending October 4, 1996 with proposals to incorporate the clarifications and resolutions of soil issues that were reached after RFCA was signed. The proposed soil action level changes are expected to be finalized by October 18, 1996. The following sections summarize the approaches delineated in this document for monitoring and remediating surface water, groundwater, and subsurface soils for the purpose of protecting surface water quality and ecological resources.

3.1 SURFACE WATER

Groundwater will be managed to protect surface water quality. During active remediation, surface water quality standards and surface water management activities may be different than those applied after remediation. During active remediation, the water quality standards will apply at points of compliance located at the outfalls of the terminal ponds and at the Site boundary. These values will also be used as action levels upstream from the terminal ponds at existing gauging stations. When cleanup activities are complete, on-site surface water will meet surface water quality standards, and surface water leaving the site will be acceptable for all uses.

3.2 GROUNDWATER

As stated in the RFCA Preamble, domestic use of groundwater at RFETS will be prevented through institutional controls, and the only use on-site will be related to cleanup activities. Because no other human exposure to groundwater is foreseen, groundwater action levels are not based on human consumption or direct contact. Instead, action levels for groundwater have been selected to be protective of surface water quality and ecological resources. This framework for groundwater action levels is based on the assumption that contaminated groundwater emerges as surface water before leaving RFETS.

3.2.1 Action Levels

The Working Group has defined the action levels for groundwater Volatile Organic Compounds (VOCs) only, based on Maximum Contaminant Levels (MCLs) established under the Safe Drinking Water Act. MCLs are well-established and accepted values that have been used to guide cleanup at other contaminated sites. Where an MCL for a particular VOC contaminant is lacking, the residential, ingestion-based Programmatic Risk-Based Preliminary Remediation Goal (PPRG)* value will apply. A two-tiered action level approach to groundwater cleanup and monitoring was developed to protect surface water and identify areas of groundwater contamination potentially requiring cleanup. Tier I action levels consist of near-source action levels for accelerated cleanups, and Tier II action levels are protective of surface water quality. This approach is described below.

Tier I

Groundwater Tier I action levels are based on 100 times the MCL (100 x MCL) and were developed to identify potential cleanup targets. Contaminant concentrations in groundwater above the Tier I action levels indicate the presence of groundwater contaminant sources which may pose a risk to surface water quality. If Tier I action levels are exceeded, an evaluation is required to determine if source removal, or other cleanup or management action is necessary to prevent highly contaminated groundwater (i.e., contaminant concentrations exceeding 100 x MCLs) from reaching surface water. (The evaluation process is described in Section 4.1). This report represents the first phase of this evaluation.

Where action is necessary, the type and location of the action will be delineated and implemented as an accelerated action. Additional contaminated groundwater that does not exceed the Tier I action levels may also need to be remediated or managed to protect surface water quality or ecological

* PPRGs were developed and approved by DOE, EPA,.CDPHE, and EG&G in 1995 to establish sitewide cleanup targets for environmental contamination.

resources. The plume areas to be remediated and the cleanup levels or management methods used, will be determined on a case-by-case basis.

Tier II

The Tier II VOC action levels for surface water quality protection were developed to prevent contaminated groundwater above MCLs from reaching surface water. When Tier II action levels are exceeded at the designated Tier II wells, groundwater management actions are triggered. Tier II wells are located downgradient of existing plumes to detect the possible spread of the contaminant plumes. If concentrations in a Tier II well exceed MCLs during a regular sampling event, monthly sampling of that well will be required. Three consecutive monthly samples showing contaminant concentrations greater than Tier II action levels will trigger a groundwater action. These actions will be determined on a case-by-case basis and will be designed to treat, contain, manage, or mitigate the contaminant plume. Such actions will be incorporated into the Environmental Restoration Ranking and will be given weight according to measured or modeled impacts to surface water.

The Tier II action levels will be applied only at certain wells as described in Section 3.2 of RFCA Attachment 5. Table 3-1 presents the list of groundwater monitoring wells designated as Tier II monitoring locations. These wells are located at or near the boundaries of the composite VOC plumes shown in Figure 3-1. Additional Tier II monitoring wells may be installed, if necessary. The results of groundwater sampling and analysis at these wells will be integrated with concurrent surface water data for the purpose of evaluating potential impacts to surface water.

Table 3-1 Tier II Groundwater Monitoring Wells

Well Number	*Well Number*
6586	P314289
23196	P313589
23296	7086
75992	10992
06091	1786
23096	10692
10194	4087
1986	B206989
1386	

Groundwater Monitoring

All long-term monitoring requirements for RFETS, along with the Tier II wells identified in this report, will soon be incorporated into an Integrated Monitoring Plan (IMP). The document will combine and replace two pre-existing plans: (1) the Groundwater Protection and Monitoring Program Plan (GPMPP) (DOE 1993); and (2) the Groundwater Assessment Plan (GWAP) (DOE 1992a). The document also will describe recent changes to the groundwater monitoring network.

The IMP will list the wells with their appropriate data quality objectives, the sampling frequency, and analyte suite, as well as describe data evaluation and reporting methodologies. The IMP will also reference other implementation plans and decision documents from which the requirements are derived, and will be updated regularly as programmatic changes occur.

Analyte suites, sampling frequency, and specific monitoring locations will be evaluated annually to adjust to changing conditions such as plume migration and increased understanding of contaminant distributions. The present groundwater monitoring network will continue to operate as recently modified, until changes proposed in the IMP are agreed to by all parties. All groundwater monitoring data, as well as changes in hydrogeologic conditions and any exceedance of groundwater action levels, will be reported quarterly and summarized annually.

All groundwater remedies, as well as some soil remedies, will require groundwater performance monitoring. The amount, frequency, and location of any required performance monitoring will be based on the type of remedy implemented and will be determined on a case-by-case basis within the specific decision documents.

3.3 SUBSURFACE SOILS

Action levels for VOCs in subsurface soils were developed to be protective of surface water quality through groundwater transport of leached contaminants. Action levels for VOCs in subsurface soils were calculated using a soil/water partitioning equation and a calculated dilution factor (EPA 1994). The partitioning equation used chemical-specific parameters and site-specific subsurface media characteristics to calculate the expected equilibrium partitioning of a given contaminant between the soil and groundwater. The dilution factor accounts for dilution up to the edge of the source location. Subsurface soil contaminant levels that would be protective of groundwater to Tier I action levels of 100 x MCLs were then calculated. These action levels for subsurface soils are provided in Table 4 of RFCA Attachment 5.

It is currently not possible to accurately model transport of inorganics (e.g. metals and radionuclides) in subsurface soils. The proposal that is out for public comment between September 1 and October 4, 1996 is that the action levels for inorganic contaminants in subsurface soil will be the same as action levels for the corresponding contaminants in surface soil. These action levels are human-health risk based for the appropriate land-use receptor (office worker or open-space recreational user).

Tier I action levels for radionuclides in subsurface soils are the more conservative of:

- An annual radiation dose limit of 15 mrem for the appropriate land use receptor; or
- An annual radiation dose limit of 85 mrem for a hypothetical future resident assuming failure of passive control measures.

Tier II action levels for radionuclides in subsurface soils are an annual radiation dose limit of 15 mrem for a hypothetical future resident.

Where multiple radionuclides are present, the total dose from multiple radionuclides is calculated by the sum-of-ratios method. Additional subsurface soil may need to be remediated or managed to protect surface water quality or ecological resources. These additional sites will be determined on a case by case basis.

3.4 SURFACE SOILS

Surface soils are defined as the upper six inches of soil. Tier I action levels for non-radionuclides are human-health risk based (carcinogenic risk equal to 10^{-4} and/or a Hazard Index of 1) for the appropriate land use receptor. In the industrial use area, action levels are based on Office Worker exposure. For the buffer zone area, action levels are based on open space recreational user exposure.

Tier II action level for non-radionuclides are human-health risk based (carcinogenic risk equal to 10^{-6} and/or a Hazard Index of 1) for the appropriate land use receptor.

Action levels for radionuclides in surface soil are the same as described above for subsurface soils. Additional surface soil may need to be remediated or managed to protect surface water quality via runoff, or ecological resources. These additional sites will be determined on a case by case basis.

4.0 GROUNDWATER CONTAMINANT PLUMES AND REMEDIATION

4.1 IDENTIFICATION

The VOC-contaminated groundwater plumes at RFETS have the most potential to impact surface water or to migrate offsite as the mobility of VOCs in groundwater far exceeds the mobility of metals and radionuclides. These plumes were defined on the basis of the exceedances of the Tier II action levels and are shown on Figure 3-1. Tier I action levels were compared against all groundwater data to locate areas of highly contaminated groundwater. These areas were plotted and are shown on Figure 4-1 along with proposed locations of the conceptual groundwater actions.

The probable sources of the VOC contaminated groundwater plumes were identified using the available data and process knowledge. The RFCA Implementation Guidance Document (in preparation) will describe the method used to determine if remedial or management action is appropriate for an area.

There are six groundwater contaminant plumes identified where contaminant concentrations exceed Tier I action levels. In addition, there are several plumes and areas of interest where contaminant concentrations do not exceed Tier I action levels, or are of very limited extent, but that are of interest due their potential to impact surface water above RFCA action levels, or due to their contaminant concentrations. The groundwater contaminant plumes with VOC concentrations exceeding Tier I action levels are: (1) 881 Hillside Drum Storage Area Plume, (2) Mound Plume, (3) 903 Pad and Ryan's Pit Plume, (4) Carbon Tetrachloride Spill Plume, (5) East Trenches Area Plume, and (6) IA Plume. Additional plumes discussed that do not exceed the Tier I action levels, but may have the potential to impact surface water, include those at the Present Landfill, Solar Ponds, and the Property Utilization and Disposal (PU&D) Yard.

The 903 Pad and Ryan's Pit Plume, the Mound Plume, and the East Trenches Plume are part of a large composite plume on the east side of RFETS. Even though these contaminant plumes overlap, differing sources and flow paths make it effective to treat these parts of the large plume individually.

4.2 DESCRIPTIONS OF CONTAMINATED GROUNDWATER PLUMES

The extent of contaminated groundwater plumes in RFETS groundwater is not rapidly changing (see Section 2.0). The contaminated groundwater plumes are described below with much of the data derived from the relevant OU reports, and the Hydrogeologic Characterization Report (EG&G 1995b).

4.2.1 881 Hillside Drum Storage Area Plume

The 881 Hillside Drum Storage Area (IHSS 119.1) was in use from 1968 to December 1971. Primarily empty drums and scrap metal were stored at this location. Some of the drums had previously contained solvents and other organic chemicals. Other drums may have contained solvents or other organic chemicals contaminated with plutonium as indicated by the fact that hotspots removed in 1994 from this location had elevated plutonium levels (DOE 1995a).

The OU 1 881 Hillside is located on a south facing hillside that slopes downward from Building 881 to Woman Creek (Figure 4.2.1-1). The 881 Hillside is crossed by the South Interceptor Ditch (SID) which was designed to intercept surface water flow from the plant. In 1992, a French Drain was installed across the 881 Hillside to intercept contaminated UHSU groundwater suspected to be flowing down the 881 Hillside. A 3-foot-diameter recovery well was installed in an area of known contaminated groundwater to recover water containing high levels of dissolved VOCs.

At the 881 Hillside, groundwater occurs in the unconsolidated surficial materials. The surficial materials and underlying 5 to 25 feet of weathered claystone are 100 to 10,000 times more permeable than the underlying unweathered claystone. This significantly limits the flux of groundwater into and through the unweathered claystone (DOE 1994a).

Groundwater at the 881 Hillside does not exist within a continuous, homogenous, shallow aquifer system. The UHSU has a highly variable lithology and is not uniformly saturated across the Hillside. Large areas are dry, or contain water only in the spring when water table elevations are typically the highest. Groundwater is typically found in disconnected northwest-southeast trending paleochannels cut into the bedrock surface where there is a thicker section of colluvium and/or alluvium. Dry areas appear to be coincident with bedrock highs and other areas with thinner sections of colluvium and/or alluvium. The bedrock topography and surficial deposit thickness can be used to extrapolate where groundwater flow may occur (DOE 1994a).

Recharge to the UHSU is primarily through precipitation, with minor seepage from the Rocky Flats Alluvium. Discharge is primarily from evapotranspiration due to the dry climate and slow percolation rates, and is enhanced by the south facing slope of the Hillside. Discharge also occurs to the French Drain, the recovery well, and to surface water. Several small seeps are found along Woman Creek and along slump boundaries where UHSU groundwater intersects the surface.

Aquifer tests estimate the average flow velocity at 70 feet per year near the 881 Hillside Drum Storage Area. Hydraulic conductivities of the surficial materials range from 3×10^{-3} to 2×10^{-6} cm/sec. The transmissivity of the UHSU was calculated as 1.2×10^{-6} m^2 /sec, approximately 100 times less than what Driscoll (1989) considered sufficient to supply water for domestic or other low yield purposes. The volume of UHSU groundwater within the entire OU 1 881 Hillside Area was estimated at 5 acre-feet in April 1992 (DOE 1994a).

Groundwater data collected since the installation of the French Drain suggests that the drain is successful in collecting much of the UHSU groundwater. For example, the UHSU monitoring wells downgradient of the French Drain are generally dry, suggesting that the area has been dewatered (DOE 1994a).

The 881 Hillside Drum Storage Area (IHSS 119.1) is the site of historic releases of chlorinated VOCs to the environment from drums stored at this location (Figure 4.2.1-1). These releases have resulted in the contamination of shallow alluvial groundwater which has formed a small contaminant plume extending about 300 feet to the south-southeast down the 881 Hillside along a paleochannel incised into the underlying weathered claystone. Unconsolidated sediments on both sides of this plume are unsaturated.

The source of the groundwater contamination was further characterized during the 1996 field program to obtain sufficient data to plan a source removal. The field investigation identified two potential source areas: one immediately east of the collection well and one 50 feet northwest of the collection well (Figure 4.2.1-1). The eastern source area underlies one of the radiological hot spots removed in 1994. Both source areas could have been caused by leakage from individual drums (RMRS 1996b).

The contaminants in the plume which exceed Tier I concentrations are primarily carbon tetrachloride, 1,1 dichloroethene, tetrachloroethene, 1,1,1-trichloroethane and trichloroethene. Figure 4.2.1-1 provides the distribution of contaminant concentrations in groundwater at this location. A small seep located south of IHSS 119.1 and downgradient of the French Drain along Woman Creek was sampled once and this sample contained a trace amount of VOCs. It is not clear if the VOC concentrations in the seep water are related to the contaminant plume.

The contaminated groundwater plume is upgradient of the French Drain and does not appear to be increasing in size. The recovery well is located within this plume and collects approximately 100 to 150 gallons per day. This well appears to collect most of the contaminated groundwater originating from the contaminated groundwater plume. The French Drain remains in operation and continues to collect relatively uncontaminated groundwater which is treated at the Building 891 Consolidated Water Treatment Facility. The area immediately downgradient of the French Drain is unsaturated, indicating that the French Drain has dewatered much of the area.

The preferred remedy for this plume is source removal which was mandated by the 1995 dispute resolution committee composed of DOE RFFO, EPA and CDPHE. A Record of Decision (ROD) is currently in progress which will establish a remedial action based on the Public Comments to the recommended alternative of source excavation presented in the Proposed Plan (DOE 1996a).

4.2.2 Mound Site Plume

The Mound Site was used for as a disposal site for approximately 1,405 drums from April 1954 to September 1958. Drums contained depleted uranium, beryllium, lathe coolant (about 70% hydraulic oil and 30% carbon tetrachloride) and tetrachloroethene. Plutonium contaminated waste was also stored at this location, but plutonium levels were below detection limits. In 1970, the drums were removed along with radioactive soils identified using hand-held instruments. Additional radioactive soils were identified and removed at later dates (DOE 1992).

The OU2 Phase II RCRA Facility Investigation/Remedial Investigation (RFI/RI) investigation identified acetone, methylene chloride, tetrachloroethene, trichloroethene and cis-1,3,-dichloropropene in the subsurface soils (DOE 1995b). Characterization results indicate increasing concentrations of tetrachloroethene and trichloroethene to a depth of 20 feet and decreasing concentrations below that depth. The recent Mound Site investigation (in preparation) delineated the area of contamination as occurring near borehole 14295 and well 1987, comprising approximately 600 cubic yards.

The Mound Site is located at the northern edge of the pediment where up to 12 feet of Rocky Flats Alluvium overlies fractured claystone of the Arapahoe Formation. The topography slopes steeply to the north away from the Mound Site towards the incised drainage of South Walnut Creek. The Arapahoe No. 1 Sandstone subcrops under the alluvium at the northwest corner of the Mound Site. This sandstone is truncated by the South Walnut Creek drainage and subcrops beneath the colluvium between the Mound Site and South Walnut Creek.

In the vicinity of the Mound Site, the Rocky Flats Alluvium consists of beds and lenses of poorly to moderately sorted clayey and silty gravels and sands interbedded with clay and silty lenses. The hill slope below the contact between the Rocky Flats Alluvium and the underlying Arapahoe Formation is covered with unconsolidated colluvium primarily composed of clay, or silty and/or sandy clay. Caliche is common in both alluvium and colluvium. There are numerous slump features present on the hill slope.

Depth to groundwater is approximately 12 feet at the Mound Site (within the weathered bedrock), and unconsolidated materials are generally dry for much of the year. Saturated alluvium occurs in bedrock lows and paleoscours in the top of the bedrock. The groundwater flow appears to be primarily along the bedrock surface and is probably controlled by small channels incised into the bedrock surface. Groundwater flows to the north through the No. 1 Sandstone until it subcrops beneath the colluvium, indicated by a line of seeps along the slope towards South Walnut Creek. The geometric mean for the Rocky Flats Alluvium hydraulic conductivity is 6×10^{-4} cm/sec. The geometric mean for the Araphoe No. 1 Sandstone hydraulic conductivity is 7×10^{-4} cm/sec. The

geometric mean for unweathered bedrock is 8 x 10^{-8} cm/sec. Infiltration of precipitation or UHSU groundwater into the underlying unweathered claystone is limited (DOE 1995b).
Recharge occurs primarily through local infiltration of precipitation. The Central Avenue Ditch runs along the southern boundary of the Mound Site and probably also recharges the UHSU groundwater in this area. Discharge from the UHSU is mostly through seeps located where the water bearing units are truncated by the South Walnut Creek, and through evapotranspiration.

The groundwater contaminant plume is poorly defined, but it is suspected to extend northward from the former location of the Mound Site (Figure 4-1) to a point of discharge along the south bank of South Walnut Creek upstream of the RFETS Sewage Treatment Plant. Depending on the season, there may be many unsaturated areas within the plume. Dense nonaqueous phase liquids (DNAPLs) in the Mound Site area are suspected to be the source of the groundwater contamination. Trench T-1 could possibly contribute to this plume; however, dry wells between the Trench T-1 and the Mound Site indicate that the Mound Site is the primary source of the contaminated groundwater plume. The groundwater plume at the Mound Site apparently receives only minor contribution from VOC contamination at the 903 Pad. Wells in both the No. 1 Sandstone and alluvium upgradient of the Mound Site contain 0 to 2 micro grams per liter (ug/l) total VOCs (DOE 1995b) (Figure 4.2.2-1). There is an east-west bedrock high located between the 903 Pad and Mound Site, near the south side of the Mound Site (Figure 4.2.2-2). VOC contaminated groundwater from the 903 Pad generally flows to the south of the Mound Site, on the south side of this bedrock high.

Thirty-five VOCs were detected in the contaminated groundwater at the Mound Site. All except tetrachloroethene, trichloroethene, cis-1,2-dichloroethene and vinyl chloride were below 100 ug/l. Tetrachloroethene was the predominant contaminant with the highest concentration of 13,000 ug/l found at the Mound Site. The maximum concentrations of cis-1,2-dichloroethene (214 ug/l) and trichloroethene (410 ug/l) were detected with the maximum tetrachloroethene value. Concentrations of these chemicals decrease towards South Walnut Creek. The maximum vinyl chloride concentration detected was 860 ug/l in a well along the South Walnut Creek drainage. The well is located over 500 feet from the source area, which indicates that this is a degradation product, not a primary constituent (DOE 1995b).

The contaminant plume is discharging through surface and subsurface seeps along the hillside, and along seeps on the south bank of South Walnut Creek. At seep SW059, groundwater containing low levels of VOCs with trace amounts of radionuclides discharges at a rate of 0.5 gallons per minute, or less. The seep water is collected and treated at the Building 891 Combined Water Treatment Facility.

4.2.3 The 903 Pad and Ryan's Pit Plume

This contaminant plume has two closely spaced sources: (1) VOCs associated with drums formerly stored at the 903 Storage Area, where the contents of the drums leaked into the subsurface and groundwater; and (2) Ryan's Pit where VOCs were disposed of in a trench (Figure 4-1). The 903 Pad was characterized as part of the OU 2 Phase II RFI/RI investigation (DOE 1995b) and the following information was derived from that report.

The 903 Pad area was used to store drums that contained radioactively contaminated oils and VOCs from the summer of 1958 to January 1967. Approximately three quarters of the drums contained plutonium-contaminated liquids while most of the remaining drums contained uranium-contaminated liquids. Of the drums containing plutonium, the liquid was primarily lathe coolant and carbon tetrachloride in varying proportions. Also stored in the drums were hydraulic oils, vacuum pump oils, trichloroethene, tetrachloroethene, silicone oils, and acetone still bottoms.

Leaking drums were noted in 1964 during routine handling operations. The contents of the leaking drums were transferred to new drums, and the area was fenced to restrict access. When cleanup operations began in 1967, a total of 5,237 drums were at the drum storage site. Approximately 420 drums leaked to some degree. Of these, an estimated 50 drums leaked their entire contents. The total amount of leaked material was estimated at around 5,000 gallons of contaminated liquid containing approximately 86 grams of plutonium. From 1968 through 1969, some of the radiologically contaminated material was removed, the surrounding area was regraded, and much of the area was covered by clean road base and an asphalt cap.

Ryan's Pit, previously referred to as Trench T-2, is located approximately 150 feet south of the 903 Pad (Figure 4.2.2-1) and is approximately 20 feet long, 10 feet wide, and five feet deep. Ryan's Pit was used as a waste disposal site from 1969 and 1971 for nonradioactive liquid chemical disposal. VOCs disposed at this location included tetrachloroethene, trichloroethene, and carbon tetrachloride. In addition to VOC disposal, paint thinner and small quantities of construction-related chemicals may also have been placed in Ryan's Pit. According to historical data, only the liquids themselves were put in the pit; their containers were either reused or disposed of in other areas (DOE 1992b).

Materials placed in the Ryan's Pit were supposedly screened for radionuclide activity prior to disposal. However, field investigations conducted in 1987 through 1993 do not substantiate this claim. The contaminated soils were removed from this site and treated during the 1995 removal action at Ryan's Pit. Free phase tetrachloroethene and motor fuel constituents were found during this removal action, along with degraded drums and plutonium contaminated soils. Free phase DNAPLs are also suspected to exist underneath the 903 Pad as high concentrations of VOCs are present in the groundwater (greater than 1% of the chemical's solubility).

The 903 Pad is located on the flat surface at the southern edge of the pediment. A south facing hillside slopes downward from the 903 Pad to the SID and Woman Creek. Ryan's Pit is located on the hillside about 200 feet from the southern edge of the 903 Pad. In the 903 Pad area, the Rocky Flats Alluvium is 10 feet thick at the northwest corner of the Pad which is near a bedrock high, and 25 feet thick at the southeast corner which is within a bedrock channel. The 903 Pad is paved with asphalt, and artificial fill is present under the 903 Pad and covers a large area to the south and east of the Pad.

The Rocky Flats Alluvium is truncated by erosion and does not extend to Ryan's Pit. The Ryan's Pit surficial deposits consist of reworked Rocky Flats Alluvium that has been transported down slope, along with other clay-rich colluvium deposits and fill material. Surficial deposits consist of colluvium between one and eight feet thick which is primarily clay, and silty or sandy clay. Caliche is common in both the alluvium and colluvium. Groundwater at Ryan's Pit is between 3 to 10 feet below ground surface. On the slope, there are numerous slump features, and a large scarp face is located between the 903 Pad and Ryan's Pit.

Bedrock in the 903 Pad and Ryan's Pit area is primarily composed of weathered claystone of the Arapahoe and Laramie Formations. In addition, the Arapahoe No. 1 Sandstone subcrops under the alluvium at the extreme northwest corner of the 903 Pad. This sandstone is continuous with the Arapahoe No. 1 Sandstone at the Mound Site, where it is truncated by the South Walnut Creek drainage. The geometric mean for the Rocky Flats Alluvium hydraulic conductivity is 6×10^{-4} cm/sec. The geometric mean for the Araphoe No. 1 Sandstone hydraulic conductivity is 7×10^{-4} cm/sec. The geometric mean for unweathered bedrock is 8×10^{-8} cm/sec. Infiltration into the underlying unweathered claystone is limited (DOE 1995b).

Groundwater flow is complex and is primarily controlled by bedrock surface features, interactions between geologic units, and variations in saturated thicknesses. Groundwater flow paths in alluvial materials in the 903 Pad and Ryan's Pit area are relatively well-defined by contact seeps with the underlying bedrock materials and by numerous wells. However, groundwater flow through the hillside colluvium and bedrock is poorly understood. Areas of unsaturated colluvium are common and prediction of local flow paths is difficult. Depending on the season, there may be many unsaturated areas within the plume. Discharge of contaminated groundwater has not been observed from the colluvium or weathered bedrock portion of this plume.

A large bedrock low (paleoscour) extends from the 903 Pad east and passes directly south of the northern East Trenches. This paleoscour is bounded by bedrock highs to the north and south. Near the 903 Pad, there is 20 to 25 feet of relief between the paleoscour and the northern bedrock high, and 5 to 10 feet of relief between the paleoscour and southern bedrock high (see Figure 4.2.2-1). The paleoscour directs groundwater flow to the east till it is truncated by the South Walnut Creek drainage where alluvial groundwater discharges into the head of a well-developed gully. Groundwater flow from the 903 Pad towards the SID and Woman Creek also occurs either by overtopping of the lower, southern bedrock high, or through breaks in the bedrock high. During dry periods, the bedrock highs restrict alluvial groundwater flow to the south and north. During wet periods, when the alluvial groundwater levels are very high, flow may overtop these barriers, primarily to the south (DOE 1995b).

Groundwater flow in the colluvium follows north-south trending small paleochannels cut into the underlying bedrock claystone. One narrow paleochannel, approximately 150 to 300 feet wide, extends from the 903 Pad south through Ryan's Pit (Figure 4.2.2-1). The areas surrounding these paleochannels is unsaturated. The southern extent of groundwater flow is not well defined due to lack of well control.

Recharge is primarily from infiltration of precipitation along with some recharge from ditches and other surface water features. Wells located to the west of the 903 Pad are generally dry as alluvial groundwater inflow from the west is restricted by the claystone bedrock high just west of the 903 Pad. Unconsolidated materials within the medial portion of the paleoscour tend to be saturated, with the extent of saturation greatest during the spring. Groundwater flow occurs through the No. 1 Sandstone until it subcrops beneath the colluvium. Discharge is primarily to seeps located where the water bearing units are truncated by the South Walnut Creek drainage. All UHSU groundwater is discharged to seeps or into the colluvium.

The 903 Pad and Ryan's Pit Plume is defined as the lobe of contaminated groundwater that flows southward from these two source areas. This plume flows southward toward the SID and Woman Creek drainage. The lobe of contaminated groundwater which flows eastward from the 903 Pad is addressed as part of the East Trenches Plume (Figure 4.2.2-1).

Contaminated groundwater in the 903 Pad and Ryan's Pit area is primarily confined to the alluvium and colluvium. Total VOC concentrations for the Arapahoe No. 1 Sandstone are approximately 2,500 ug/l adjacent to the west edge of the 903 Pad with concentrations at other locations less than 2 ug/l or non-detect. Fifty-seven VOCs were detected in UHSU groundwater for this plume. However, the primary contaminants are carbon tetrachloride, tetrachloroethene, and trichloroethene. The southern component of the contaminant plume derived from the 903 Pad contains total VOCs in the 5,000 ug/l range near the Pad, diminishing to 1,500 to 2,000 ug/l range upgradient of Ryan's Pit. Downgradient of Ryan's Pit, the total VOC concentration in groundwater ranges from 57,000 ug/l near the Pit to 5 ug/l near the distal end of the plume. The total VOC concentration in contaminated groundwater from the 903 Pad which does not also flow through the Ryan's Pit source is also estimated at 5 ug/l when it nears Woman Creek drainage (DOE 1995b).

The highest concentrations of many VOC contaminants in the former OU 2 area are located within this plume. The highest concentration of tetrachloroethene (150,000 ug/l) was detected immediately downgradient of Ryan's Pit and occurred with 1,1-dichloroethene at 380 ug/l. A well installed through the center of the 903 Pad contained concentrations of carbon tetrachloride in groundwater at 20,000 ug/l, chloroform at 39,000 ug/l and methylene chloride at 35,000 ug/l. A well installed though the northeast corner of the Pad detected tetrachloroethene at 14,000 ug/l. The highest concentrations of VOCs in groundwater are near the 903 Pad and Ryan's Pit sources, although wells with VOC concentrations exceeding Tier I levels have been observed within the plume away from these sources (Figure 4.2.2-1).

Contaminated groundwater containing tetrachloroethene and trichloroethene may eventually enter the SID and Woman Creek surface water pathways if no actions are taken to manage this plume. Discharge of contaminated groundwater into Woman Creek would pose a potential risk to the environment. Collection and treatment of contaminated groundwater from the 903 Pad and Ryan's Pit plume may reduce the potential risk to the environment posed by uncontrolled releases to surface water.

4.2.4 Carbon Tetrachloride Spill Plume

The Carbon Tetrachloride Spill (IHSS 118.1) is located due north of Building 776 and east of Building 730 (Figure 4.2.4-1). While there are other IHSSs that overlap IHSS 118.1, (IHSSs 121-Tank 9, 121-Tank 10, 131, and 144[N]), the contamination in the area is primarily related to the carbon tetrachloride spills.

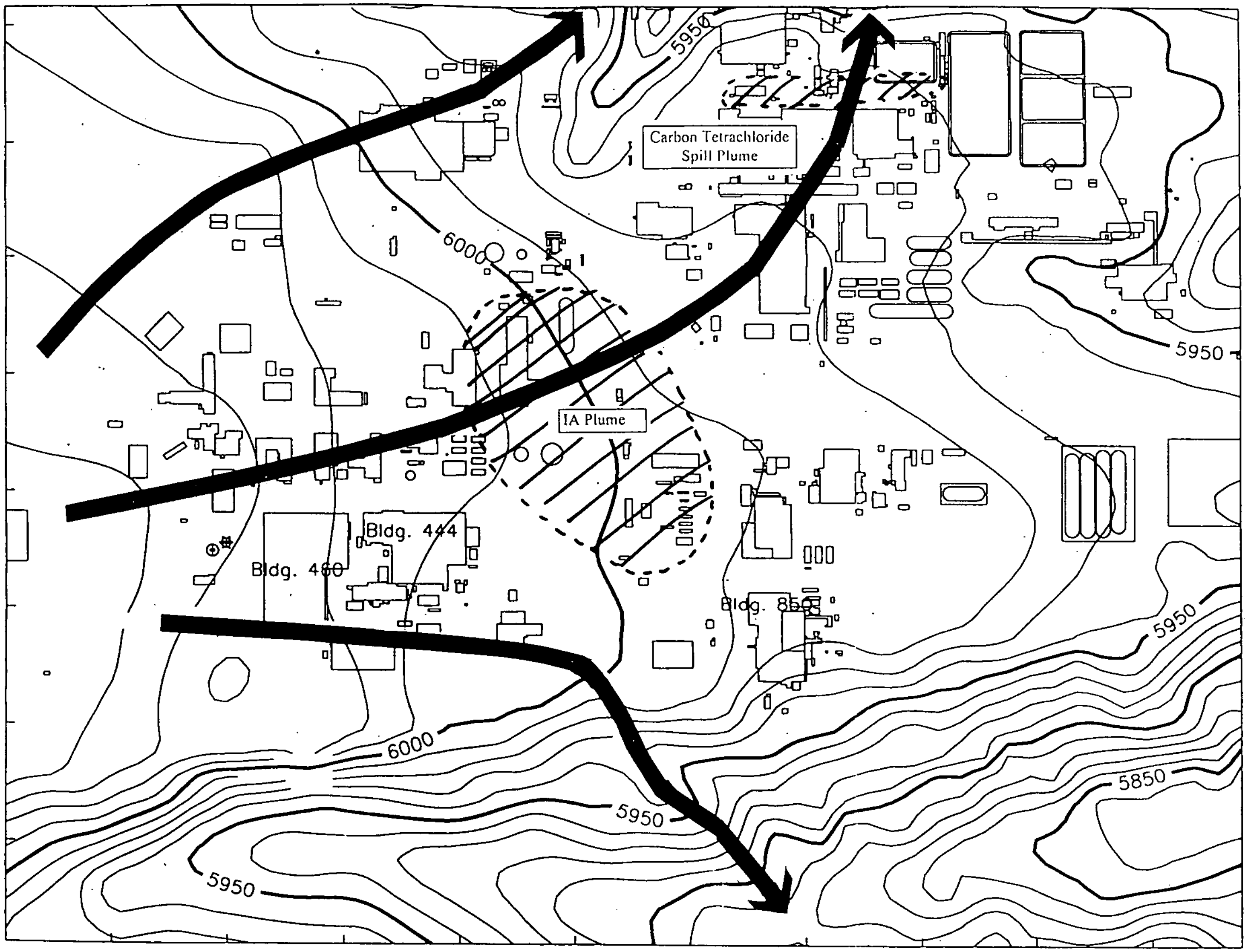
IHSS 118.1 is the site where an underground, 5,000-gallon, carbon tetrachloride steel storage tank and the associated piping were formerly located. The tank was installed prior to 1970, and probably began leaking shortly after installation. Numerous spills occurred before 1970, some between 100 to 200 gallons. The tank ultimately failed in June 1981, releasing carbon tetrachloride into the containment structure. The carbon tetrachloride was pumped from the containment structure to the surrounding ground surface, and the tank was removed along with a limited amount of soil surrounding the tank. The surrounding concrete containment structure was probably removed at this time also, but this has not been verified (DOE 1992b).

The surrounding area has numerous underground and overhead utilities and structures. These include clay sanitary sewer lines, electrical lines, tunnels between buildings, process waste lines and process waste tanks. Immediately east and partially overlapping this site is a group of four process waste tanks oriented east-west, tank groups T-9 and T-10. T-9 consists of two 22,500 gallon underground concrete storage tanks. T-10 consists of two 4,500 gallon concrete underground tanks. Both sets of tanks were installed in 1955, but are no longer used as process waste tanks. T-9 is currently being utilized as a plenum deluge catch tank for Building 776. No releases from either set has been documented (DOE 1995c).

Due to past construction activities in this area, the material overlying the claystone bedrock is predominantly fill material, probably derived from the Rocky Flats Alluvium, along with some remaining undisturbed Rocky Flats Alluvium. The Rocky Flats Alluvium consists of unconsolidated gravels, sands and clays with discontinuous lenses of clay silt and sand. The geometric mean for the hydraulic conductivity of the Rocky Flats Alluvium is estimated at 2.06×10^{-4} cm/sec (EG&G 1995b).

The recent IA investigation found free product in the subsurface soil and groundwater related to IHSS 118.1. All four of the soil borings drilled around T-9 and T-10 intercepted free-phase carbon tetrachloride (DOE 1995c). When a water sample was collected at this location, the liquid separated into two distinct phases. Other VOCs may be present, but the high concentrations of carbon tetrachloride may mask their detection. The top of bedrock surface prior to construction of Building 771 sloped to the northeast. Excavation during construction of this building altered this surface as the claystone surface was found 10 feet or more below where it was expected during the recent field investigations. Excavation may have either increased the slope of the bedrock surface, or created a bedrock low closed by the building. The bedrock in this area is claystone which limits vertical migration of the carbon tetrachloride. As carbon tetrachloride sinks to the lowest possible depth, the bedrock surface, building footing drains, and subsurface structures probably control the extent of the free-product plume and much of the dissolved phase portion of the contaminated groundwater plume.

Groundwater flow in this area is to the northeast towards Buildings 771 and 774 where there are known footing drains (Figure 4.2.4-2). Buildings 701 and 730 are not believed to have subsurface structures. Monitoring wells in the area contain carbon tetrachloride which indicates that a dissolved



Groundwater Flow Direction

Groundwater Contaminant Plume (100 x MCL)

Note: Contours reflect local influence of building foundation and footing drains

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Figure 4.2.4-2 Industrial Area Potentiometric Surface and Plume Location Map plume is present in the groundwater. In addition to carbon tetrachloride, several other VOCs are present in the groundwater plume; primarily 1,1-dichlorethene, chloroform and acetone (Figure 4.2.4-1). This contaminated groundwater plume may eventually reach the North Walnut Creek drainage, especially after removal of the surrounding buildings.

Carbon tetrachloride and trichloroethene concentrations have been detected in a downgradient well completed in the Arapahoe No. 1 Sandstone at the western edge of the Solar Ponds, due east of IHSS 118.1. The RFEDS database shows that for this well, carbon tetrachloride concentrations range from approximately 1,000 to 21,000 ug/l and the trichloroethene concentrations range from 2,000 to 8,000 ug/l. The concentrations fluctuate greatly over time, but there is a general decreasing trend. The carbon tetrachloride spill is believed to be the source of this contamination and, if true, this would indicate that there is some eastward movement of the dissolved phase of the plume. The decreasing trend over time may be a result of the VOCs originally in the vadose zone at the time of the spill, flushing out of the upper soil horizon and/or settling to the bedrock surface, where there is less contact with groundwater. It is also possible that the Solar Ponds VOC contamination is related to a still unidentified contaminant source.

The Solar Ponds area is in hydraulic connection with subcropping Arapahoe No. 1 Sandstone which could act as a conduit to surface water for the dissolved phase carbon tetrachloride plume. The extent of the contamination in the sandstone is unknown, and a limited investigation is proposed to determine the extent of contamination and whether there is a pathway to surface water.

4.2.5 East Trenches Plume

A large plume of contaminated groundwater is located in the East Trenches area, primarily associated with the trenches on the north side of the East Access Road. These trenches are known as the Northeast Trenches and include Trenches T-3, T-4, T-10 and T-11. Upgradient wells indicate a component of the contaminated groundwater in this area is derived from the VOC contamination in the 903 Pad (see Section 4.2.3 and Figure 4.2.2-1). However, the VOC concentrations in groundwater increase over 100 times after the groundwater passes through Trenches T-3 (IHSS 110) and T-4 (IHSS 111.1), indicating a VOC source is present (DOE 1995b).

Trench T-3 is located approximately 300 feet north of the East Access Road and immediately west of Trench T-4. Trench T-3 is approximately 134 feet long, 20 feet wide and 10 feet deep (DOE 1992b). Trench T-4 is approximately 110 feet long, 15 feet wide, and 10 feet deep (RMRS 1996c). The trenches were reportedly used sometime between 1954 to 1968 for disposal of sanitary sewage sludge, potentially contaminated with uranium and plutonium, and flattened empty drums contaminated with uranium. The trenches are also known to contain DNAPLs, crushed drums, and other miscellaneous waste. Except for the debris found in the trenches, activities of the trench material are below the RFETS soil put-back levels.

Trench T-3 and T-4 are located at the northern edge of the pediment where up to 18 feet of Rocky Flats Alluvium overlies fractured claystone and the No. 1 Sandstone of the Arapahoe Formation. Beyond the pediment boundary, the topography slopes steeply to the north towards South Walnut Creek. Both the alluvium and the Arapahoe No. 1 Sandstone are truncated by the South Walnut Creek drainage. Both of these trenches have been excavated as a source removal action in 1996.

The unconsolidated surficial deposits consist of the Rocky Flats Alluvium and artificial fill in the trenches and are generally dry. The Rocky Flats Alluvium consists of beds and lenses of poorly to moderately sorted clayey and silty gravels and sands interbedded with clay and silty lenses or beds. Thickness of the alluvium is approximately 18 feet at Trench T-4 and 16 feet at Trench T-3. Below the outcrop of the contact between the Rocky Flats Alluvium and the underlying Arapahoe Formation, the slope is covered with unconsolidated colluvium primarily composed of clay, or silty and sandy clay. Caliche is common in both alluvium and colluvium. On the slope, there are numerous slump features.

Underlying the alluvium to the north of the trenches is the continuation of the claystone bedrock high from the 903 Pad Area. The center of the associated paleoscour runs beneath Trenches T-11 and T-10 to the south of Trenches T-3 and T-4 (Figure 4.2.2-2). This feature directs the surficial groundwater flow to the east, away from South Walnut Creek. However, the Arapahoe No. 1 Sandstone subcrops beneath the eastern portion of trench T-3 and most of Trench T-4. This fluvial sandstone is incised into the surrounding bedrock claystone and consists of sandstone, clayey sandstone, and silty sandstone. The channel of the Arapahoe Formation No. 1 Sandstone is approximately 40 feet thick and mostly saturated. Groundwater flow is generally unconfined, and flow within the channel is northward towards South Walnut Creek (EG&G 1995c). The sandstone subcrops beneath the colluvium between the trenches and South Walnut Creek at a spring and seep complex.

The geometric mean for the Rocky Flats Alluvium hydraulic conductivity is 6 x 10^{-4} cm/sec. The geometric mean for the Arapahoe No. 1 Sandstone hydraulic conductivity is 7 x 10^{-4} cm/sec and the geometric mean for unweathered bedrock is 8 x 10^{-8} cm/sec. Infiltration into the underlying unweathered claystone is limited.

Recharge of the Rocky Flats Alluvium is primarily through infiltration of precipitation, and upgradient flow from within the paleoscour. Recharge to the No. 1 Sandstone is from infiltration of precipitation through the surficial deposits, and some flow from upgradient. Discharge is primarily to seeps and springs located where the water bearing units are truncated by South Walnut Creek and by evapotranspiration.

Contaminated groundwater occurs in the alluvium and in the No. 1 Sandstone that is in hydraulic connection with the alluvium. While 27 VOCs were detected within the UHSU groundwater, the majority were detected at concentrations below 100 ug/l. The major contaminants are trichloroethene (maximum value of 94,000 ug/l), carbon tetrachloride (maximum value of 4,500 ug/l), and tetrachloroethene (maximum value of 1,000 ug/l). During the Soil Vapor Extraction Pilot Test Project, stratified water/NAPL samples were collected and analyzed from Trench T-3. These samples contained high levels of VOCs, up to 37,000,000 ug/l for tetrachloroethene along with semivolatiles, petroleum compounds, and uranium-238 at concentrations up to 3,240 pCi/g (DOE 1995b). In addition, borehole samples collected from T-4 contained 12,000 ug/kg tetrachloroethene and 1,000 ug/kg trichloroethene.

The downgradient boundary of the contaminant plume is located at a spring and seep complex on the south bank of South Walnut Creek, above Ponds B-1 and B-2, where the No. 1 Sandstone subcrops. Concentrations of VOCs above 100 x MCLs have been detected by a recent sampling program conducted at the seep complex. There may be potential ecological impacts because water from the contaminant plume containing tetrachloroethene and trichloroethene has reached South Walnut

Creek. If concentrations in the seep complex increase over time, a greater contaminant mass may reach surface water.

A lobe of this contaminant plume extends to the east of the East Trenches area along the paleoscour cut into the bedrock surface. However, contaminated groundwater has not reached surface water. Uncontaminated alluvial groundwater discharges downgradient of this lobe as seeps in an unnamed tributary drainage to South Walnut Creek. This groundwater will continue to be monitored ensure that contaminated groundwater from this lobe does not impact surface water.

4.2.6 IA Plume

Several sources in the IA contribute trichloroethene, tetrachloroethene, and carbon tetrachloride to the contaminated groundwater plume in the IA. The plume is defined based on a small number of wells, and is thought to be principally confined to the east central side of the plant. It is not clear whether it is a large coalesced plume, or discrete areas of contaminated groundwater closely associated with individual source areas. The contaminated groundwater plume is outside of the fenced portion of the protected area (PA) and extends downgradient towards the central portion of the IA. Primary contaminant sources are described below and shown on Figure 4.2.4-1.

IHSSs 117.1 was used as a general storage yard from before 1959 to the early 1970s and is located northeast of Building 551 (DOE, 1992b). The IA soil gas investigations found elevated soil gas levels of tetrachloroethene (2,200 ug/l), with less than 20 ug/l concentrations of trichloroethene and carbon tetrachloride and cis-1,2-dichloroethene. Elevated benzene, toluene, ethylbenzene and xylene (BTEX) levels are present in the southwest edge of the IHSS (DOE 1995d).

IHSS 117.2, located east of Building 551, was used as a chemical storage site from prior to 1971 until approximately 1988. This site was used to store acids, oils, soaps, solvents, and beryllium scrap metal. Minor leaks and spills occurred (DOE 1992b). The IA soil gas investigations determined the presence of elevated levels of 1,1-dichlorethene (2,700 ug/l) along with concentrations above 100 ug/l for vinyl chloride, cis-1,2 dichloroethene, trans-1,2-dichloroethene, trichloroethene, and tetrachloroethene. Elevated concentrations of BTEX are also present (DOE 1995d).

There have been numerous carbon tetrachloride spills within Building 776, resulting in suspected under building contamination. This building may be the source of low level concentrations of carbon tetrachloride in groundwater on the eastern side of the plantsite.

The IHSS 157.1 is adjacent to the Building 442 Laundry. Very low level concentrations (below 5 ug/l) of tetrachloroethene were detected in soil gas samples from this location (DOE 1995d).

IHSS 158 is an area where waste boxes were staged and loaded onto rail cars. This area is considered a radioactive site, and is located north of Building 551. Soil gas surveys found concentrations above 100 ug/l for vinyl chloride, toluene, and BTEX at this location (DOE 1995d).

IHSS 160 is a parking lot on the west side of Building 444. Drummed and boxed wastes were stored at this location prior to paving, and leaked (DOE 1992b). The soil gas survey detected tetrachloroethene at 99 ug/l at this location. Concentrations less than 10 ug/l each of toluene, acetone, and benzene are also present (DOE 1995e).

IHSS 171 is a training area for fire department personnel. In the past, diesel, gasoline and possibly waste solvents were ignited for fire fighting training purposes. The area is currently in use, and a metal tree is used for burning propane for training. Large volumes of water are used during training which may tend to accelerate migration of any contaminant plume. As expected, large concentrations of BTEX are present in the subsurface soils. Soil gas samples do not indicate high concentrations of VOCs. However, during drilling of a geoprobe hole in this IHSS, the rod came up coated with a brown liquid. Unfortunately, a sample could not be collected for analysis. It is possible that free product VOC does exist at this location (DOE 1995d).

The hydrogeology of the IA has not been as extensively studied as other areas at RFETS. The Hydrogeologic Characterization Report (EG&G 1995) was the primary source for the following hydrogeologic information. The IA is located on a pediment capped by the Rocky Flats Alluvium. The pediment has been eroded at the sides to expose the underlying claystone of the Arapahoe and Laramie Formations. The Rocky Flats Alluvium consists of unconsolidated gravels, sands and clays with discontinuous lenses of clay silt and sand. Fill material is abundant and usually consists of reworked Rocky Flats Alluvium. The geometric mean for the hydraulic conductivity all of RFETS Rocky Flats Alluvium is 2.06 x 10^{-4} cm/sec (EG&G 1995b).

Groundwater occurs under unconfined conditions and flow is generally controlled by the topography of the underlying bedrock surface. Groundwater flow direction in the IA is generally eastward, with groundwater in the northern sections flowing to the northeast (Figure 4.2.4-2). Several building footing drain systems locally impact groundwater flow. Small bedrock channels are known to occur which direct the groundwater flow.

The IA groundwater plume is greatly influenced by the RFETS infrastructure. Groundwater recharge in the IA is from upgradient flow, infiltration of precipitation and substantial water losses from sewers and water-supply pipelines. Reduction of recharge from these sources could significantly reduce the potential for contaminant migration in the subsurface.

The saturated thickness in the IA is typically 5 feet or less, with the greatest saturated thicknesses in the western part of the IA, decreasing to less than 5 feet in the eastern half of the IA. There are many unsaturated zones, particularly in the eastern half of the IA. These unsaturated areas are controlled by the bedrock, with bedrock highs generally dry. The decrease in saturated thickness in the eastern half of the IA may be caused by impermeable areas, such as parking lots and buildings, which greatly limit infiltration. In addition, areas of high local recharge may be created adjacent to the impermeable areas. Approximately 190 of 438 acres within the IA are covered by impermeable material. As a result, a greater amount of storm water runoff is channeled to permeable areas and may account for the large variations in saturated thickness.

Discharge from the IA is probably primarily to building footing drains, engineered structures such as the OU 1 French Drain and the Solar Ponds Interceptor Trench System, and potentially to seeps at the boundary of the IA. Both the Interceptor Trench and OU 1 French Drain have removed sufficient water from the surficial deposits to cause these to be locally unsaturated. Infiltration of groundwater into the underlying bedrock is generally limited due to the low hydraulic conductivity of the unweathered bedrock.

The IA groundwater contaminant plume extent is also controlled by interception of the plume by building footing drains and by the increased permeability and hydraulic conductivity through buried utility corridors. Full understanding of the migration of this plume depends on knowing how the various buildings, utility corridors, and sources interact. Unfortunately, there is insufficient knowledge of these factors to completely determine the configuration of this plume.

Figure 4.2.4-2 shows the average concentrations of VOC contaminants in the groundwater wells, and the probable contaminant sources. Treatment of contaminated groundwater within the IA does not appear to be necessary to protect surface water, because of the limited potential for migration. However, ongoing monitoring and evaluation of the groundwater will continue, to detect any movement or expansion of the plume. Groundwater remedial actions may become necessary if the contaminant plumes expand, migrate significantly or become a threat to surface water. Actions such as removal of buildings, removal of subsurface structures, and placing impermeable caps over areas must be examined to determine whether these will increase the movement of the contaminated groundwater plume. Controls may be required if increased groundwater contaminant plume movement results from these actions.

4.2.7 Additional Plumes and Areas of Contaminated Groundwater

There are several areas where there are sporadic occurrences of VOC-contaminated groundwater, or where there are contaminant plumes with VOC concentrations less than 100 x MCLs. Contaminant plumes in the Present Landfill and Solar Ponds groundwater do not contain VOC concentrations greater than 100 x MCLs. However, these plumes are of interest because they are associated with RCRA units. In addition, a widespread but diffuse VOC plume is located near the PU&D Yard west of the Present Landfill. The setting and status of many of these plumes and occurrences are discussed below.

Present Landfill Plume

Operation of the Present Landfill (IHSS 114) for disposal of nonradioactive solid waste began in 1968 and will continue until the new landfill opens, or another method of waste disposal is available. The landfill covers an area of approximately 27 acres (Figure 1-1). The total volume of landfill material is approximately 415,000 cubic yards and consists of approximately 291,000 cubic yards of waste and 124,000 cubic yards of soil cover.

Elevated tritium and strontium concentrations were detected in leachate draining from the landfill in 1973. To control the migration of contaminants, interim response actions were taken. Interim response activities included construction of a surface-water diversion ditch around the perimeter of the landfill, two detention ponds immediately east of the landfill (West Landfill Pond and East Landfill Pond), a subsurface intercept system for diverting groundwater around the landfill and a subsurface leachate collection system. Between 1977 and 1981, the leachate collection and groundwater intercept system were buried beneath waste during landfill expansion. The lateral expansion of waste placement resulted in waste being located beyond the extent of the subsurface drains to the north and south. In 1982, two soil bentonite slurry walls were constructed to prevent groundwater migration into the expanded landfill area.

Leachate is a product of natural biodegradation, infiltration, precipitation, and migration of groundwater through waste. Approximately 5,756,000 gallons of leachate are present in landfill debris within the intercept system and above the unweathered claystone bedrock which is considered the underlying confining unit. The saturated thickness of surficial materials is greatest near the center of the landfill which suggests that recharge may be occurring by groundwater flow under or through the north groundwater intercept system. Groundwater inflow may be occurring where the groundwater intercept system is not keyed into bedrock. Although an area of the south slurry wall is also not keyed into bedrock, well data indicates that it is effective in diverting groundwater.

During the Phase I RI/RFI investigation, 38 discrete groundwater samples were taken. In addition, 1990-1993 monitoring well data from 52 wells were used as the basis for determination of preliminary contaminants of concern. Groundwater in the UHSU at OU 7 contained metals, radionuclides, organic constituents and nitrates at concentrations higher than background (EG&G 1994).

The highest concentration of chlorinated hydrocarbons occurred in groundwater upgradient of the landfill. VOC contamination upgradient is composed entirely of chlorinated hydrocarbons. In contrast, average BTEX concentrations were highest in leachate collected from within the landfill. The BTEX compounds were not detected in upgradient groundwater. Different types of VOC contamination are presented within the landfill and upgradient (southwest) of the landfill, suggesting that a distinct source of VOC contamination is present upgradient of the landfill.

Two separate groundwater plumes exist in the vicinity of the Present Landfill (Figure 3-1). The plume from the landfill source is located west of the landfill and is migrating down the No Name Gulch drainage. A second plume from an unknown source upgradient of the landfill is located in the groundwater south of the current landfill. The second plume is diverted to the south of the southern slurry wall. A groundwater divide is located approximately 500 feet south of the southern slurry wall.

Antimony, iron, manganese, tritium, uranium-238, chloromethane, ethylbenzene, and vinyl chloride concentrations in the groundwater from the landfill plume exceed the Groundwater Tier II Action Levels. Because of the proximity to No Name Gulch, monitoring and further evaluation are required.

Solar Ponds Nitrate Plume

The Solar Evaporation Ponds (SEPs) consists of five surface water impoundments (Figure 1-1). From 1953 to 1986, these were used to store and evaporate radioactive process wastes and neutralized acidic process wastes containing high levels of nitrate and aluminum hydroxide. The materials placed into the SEPs included radioactively contaminated aluminum scrap metal, alcohol wash solutions, drums of waste radiography solutions, leachate from the Present Landfill, treated sanitary effluent, groundwater intercepted from the Interceptor Trench System (ITS), salt water solutions, wash water from the decontamination of production personnel, cyanide wastes, acid wastes and miscellaneous other compounds (DOE 1995f). Removal of pond sludge began in June 1985 and was completed for all SEPs by January 1995.

The SEPs are on the eastern boundary of the pediment capped by the Rocky Flats Alluvium. Streams have eroded the pediment to the north and south with topographic relief of 50 to 100 feet. Much of the surficial deposits have been disturbed by construction of the SEPs, the ITS, nearby buildings and other infrastructure, however, borehole logs suggest that undisturbed Rocky Flats Alluvium often occurs below the disturbed ground.

Thickness of the unconsolidated material ranges from 0 to 25 feet, and averages about 10 feet. The Rocky Flats Alluvium overlies over the erosional bedrock surface and consist of poorly to moderately sorted gravel, sand, silt and clay with boulder to pebble size clasts derived from the nearby Front Range. Artificial fill was used as for road grade fill, berm construction, recontouring around engineered structures, and to fill in lows for the surface impoundments. Fill consisted of reworked Rocky Flats Alluvium with imported offsite materials including crushed rock, plus sandy clay and gravel with fragments of concrete rubble. The Arapahoe Formation unconformably underlies the Rocky Flats Alluvium and fill materials. Claystone is the predominant subcropping lithology, but the No. 1 Sandstone subcrops in the vicinity of South Walnut Creek.

The shallow, unconfined groundwater occurs in unconsolidated surficial material and fractures in the underlying bedrock and the potentiometric surface generally mimics the surface topography. General flow direction is to the northeast under the SEPs. A bedrock high trending east-west under the SEPs diverts the northern flow to the north-northeast towards North Walnut Creek, and the southern flow to the east-southeast towards South Walnut Creek. Unsaturated areas are present over a large part of the area, in part due to the ITS. However, unsaturated areas to the south and east are not impacted by the ITS. The saturated thickness varies from 0 to 5 feet over most of the area, and is thinner along topographic highs, or on slopes where there are thin alluvium or colluvium deposits. Along North and South Walnut Creek, the saturated interval can be as much as 10 feet thick.

Hydraulic conductivity for the Rocky Flats Alluvium in this area is around 10^{-5} cm/sec. No data were given for the fill material. The hydraulic conductivities for the subcropping bedrock claystone ranges from 10^{-7} to 10^{-9} cm/sec. The hydraulic conductivities for the subcropping bedrock sandstone ranges from 10^{-5} to 10^{-6} cm/sec (DOE 1996b).

A large UHSU nitrate plume extends north and east from the Solar Ponds to the North Walnut Creek drainage above Pond A-1. Three wells with uranium concentrations above background are also found in the contaminated groundwater plume. A lobe of this nitrate plume extends to the southwest for a short distance. While the primary nitrate source has been removed for several years, this contaminant plume still contains nitrates at concentrations above 100 x MCLs. However, samples taken from the ITS show that nitrate concentrations within the plume are decreasing. For November 1993, nitrate concentrations were 366 mg/l, and in June 1995, nitrate concentrations were 277 mg/l (RMRS 1996d). The ITS was installed to intercept contaminants and capture the nitrate plume. It was replumbed in 1993 to increase its effectiveness. The ITS captures approximately 2.7 million gallons of water per year, but is not entirely effective in preventing nitrate contamination from impacting the North Walnut Creek drainage (DOE 1994b).

VOCs are present in the groundwater at the western edge of the Solar Ponds Area and are most likely related to the carbon tetrachloride spill from IHSS 118.1 discussed earlier (Section 4.2.4.) Carbon tetrachloride is present at well P210189 at concentrations of 4,700 ug/l, along with tetrachloroethene at 1981 ug/l and trichloroethene at 2,200 ug/l. This well is completed through 4 feet of silty sandstone at a depth of 31 feet which is believed to be the Arapahoe No. 1 Sandstone. This subcropping sandstone could act as a conduit for the dissolved phase carbon tetrachloride plume. The extent of the contamination in the sandstone is unknown, and a limited investigation is proposed to determine the extent of contamination and whether there is a pathway to surface water.

PU&D Yard Plume

The PU&D Yard has been used since 1974 to store drums, cargo boxes and dumpsters. The PU&D Yard is located northwest of the industrial area in an area approximately 225 feet by 830 feet (Figure 1-1). Materials known to have been stored there include spent batteries, metal shavings coated with lathe coolant, and drums of spent solvents such as paint thinners and waste oils. Drummed hazardous material was also transferred in this area. Subsurface contamination may exist from historical spills associated with past hazardous material transfer operations and storage at the site. Releases of battery acids and leaks from dumpsters and drums of spent solvents and waste oils have been reported.

The PU&D Yard is underlain by the Rocky Flats Alluvium which is approximately 25-30 feet thick in the vicinity. The alluvium is underlain by Arapahoe Formation claystone. Groundwater in this area flows to the east through the UHSU materials, mimicking the surface topography.

Recent soil gas investigations have verified the presence of volatile organic compounds immediately outside the eastern boundary of the PU&D Yard. Organics, metals, and radionuclides have also been detected in surface soils (DOE 1995g). However, there are no subsurface samples of the soil and groundwater from this area.

An area of poorly defined, contaminated groundwater, with VOC concentrations slightly above the MCLs, is located downgradient of the PU&D Yard, and upgradient and to the south of the Present Landfill. Further investigation is required to identify the source or determine whether there is potential for impact to surface water quality.

Other 881 Hillside Groundwater Contamination

There are several one-time detects of VOCs in groundwater along the 881 Hillside (Figure 1-1). These do not seem to be related to a source, and may be more related to the problems of detecting very low levels of VOCs. In addition, there are two areas where contaminated groundwater has been identified, but where no action is required. Immediately adjacent to Building 881, there are sporadic detects of low concentrations of chlorinated solvents in groundwater. This suggests that several small point sources may exist in this area that are related to building operations.

The UHSU monitoring wells within the IHSS 119.2 drum storage area are dry or do not detect VOCs. However, there are infrequent detects of VOCs in groundwater sampled from two wells located within the drainage downgradient from IHSS 119.2. The source of these sporadic VOC detections may be the volatile plume derived from the 903 Pad.

In addition to the VOC contamination, the 881 Hillside groundwater contains selenium and vanadium at above background levels. Neither of these elements is a documented RFETS waste, nor requires remedial action to protect surface water.

Original Landfill Groundwater Contamination

The Original Landfill was in operation from 1952 to 1968 and was used to dispose of approximately 2 million cubic feet of miscellaneous RFETS waste (Figure 1-1). Accurate and verifiable records of the material placed into this landfill are not available, but all of the waste material was considered non-hazardous at the time. However, paint, solvents, paint thinners, oil, pesticides, and cleaning agents were placed in the landfill as these were not considered hazardous in 1968. The landfill also received some beryllium, depleted uranium, and used graphite. The Original Landfill does not have a liner, but the underlying unweathered claystone has a permeability of 10^{-5} to 10^{-7} cm/sec. The landfill was closed with a soil cover sometime after 1968 and prior to 1980 (DOE 1996c).

Groundwater occurs in the surficial deposits, primarily in the landfill material and alluvium. Many groundwater samples were collected during the OU5 RFI/RI investigation from wells, hydropunch samples from boreholes, and one-time samples from well points. The groundwater COCs identified for the Original Landfill are barium, manganese and radium, however, these do not correlate well with the waste known to be disposed at this site. Two small areas of VOC contaminated groundwater in are present in the Original Landfill area. One area is associated with a subsurface soil gas anomaly, the other is upgradient of the Original Landfill, probably related to the IA (Section 4.2.6).

The OU5 RFI/RI soil gas investigation (DOE 1996c) located two, small, subsurface soil gas anomalies at the Original Landfill. One area is approximately 50 feet by 50 feet and associated soil gas samples contain trichloroethene and 1,1,1-trichloroethene, and the other is about 64 feet by 64 feet and associated soil gas samples contain tetrachloroethene and trichloroethene. Trichloroethene (maximum concentration of 19 ug/l) is sporadically detected in groundwater at one well associated with the larger anomaly. There are no VOCs in groundwater associated with the other anomaly.

One well upgradient of the Original Landfill (P416789) has had three historical detects of TCE. This well is probably detecting contaminated groundwater from the Industrial Area Plume. Seep samples from a location immediately downgradient of this well also contained trace amounts of VOCs.

Walnut Creek Drainage Groundwater Contamination

Several wells in the area of the OU 6 trenches (IHSSs 166.1, 166.2 and 166.3) have detected low-level VOC and metal groundwater contamination. Neither the subsurface soil samples taken from the OU 6 trench area nor the wells within the nearby Present Landfill contain the same contaminants found in the OU 6 wells which are located outside of the Present Landfill slurry wall. However, wells upgradient of the Present Landfill and outside of the slurry wall exhibit similar contaminants and concentrations (see PU&D Yard plume above) (DOE 1996d and EG&G 1994).

There several theories for the occurrence of these low levels of VOCs and metals (DOE 1996d):

- The trenches (IHSSs 166.1 to 166.3) may be the source of contamination and the field investigation did not detect these sources;
- The Present Landfill is the source, and the southern intercept wall is inadequate;
- Wastes may have been emplaced beyond the southern slurry wall; or
- Contamination is from a source upgradient of the Present Landfill, potentially the PU&D Yard.

VOC contaminated groundwater is found upgradient of the Present Landfill (average total VOC concentration of 71 ug/l), as well as south of the slurry wall (31 to 68 ug/l average total chlorinated hydrocarbons). In addition, well data indicates the south slurry wall is effective (EG&G 1994). Therefore, it is most likely that the contamination has migrated from a source upgradient of the Present Landfill.

4.3 CLEANUP ALTERNATIVES

The goal of this Groundwater Conceptual Plan is to manage and/or cleanup groundwater in order to be protective of surface water quality. The proposed cleanup of contaminated groundwater involves source removal or source containment, with treatment or management of the contaminated groundwater plumes, to achieve this goal. Conceptual remedies for each major contaminant plume were developed by assessing the available technologies, and proposing a cost-effective, readily available technology.

Both active and passive remedial actions were initially considered. Active treatment actions such as pump-and-treat methods are well-known and accepted, but typically have high operation and maintenance costs, can have a negative impact on wetlands, may consume groundwater, have limited application in clayey aquifers, and are relatively inefficient for DNAPL source removal. Passive treatment actions include passive collection of groundwater with *ex situ* or *in situ* treatment. These systems may have higher initial capital costs, but have lower operation and maintenance costs, low energy consumption, no water consumption, and reduced equipment requirements. Passive treatment will collect contaminated groundwater, but will not remove the source.

The pump-and-treat methodology is commonly used and accepted. EPA has identified the pump-and-treat methodology as one of the most frequently used methods for groundwater remediation, but recognizes that pump-and-treat methods may require decades of potentially expensive operations to achieve cleanup levels (EPA 1992). A preliminary analysis was performed on the potential effectiveness of pump-and-treat methods at RFETS. The analysis concluded that pump-and-treat methods would not be an effective treatment for most contaminant plumes at RFETS, based on the following:

- Neither the UHSU nor the LHSU are capable of producing significant quantities of water, because both have a relatively large clay content.

- Aquifer tests conducted at RFETS show that, for the most part, aquifer yields are low, ranging from 0.000006 gpm to 12 gpm, with an average of 0.3 gpm (EG&G 1995b).

- Factors limiting water production within the UHSU include relatively thin saturated thicknesses and the presence of broad areas that become unsaturated during the fall and early winter (EG&G 1995b).

- Surficial deposits at RFETS have hydraulic conductivities in the 10^{-3} to 10^{-4} cm/sec range, whereas weathered and unweathered claystone bedrock have hydraulic conductivities in the 10^{-7} cm/sec range. The valley-fill alluvium is the most permeable unit, but no contaminant sources are known to be present in this unit.

- Due to the relatively low permeability of the geologic units at RFETS, cones of depression induced by groundwater removal would typically have very steep gradients, requiring a large number of closely spaced wells to effectively implement pump-and-treat remediation.

- Upgradient extraction of groundwater may adversely impact the present widespread distribution of seeps and springs (EG&G 1995b).

- Most of the contaminant plumes in RFETS groundwater have suspected DNAPL sources. It is probably not cost effective or even possible to eliminate the DNAPL sources of dissolved plumes. EPA (1993) recognizes that conventional methodology such as pump-and-treat may not be effective for DNAPL sources, and that short term remediation objectives should generally involve removal of the source material, prevent exposure to contaminated groundwater and containment of the plumes. Pump-and-treat or passive methods tend to be ineffective because:

  - DNAPLs have low dissolution rates in water and are denser than water, and therefore tend to sink to the bottom of the unit;
  - The high clay content tends to adsorb DNAPLs, making these difficult or impossible to remove; and
  - Pump-and-treat remediation leaves residual DNAPLs, which will continue to act as a source, further releasing dissolved contaminants to the groundwater system.

It may be possible to implement pump-and-treat methods for groundwater near the East Trenches, where the No. 1 Sandstone is contaminated. However, a large number of closely-spaced wells would be required to effectively pump-and-treat groundwater due to the low conductivities and the resulting steep cones of depression. DNAPL contamination could easily remain after treatment. For these reasons, and the associated higher costs for this methodology, the pump-and-treat option was not considered as the proposed remediation treatment in this area.

When properly placed, a passive collection system near the distal ends of plumes will effectively capture the dissolved phase of the contaminated groundwater, but a contaminated plume would be left upgradient to naturally attenuate (DOE 1995h). The contaminants in the plume will degrade with time, and upgradient water will flush the source material toward the collection system.

All proposed actions discussed below were selected to be effective, inexpensive to install and operate, and require minimal plant infrastructure support. For these and the preceding reasons, passive treatment actions are the preferred proposed remediation.

Passive systems proposed for treatment of contaminant plumes in RFETS groundwater include:

- *In situ* passive collection and treatment system such as a funnel and gate, where contaminated groundwater is funneled into a reactive barrier by selective placement of relatively impermeable barriers. Treated water is released back into the groundwater downgradient of the barrier. Such treatment systems have been used effectively at other sites.

- Collection of contaminated water from springs, seeps, and/or shallow drains, then pumping the collected water to an existing treatment facility (Building 891 Combined Water Treatment Facility), and discharging the treated water to the surface water system.

- Passive collection of contaminated water from springs, seeps, and/or shallow drains, then using gravity to feed the collected water through a nearby, *ex situ* treatment system, which uses granulated activated carbon, reactive iron, or other simple treatment options such as air strippers.

The passive treatments proposed in this plan could use any of these methods and are conceptual in nature. No engineering feasibility analyses were performed and the proposed remedial actions were not evaluated with regard to changing site conditions over time. Before implementation of any remedy, an evaluation will be done to determine the most appropriate, effective, implementable, and cost-effective remedy for each plume of contaminated groundwater. The result of these evaluations will be presented as part of ASAP, the 10 Year Plan, or in a planning or implementation document such as an Interim Measure/Interim Remedial Action (IM/IRA), along with the data used to make the decision. It is possible that, as a result of these evaluations, different remedial actions will be selected for the different contaminant plumes in RFETS groundwater.

Assumptions

The proposed conceptual remedial actions for treatment of contaminated groundwater were developed using the following assumptions.

- RFETS groundwater will not be used for domestic or other consumptive purposes, and there are no pathways for contaminated groundwater to directly impact human receptors.
- Groundwater will be managed or remediated to protect surface water and to minimize potential ecological impacts.
- Source removals or containment of subsurface soil sources will be designed to prevent further migration of groundwater containing contaminant concentrations greater than 100 x MCLs.
- Remediation and plume management will preserve wetlands where possible.
- Proposed actions will be implemented using cost-effective methodologies.
- Based on preliminary analysis, passive groundwater treatment or containment would appear to be the preferred remedial alternative for most contaminant plumes in RFETS groundwater.
- Performance monitoring will be conducted for all remediation systems to verify effectiveness.
- The remediation and management decisions described herein are based on the existing data set for contaminant plumes, as well as on known technologies that are believed to be applicable to treatment of RFETS groundwater.
- For this plan, the proposed actions are assumed to be passive treatment or containment devices. Passive treatment systems will be sited downgradient from the sources and coincident with the Tier I boundary within the plume, or where otherwise practicable and

feasible. The actual remedial actions and location of these actions will be decided on a case-by-case basis and detailed in an IM/IRA or Proposed Action Memorandum (PAM) before implementation.

- An abbreviated alternatives analysis for any proposed action will be presented as part of ASAP or as an IM/IRA decision document.

- As per RFCA, contaminant plumes in RFETS groundwater which are stable and do not impact surface water above action levels will not require cleanup.

- All remedial actions will be consistent with the proposed RFETS end state.

4.4 POTENTIAL CLEANUP ACTIONS

Using available information, the following potential actions were conceptually developed for each major VOC contaminant plume in groundwater. As contaminated seeps are the most distal ends of these contaminated groundwater plumes, these will be managed through cleanup of groundwater sources, natural attenuation, and/or interception at or upgradient of seep locations in accordance with the Action Level Framework and the ER ranking. Further analysis of alternatives for feasibility, cost effectiveness, and suitability must be performed before initiating any action. Figure 4-1 shows the conceptual location of the groundwater actions.

4.4.1 Potential Action for the 881 Hillside Drum Storage Area Plume

The final remedy proposed for OU 1 is to excavate those soils containing VOC concentrations greater than the Tier I action levels. The volume of the source area requiring excavation is estimated at between 900 and 1,900 cubic yards of colluvium and weathered bedrock. Excavating the source will also remove much of the contaminated groundwater above Tier I action levels (RMRS 1996b). After demonstrating that this proposed remedy has been effective, and that the source and much of the resulting contaminated groundwater have been removed, the French Drain and recovery well are expected to be removed from operation.

This remedial action will be protective of surface water quality, and should reduce or eliminate any potential long-term stress to environmental receptors of contaminants that may reach Woman Creek.

4.4.2 Potential Action for the Mound Site Plume

Cleanup of the Mound Site contaminated groundwater plume will consist of excavating the subsurface soil exceeding Tier I action levels for soil cleanup criteria for VOCs. Contaminated materials in Trench T-1 will also be removed using the same criteria. The remedial action proposed for the groundwater with concentrations of VOCs in excess of Tier I action levels is to perform near-surface collection of the plume front before it reaches South Walnut Creek. Interception of the contaminant plume will be accomplished by making improvements to the existing seep collection system at SW059. The contaminated water is expected to be treated by a passive system installed along the south bank of South Walnut Creek.

Containment and treatment of the contaminant plume in Mound Site groundwater will result in a reduction of risk to the environment posed by uncontrolled releases of contaminated groundwater to surface water.

4.4.3 Potential Action for the 903 Pad and Ryan's Pit Plume

The proposed action is to remove contaminant sources exceeding the Tier I soil action levels for VOCs in soil from the 903 Pad area. Removal of the subsurface soils in the Ryan's Pit area has already been completed. The remedial action proposed for the groundwater with concentrations of VOCs in excess of Tier I action levels is to perform near-surface collection of the plume front before it reaches Woman Creek. The contaminated water is expected to be treated by a passive system.

4.4.4 Potential Action for the Carbon Tetrachloride Spill Plume

There are three potential actions identified for this groundwater contaminant plume: (1) source removal by using shallow recovery wells to attempt to remove as much of the free-phase carbon tetrachloride as possible, (2) removal of the contaminated soils, adjacent tanks, and associated piping, and/or (3) *in situ* treatment such as steam stripping. At this time, the building infrastructure in the area is containing this plume. Monitoring must continue to ensure that contaminated groundwater does not impact surface water. After removal of the infrastructure, near surface capture of this plume may be required to minimize impacts to surface water. If required, the captured water will be treated at a nearby passive treatment plant. This area may be capped as part of the 10 Year Plan. The impact on groundwater must be determined to see if additional controls are necessary.

4.4.5 Potential Action for the East Trenches Plume

Source remediation for Trenches T-3 and T-4 was completed in 1996 to remove subsurface soils that exceed the applicable RFETS soil cleanup criteria for VOCs. This action removed the contaminant source of this contaminated groundwater plume. The remedial action proposed for the remaining contaminated groundwater plume is to install a near-surface plume capture system near the distal end of the plume, and to use passive technologies to treat the contaminated groundwater.

4.4.6 Potential Action for the IA Plume

This groundwater contaminant plume may not require action because source removals and deactivation and decontamination activities may remove contaminant sources, the source of water in the plume may be reduced over time as capping and/or regrading and revegetation reduces infiltration, and water loss from the RFETS utilities will be eliminated. Monitoring must continue to ensure that contaminated groundwater does not migrate, or create a threat to surface water. An upgradient groundwater barrier is not recommended as preliminary calculations indicate that only 15 percent of the present recharge (precipitation plus groundwater influx) to the IA could be diverted by an upgradient barrier, preventing approximately 4 gallons per minute of groundwater flux from entering the IA.

4.4.7 Potential Actions for Additional Plumes

Present Landfill Plume

An interim remedial action has been installed at this location to collect the contaminated groundwater and leachate flowing from the landfill for treatment. This gravity-driven system consists of cement vaults for collecting the contaminated water. Treatment includes a settling basin, bag filters to remove suspended solids, and granular activated carbon to remove organic chemical constituents. Contaminated water is treated to comply with established cleanup levels. This treatment should effectively mitigate the potential ecological risk from the contaminants of concern. The treatment system may change or be eliminated once the Present Landfill Cap is installed. because groundwater migration may no longer be a concern.

Solar Ponds Nitrate Plume

Proposed remedial actions for the groundwater nitrate plume, if required, will be developed at a later date, based on final cleanup standards and site-specific hydrogeologic conditions. No source removal is planned for nitrate-containing media. However, a cap/cover is being considered, which would reduce the groundwater recharge and the flow through the nitrate-contaminated soils.

Recommendations from the Working Group, if approved by the Colorado Water Quality Control Commission (CWQCC), will change the stream classification for nitrates from drinking water [10 milligrams per liter (mg/l)] to agricultural (100 mg/l). There is some possibility that this surface water will be used for irrigation. Measures are being implemented which will restrict use of this water for domestic use. If the drinking water classification is lifted, then the nitrate concentrations seen in the surface water as a result of the nitrate plume are acceptable for all of the remaining uses, and could be of benefit for irrigation.

PU&D Yard Plume

A limited field investigation will be completed in 1997 to determine the impact to surface water. This may be followed by a source removal the same year. The limited field investigation will determine whether groundwater remedial action(s) are required to protect surface water.

Other 881 Hillside Groundwater Contamination

No action is required to mitigate this plume as it is not impacting, or expected to impact surface water. Any point sources around the building are expected to be dealt with during building demolition.

Original Landfill Groundwater Contamination

The VOC contaminated groundwater associated with the Original Landfill is limited in extent, closely related to a small source area, and is not a threat to surface water quality. Therefore, this contaminated groundwater does not require any action.

Walnut Creek Drainage Groundwater Contamination

It is most likely that the contamination in this area has migrated from a source upgradient of the Present Landfill, potentially the PU&D Yard (see above). Contaminated groundwater in this area will be addressed as part of the remedy for the upgradient plume.

4.5 PLUME RANKING

Sources or contaminant plume above action levels that are determined to be candidates for remedial actions have been prioritized to determine the sequence in which remediation will occur. To accomplish this task, a methodology was developed by CDPHE, EPA, K-H, and RMRS staff to rank the known environmental risks at RFETS and is outlined in RFCA Attachment 4.

The ER Ranking is currently being updated to incorporate the new action levels. Sites are ranked using the following criteria: 1) concentrations of contaminants present in soil, subsurface soil, and groundwater; 2) impact to surface water; and 3) the potential for further release which quantifies the possibility that source material will continue to release contaminants into the environment. The resulting prioritized list is used to determine the general order in which to implement remedial actions.

This methodology incorporates a very conservative approach. As a result, IHSSs, areas, and groundwater plumes where formal risk assessments have determined that there is no unacceptable risk may rank higher than expected on the prioritized list.

The Working Group recommended that the groundwater plumes be prioritized separately from the contaminant sources to allow the groundwater actions to be initiated separately from the source removal actions. The methodology for ranking the groundwater plumes follows.

- **Action Level and Standards Framework Score**: Analytical data for VOCs in groundwater since 1990 were compared to the proposed Tier II action levels, and a ratio of the analytical result to Tier II action level value was calculated. The maximum ratio for each analyte within the contaminant plume was tabulated, and a total score for each groundwater plume was calculated by summing the maximum ratios. The resulting values were converted to a Score Ratio using Table 4-1.

- **Impact to Surface Water**: A rating of 1 to 3 was assigned to each plume based on the evaluation of whether or not the groundwater contaminant plume was impacting surface water at Tier I action levels (a rating of 3), had the potential or was impacting surface water at Tier II levels (a rating of 2), or did not pose a threat to surface water at this time (a rating of 1).

- **Potential for Further Release**: A rating of 1 to 3 is assigned based on an evaluation of whether or not there is a potential for contaminants to continue to migrate into groundwater (i.e., is an uncontained source present?). If there is probably free product present, a rating of 3 is assigned, if high concentrations of contaminant are present in soil, a rating of 2 is assigned and if there is probably no uncontained source present, a rating of 1 is assigned. Because the groundwater plumes are ranked separately from the contaminant sources, and the contaminants are already in the groundwater, the potential for further release for all plumes is rated as a 1.

Table 4-1 Conversion Table for Scores

Summed Groundwater Ratios	*Score Ratio*
> 20,000	10
10,001 - 20,000	9
5,001 - 10,000	8
1,001 - 5,000	7
501 - 1,000	6
251 - 500	5
126 - 250	4
76 - 125	3
26 - 75	2
1 - 25	1

The ER Ranking was recalculated in September 1996 using the new Action Levels And Standards Framework and included the groundwater contaminant plumes. Table 4-2 provides the rankings of the groundwater contaminant plumes above Tier I action levels as they appear within the overall ER Ranking.

Table 4-2 Ranking of the Groundwater Contaminant Plumes above Tier I Action Levels

Plume	*ER Ranking*	*Comments*
Mound Site	7	
903 Pad and Ryan's Pit	11	Ryan's Pit source removed
East Trenches	12	Trenches T-3 and T-4 sources removed
PU&D Yard	16	
881 Hillside Drum Storage Area	18	
Carbon Tetrachloride Spill	19	
IA	21	
Solar Ponds	23	Ranking due to nitrate concentrations
Present Landfill	26	Groundwater presently collected/treated

5.0 NEXT STEPS

Additional data must be collected and/or analyzed before implementing actions. Not all groundwater contaminant plumes and sources are characterized sufficiently to implement an action, and appropriate methodologies for collection and treatment must be identified. The ecological impacts of groundwater collection and treatment must be determined, as collection of the distal plume boundaries may irreparably damage wetlands and seeps.

Before implementation of any remedy, a planning or implementation document such as an IM/IRA or PAM must be prepared, and an engineering design must be completed.

Based on the currently available information, following are the steps already completed towards groundwater remediation, and the proposed next steps. All of these activities have been proposed for funding within the next 5 years.

- Soils in OU 1 881 Hillside Drum Storage Area (IHSS 119.1) that contain contaminant concentrations above action levels may be excavated, removing material above the Tier I Action Level. Because the source of groundwater contamination would be removed, the use of the French Drain system and recovery well may no longer be necessary. After monitoring demonstrates the effectiveness of the remedy, these will be removed from service.

  The seep near Woman Creek will be evaluated to determine whether it is related to the 881 Hillside Drum Storage Area, and if there is an impact to surface water above action levels.

- The source of the Mound Site Plume is anticipated to be remediated as an accelerated action. Pre-remedial investigations were completed in 1996 to delineate the extent of the contaminant source for this plume. Further pre-remedial investigations to determine the extent of the distal end of the groundwater contaminant plume, and effective, passive treatment methodologies are expected to continue in the near future. Gravity-flow passive treatment systems will be the preferred option.

- The sources of the 903 Pad and Ryan's Pit Plume have been or are scheduled to be removed. The Ryan's Pit source has already been characterized and remediated. Pre-remedial investigations are proposed to determine the extent of the source. The distal ends of the groundwater contaminant plumes require better definition in order to appropriately site collection and treatment systems. Gravity-flow passive treatment systems will be the preferred option.

- A pre-remedial investigation is proposed for the carbon tetrachloride spill plume (IHSS 118.1) to better define the source, and to evaluate remedial actions. After the source is better defined, source removal is recommended. A limited pump-and-treat system may be installed due to the large amount of free product present in a limited area. If required, after removal of the surrounding buildings and associated footing drain systems, a passive collection and treatment system may be installed to contain the dissolved phase of this plume. This system would be located along the post-building removal, downgradient flow path near the impacted drainage.

- The sources for the East Trenches plume have been removed. Accelerated actions were completed in 1996 to excavate Trenches T-3 and T-4, and materials above the Tier I action levels were removed. The distal end of this groundwater contaminant plume requires better definition in order to appropriately site collection and treatment systems. Gravity-flow passive treatment systems will be the preferred options.

- The IA plume will continue to be monitored to ensure that there is no increase in migration, and that there is no impact to surface water quality.

- Groundwater treatment systems need to be investigated to determine the optimum treatment methodology.

- The unknown extent of the chlorinated solvent plumes associated with the PU&D Yard (IHSS 170, 174a, and 174b) is a data gap. Because the nature of the southern boundary of these plumes is undetermined, the potential impact to surface water cannot be evaluated. A limited characterization investigation is proposed for 1997 to determine the extent of the plume, and to determine the location, nature and size of the source material. Previous investigations suggest that the contaminant source(s) may be located immediately east of the known PU&D Yard boundary. Source removal is expected to follow in 1997 if a contaminant source can be defined.

- Soil vegetative caps, covers or regrading and revegatation may be used throughout RFETS where necessary to limit natural recharge caused by precipitation from leaching of contaminants in the unsaturated zone and into groundwater. This would aid in reducing the movement of groundwater through the IA, and thereby reduce the mobility of the contaminant plumes. Subsurface sources of groundwater contamination would be removed where practical. At the end of the building deactivation D&D/remediation phase, the plant water supply and sanitary sewer will be shut off. This will eliminate a major source of groundwater recharge for the IA, and should greatly reduce the mobility contaminant of the IA and carbon tetrachloride spill plumes.

- A limited investigation is proposed for the Solar Ponds area to determine the extent of VOC contamination and whether there is a pathway to surface water. Carbon tetrachloride and trichloroethene are present at a well located near the western side of the SEPs. However, the extent of the contamination in the sandstone, and whether the sandstone subcrops in the North Walnut drainage are unknown.

Further analysis is required to determine optional intercept locations, actual treatment methodologies, and cost-effective project planning and scheduling.

The ER Ranking scheduled to be completed in 1996, incorporated into the IGD, and the proposed ranking of groundwater plumes presented in Section 4.5 provide the basis for establishing the priority and sequence of proposed cleanup actions. However, a schedule for implementing groundwater cleanup will be dependent on funding, data sufficiency, resource availability, and the integration with other cleanup and RFETS activities.

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Appendix A

Acronym List

ASAP	Accelerated Site Action Plan
BTEX	Benzene, toluene, ethylbenzene and xylene
CDPHE	Colorado Department of Public Health and Environment
CWQCC	Colorado Water Quality Control Commission
D&D	Decontamination and Decommissioning
DNAPL	Dense Nonaqueous Phase Liquid
DOE/RFFO	Department of Energy/Rocky Flats Field Office
EPA	Environmental Protection Agency
ER	Environmental Restoration
GPMPP	Groundwater Protection and Monitoring Program Plan
GWAP	Groundwater Assessment Plan
IA	Industrial Area
IHSS	Individual Hazardous Substance Site
IM/IRA	Interim Measure/Interim Remedial Action
IMP	Integrated Monitoring Plan
ITS	Interceptor Trench System
K-H	Kaiser-Hill
LHSU	Lower Hydrostratigraphic Unit
MCL	Federal Drinking Water Maximum Contaminant Level
OU	Operable Unit
PA	Protected Area
PAM	Proposed Action Memorandum
PPRG	Programmatic Risk-Based Preliminary Remediation Goal
PU&D	Property Utilization and Disposal
RCRA	Resource Conservation and Recovery Act
RFCA	Rocky Flats Cleanup Agreement
RFETS	Rocky Flats Environmental Technology Site
RMRS	Rocky Mountain Remediation Services, L.L.C.
SEPs	Solar Evaporation Ponds
SNM	Special Nuclear Material
TRU	transuranic
UHSU	Upper Hydrostratigraphic Unit
VOC	Volatile Organic Compound

Appendix B

Executive Summary of the White Paper

Analysis of Vertical Contaminant Migration Potential - Final Report,

RF/ER-96-0040.UN, report prepared for Kaiser-Hill Company,

August 16, 1996.

EXECUTIVE SUMMARY

This white paper was prepared as part of a comprehensive environmental initiative, known as the Accelerated Site Action Project, that seeks to establish long-term goals and approaches for the remediation of the Rocky Flats Environmental Technology Site. The purpose of this white paper is to describe and analyze the potential for shallow groundwater contaminants, particularly volatile organic compounds, to migrate vertically downward through a thick, laterally extensive confining layer and enter a deep regional artesian aquifer system known as the Laramie-Fox Hills Sandstone aquifer. The Laramie-Fox Hills Sandstone aquifer provides an important source of water for local and regional use and is the sole water supply for some residents in the Rocky Flats area.

Concerns related to contaminant migration and the long-term hydrologic integrity of this confining layer have recently been raised regarding the presence of dense non-aqueous phase liquids (DNAPLs) in the groundwater at some waste disposal sites and the occurrence of secondary permeability (i.e., fractures and faults) in bedrock materials. The combination of these factors at other hazardous waste sites have led to persistent groundwater contamination problems that have proven to be difficult to remediate and, thus, represent a long-term contaminant migration threat. In order to evaluate the potential significance of vertical groundwater contaminant transport at Rocky Flats Environmental Technology Site, two individual hazardous substance sites (IHSSs 110 and 118.1) with evidence of chlorinated solvent releases were selected for analysis and discussion. The primary DNAPL and dissolved contaminants-of-concern identified at these sites are trichloroethene, tetrachloroethene, and carbon tetrachloride. Information from numerous site reports, unpublished site data, and recently published articles provide the basis for the analyses presented in this white paper.

The Rocky Flats Environmental Technology Site is underlain by a mantle of permeable Quaternary surficial geologic deposits deposited on a 600+ foot thick sequence of low permeability Cretaceous claystone and siltstone bedrock known as the upper Laramie Formation. The upper Laramie Formation functions as a confining layer for the underlying Laramie-Fox

Hills Sandstone aquifer which subcrops west of the Industrial Area and plunges eastward beneath the plant. Vertical hydraulic conductivities for the confining layer materials are estimated to range from about 2.8×10^{-10} to 2.5×10^{-7} centimeters/second, or roughly three to seven orders of magnitude lower than for the overlying surficial deposits. Due to this contrast in hydraulic conductivity, groundwater is expected to move predominently laterally in the surficial deposits and vertically in the confining layer. Downward vertical hydraulic gradients observed in the confining layer indicate that shallow groundwater has the potential to recharge the Laramie-Fox Hills aquifer.

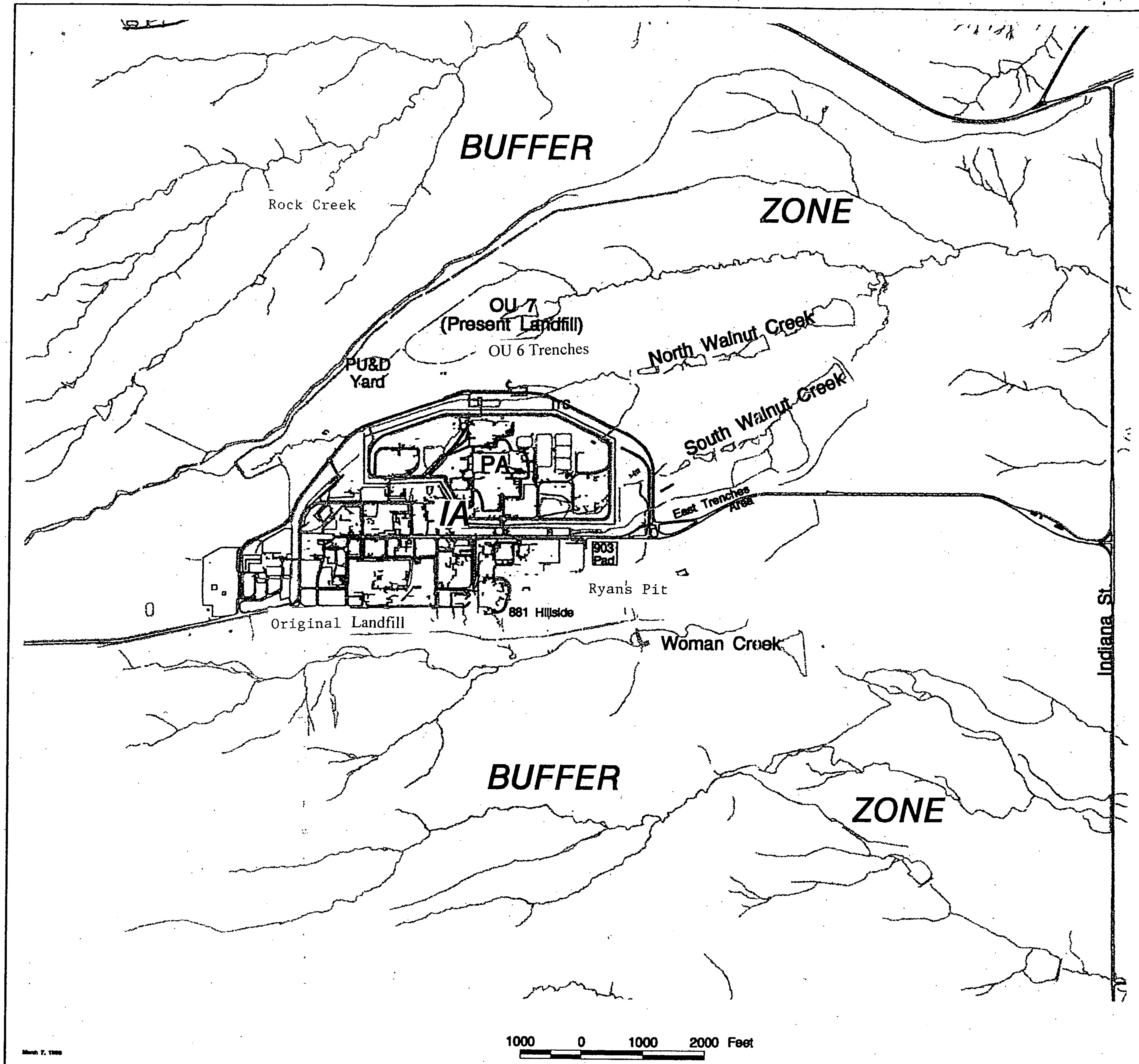
Faulting in the upper Laramie Formation has been documented regionally and recently has been documented at the Industrial Area. The influence of these fault zones on vertical groundwater flow is unknown; however, an observed trend of decreasing claystone permeabilities with depth is expected to result in a restrictive, rather than an enhanced, vertical groundwater flow regime. Fractures observed in bedrock core samples tend to be discontinuous, sub-horizontal to sub-vertical, and closed with depth. Trace concentrations of trichloroethene, tetrachloroethene, carbon tetrachloride, and chloroform found in some unweathered bedrock wells indicate that limited contaminant migration has occurred in the shallowest part of the confining layer beneath shallow groundwater plumes with high concentrations, although most detections are apparently related to laboratory or well cross contamination. Plutonium-239/240 was detected above background in three unweathered bedrock wells, but the available evidence indicates that these occurrences are attributable to cross contamination probably as a result of drilling through radionuclide contaminated soils.

Estimates of the vertical groundwater flow velocity through the confining layer indicate that groundwater movement is expected to be very slow. The calculated range of groundwater velocities, based on a potential range of vertical hydraulic conductivities, is 0.00054 to 0.468 feet/year, which translates to travel times to the Laramie-Fox Hills aquifer of 1,300 to 1.1 million years. Consideration of the hydrologic setting and declining hydraulic conductivity trend with depth suggests that the actual groundwater flow velocity will be near the low end of the range.

Analysis of the behavior of dense nonaqueous phase liquids indicates that a potential exists for entry of DNAPL into fractured bedrock. However, the threat of DNAPL migration to the Laramie-Fox Hills aquifer is rapidly mitigated by diffusive disappearance of DNAPL from fractures into the claystone matrix, which has a large contaminant mass storage capacity. Dissolved and sorbed volatile organic contaminants derived from DNAPLs therefore represent the principal concern for vertical contaminant migration to the deep aquifer.

Organic contaminants are expected to move much slower than the groundwater flow velocity in the confining layer due to the effects of sorption by high organic carbon and clay contents, dispersion and molecular diffusion, and possibly *in situ* abiotic transformation reactions. The most rapidly transported contaminant, trichloroethene, is predicted to travel for 17,000 to 15 million years before reaching the Laramie-Fox Hills aquifer, with the most likely case being on the order of a hundred thousand years or more. Assuming that natural contaminant degradation is a viable process, some contaminants with short environmental half lives, such as carbon tetrachloride, may fully degrade before reaching the aquifer. The results of simple one- and two-dimensional analytical modeling of contaminant transport indicate that dispersion will reduce contaminant concentrations at the confining layer/aquifer interface by 6 to 99 percent, depending on magnitude of the vertical flux. Under worst case conditions, the resulting contaminant concentrations derived from mass flux calculations in the Laramie-Fox Hills aquifer exceed regulatory limits; however, these calculations are exceedingly conservative and ignore some important basic factors. Using a more realistic set of assumptions, it is expected that, if contaminants should ever reach the aquifer, the concentrations will be below regulatory limits.

It is concluded from this review and analysis that the upper Laramie Formation confining beds have a sufficient amount of hydrologic and geochemical integrity to provide long-term protection of the Laramie-Fox Hills aquifer. Monitoring of vertical contaminant migration at potential bedrock source areas, rather than remediation, appears to be the most prudent and cost effective option for protection of the Laramie-Fox Hills aquifer given the apparent robust geochemical nature of unweathered bedrock materials underlying the site.



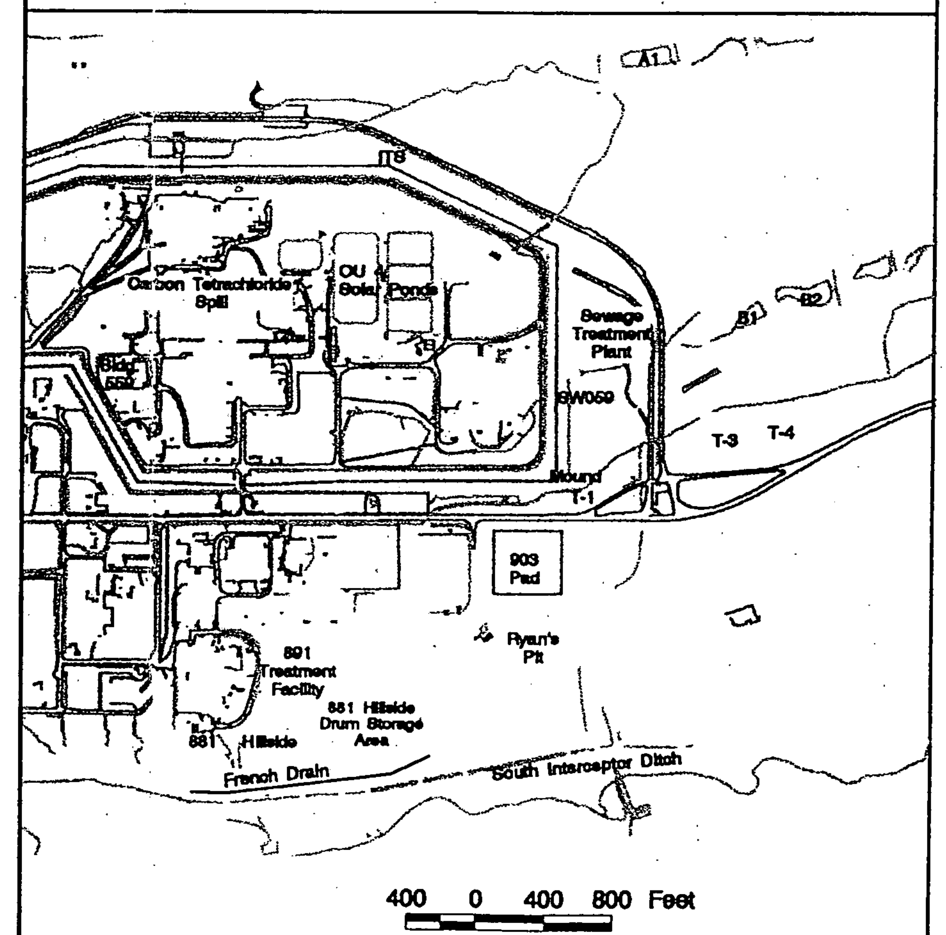
Location Reference Map

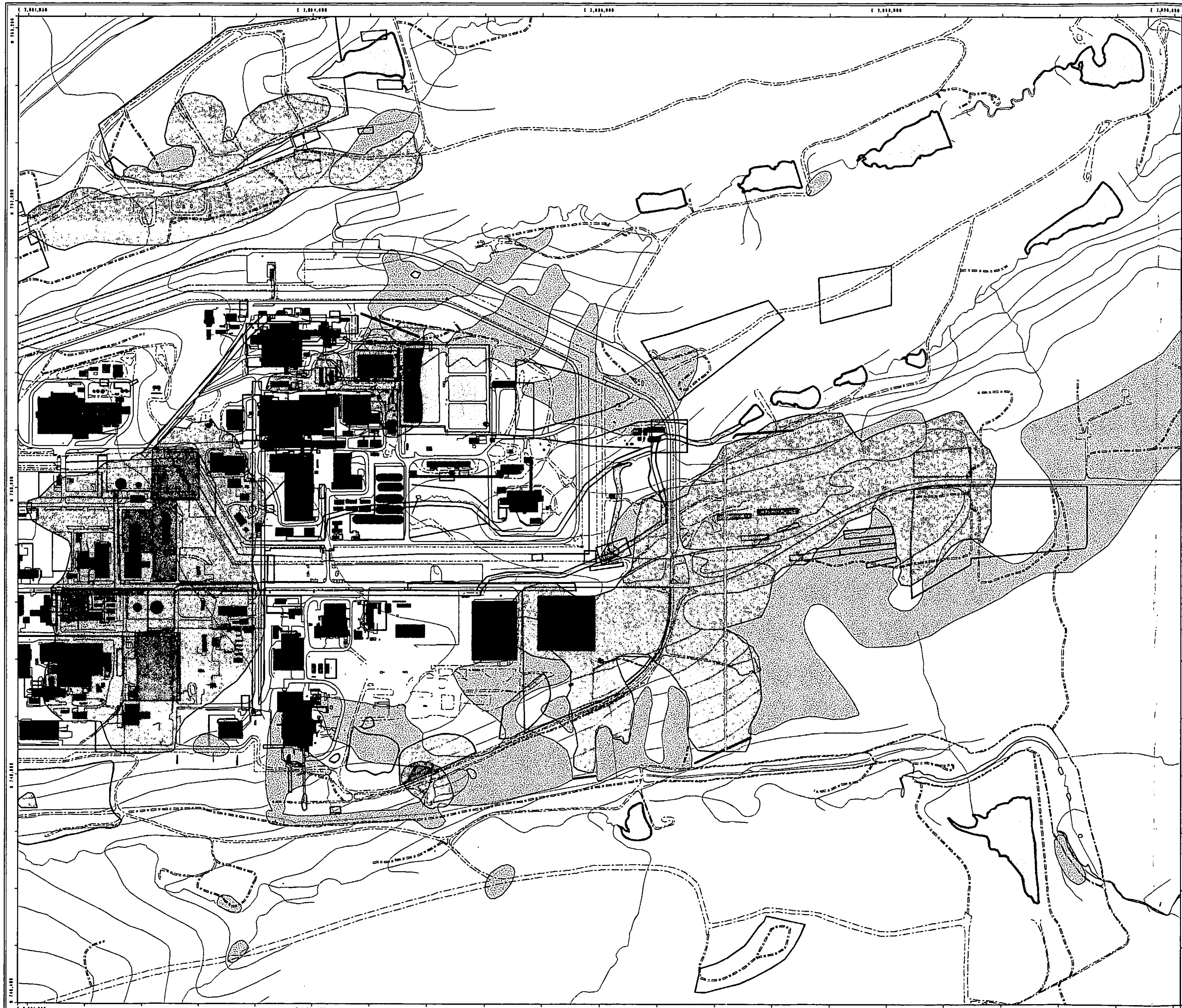
Location of areas of interest refered to in text.

Figure 1-1

N

Detailed View of East Side of Plant Site





Tier II Composite Plume Extent for VOC Concentrations > MCLs

Figure 3-1

EXPLANATION

- Plume Capture/Treatment Locations
- IHSS Boundaries
- Groundwater Elevation Contours
- Suspected VOA Sources
- Concentrations Greater Than MCLs in GW
- Unsaturated Alluvium

Standard Map Features

- Buildings or other structures
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences
- Paved roads
- Dirt roads

DATA SOURCE:
Buildings, roads, and fences provided by Facilities Engr., EG&G Rocky Flats, Inc. - 1991.
Hydrology provided by USGS - (date unknown)

Scale = 1 : 8350
1 inch represents approximately 696 feet

200 0 400 800 Ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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

Prepared by:
RMRS Rocky Mountain Remediation Services, L.L.C.
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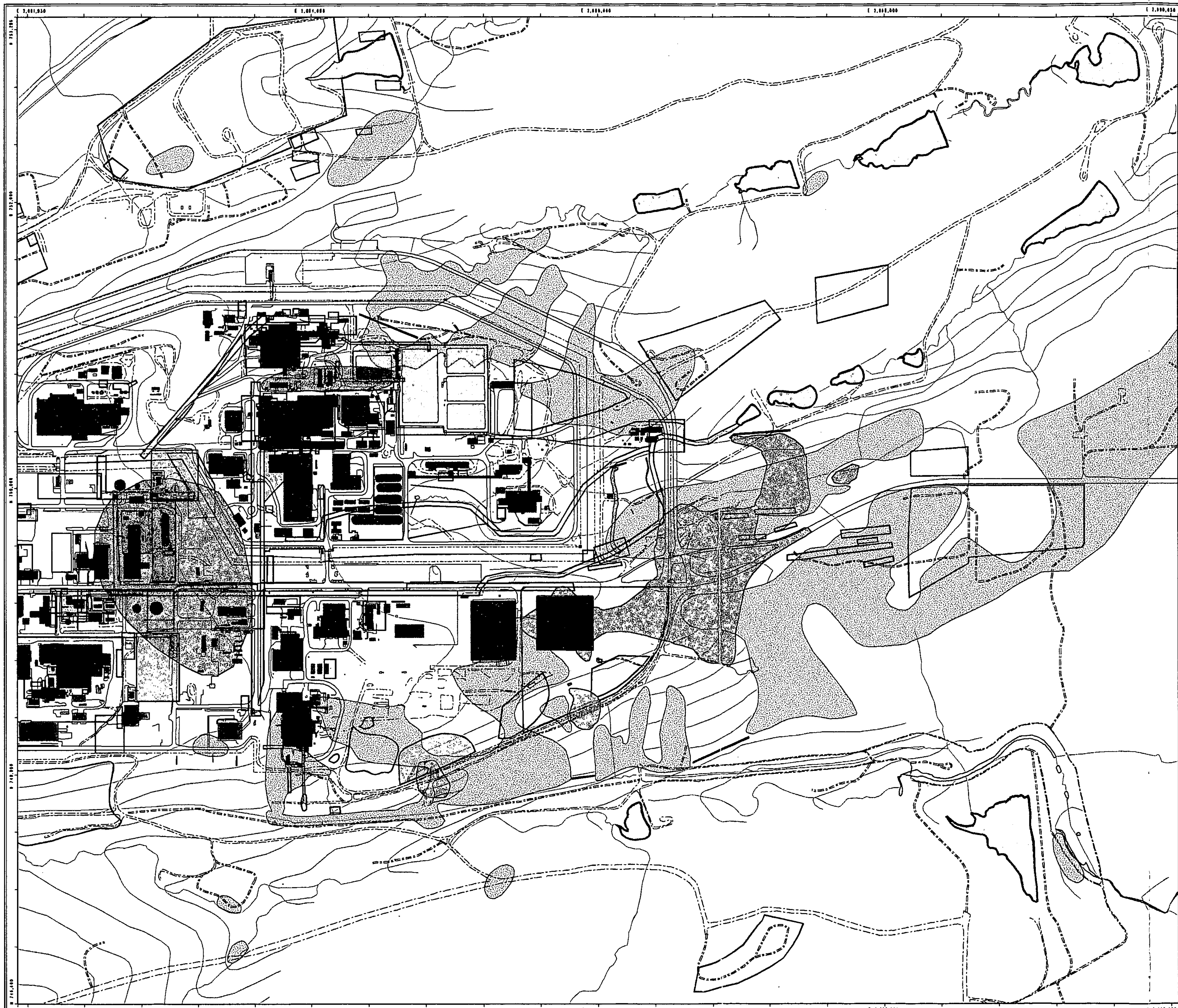
MAP ID: 97-0003 October 17, 1996



Potential Remedial Actions with Composite Plume Extent for VOC Concentrations > 100 x MCLs

Figure 4-1

EXPLANATION

- Plume Capture/Treatment Locations
- IHSS Boundaries
- Groundwater Elevation Contours
- Suspected VOC Sources
- Concentrations Greater Than 100 MCLs in GW
- Unsaturated Alluvium

Standard Map Features

- Buildings or other structures
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences
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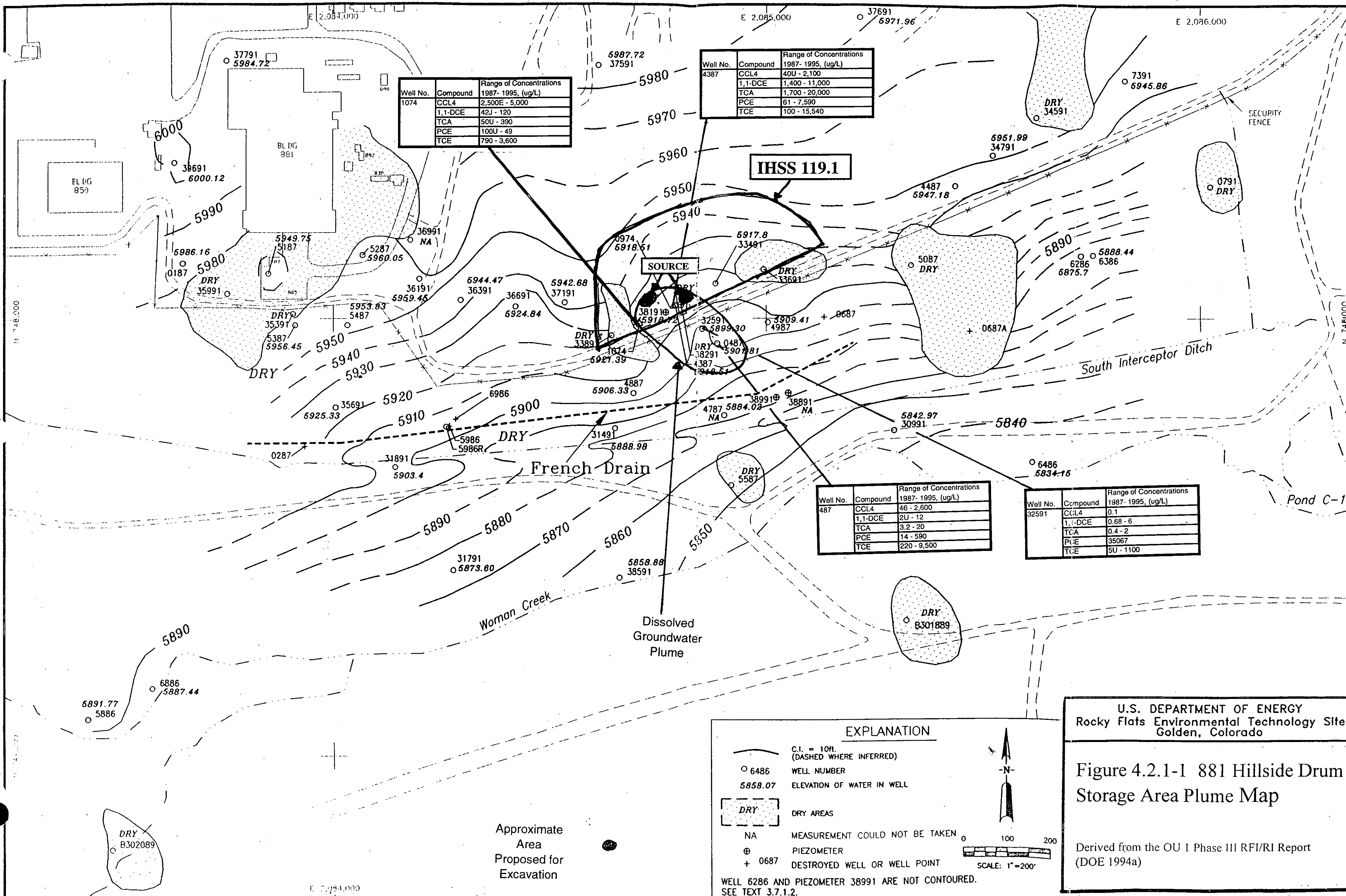


Well No.	Compound	Range of Concentrations 1987- 1995, (ug/L)
1074	CCL4	2,500E - 5,000
	1,1-DCE	42J - 120
	TCA	50U - 390
	PCE	100U - 49
	TCE	790 - 3,600

Well No.	Compound	Range of Concentrations 1987- 1995, (ug/L)
4387	CCL4	40U - 2,100
	1,1-DCE	1,400 - 11,000
	TCA	1,700 - 20,000
	PCE	61 - 7,590
	TCE	100 - 15,540

Well No.	Compound	Range of Concentrations 1987- 1995, (ug/L)
487	CCL4	46 - 2,600
	1,1-DCE	2U - 12
	TCA	3.2 - 20
	PCE	14 - 590
	TCE	220 - 9,500

Well No.	Compound	Range of Concentrations 1987- 1995, (ug/L)
32591	CCL4	0.1
	1,1-DCE	0.68 - 6
	TCA	0.4 - 2
	PCE	35067
	TCE	5U - 1100

U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site
Golden, Colorado

Figure 4.2.1-1 881 Hillside Drum Storage Area Plume Map

Derived from the OU 1 Phase III RFI/RI Report (DOE 1994a)

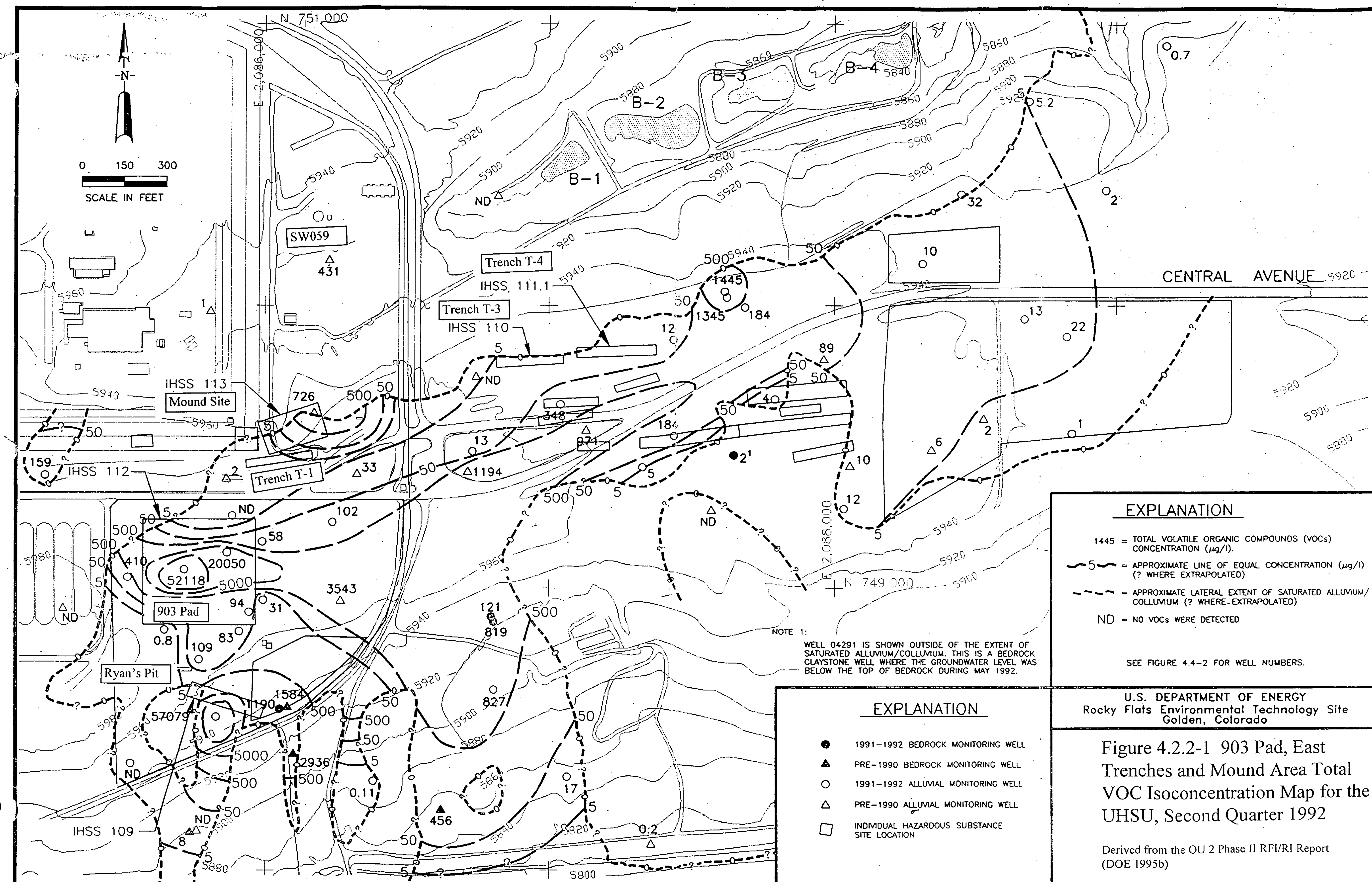


Figure 4.2.2-1 903 Pad, East Trenches and Mound Area Total VOC Isoconcentration Map for the UHSU, Second Quarter 1992

Derived from the OU 2 Phase II RFI/RI Report (DOE 1995b)

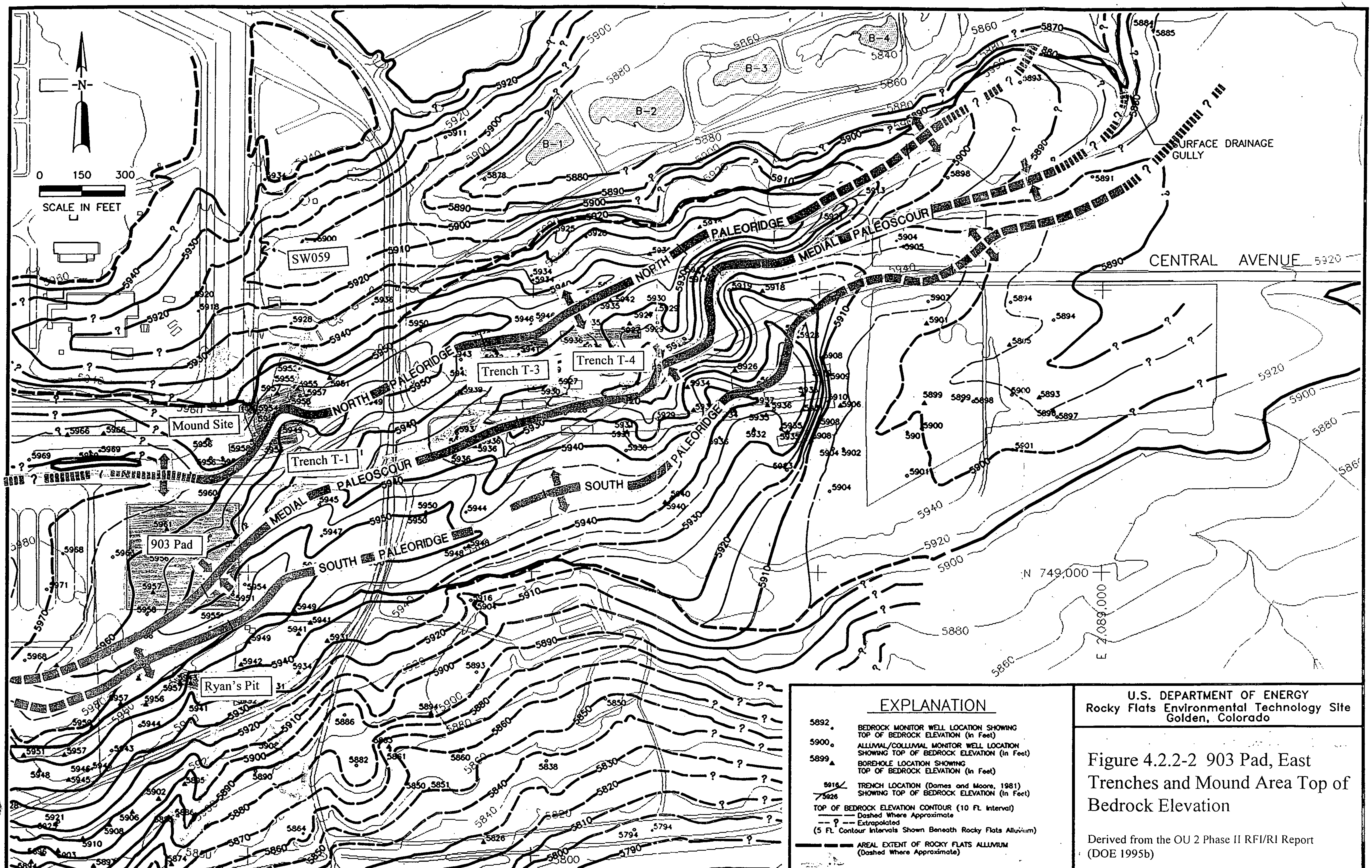
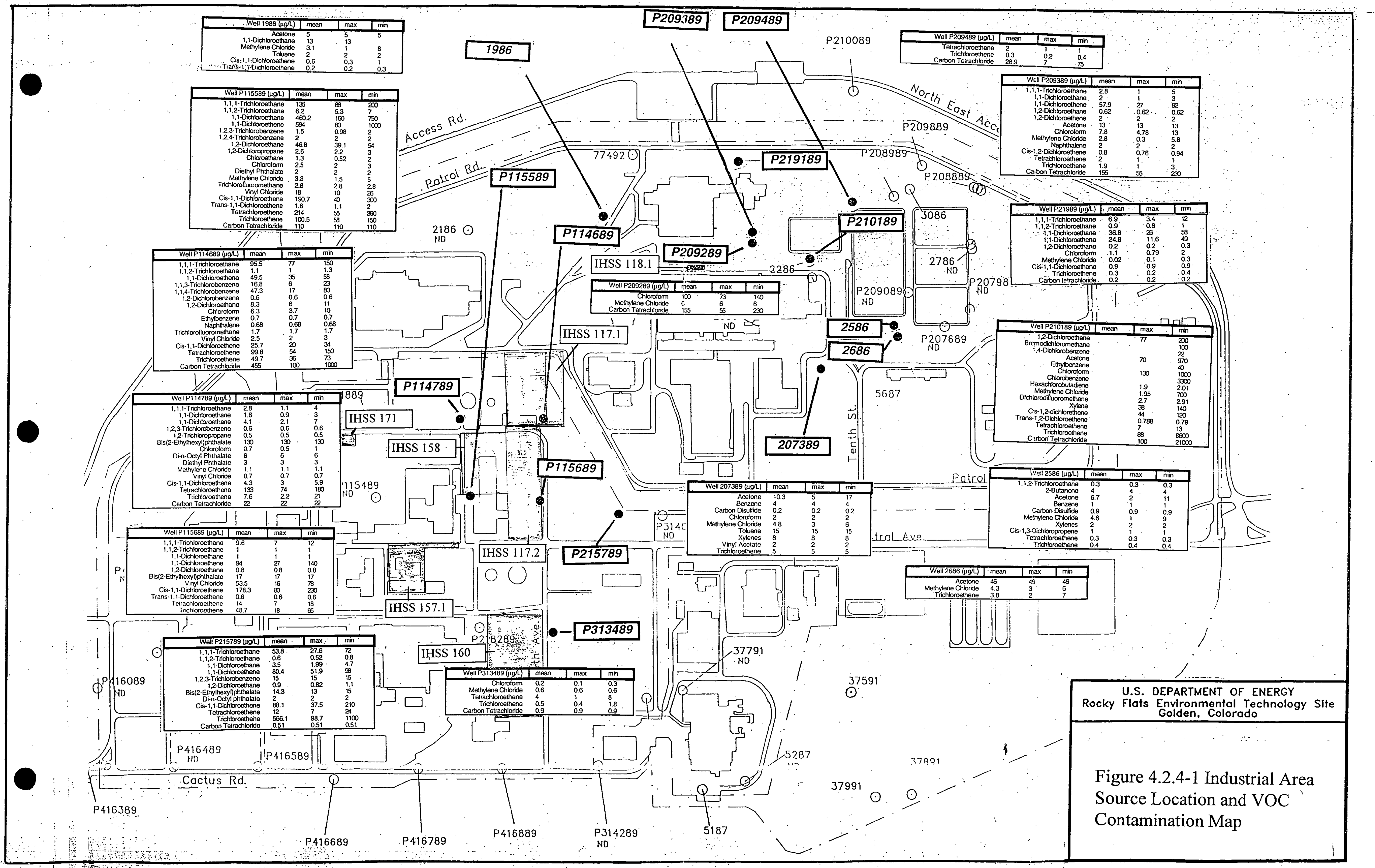


Figure 4.2.2-2 903 Pad, East Trenches and Mound Area Top of Bedrock Elevation

Derived from the OU 2 Phase II RFI/RI Report (DOE 1995b)



Well 1986 (µg/L)	mean	max	min
Acetone	5	5	5
1,1-Dichloroethane	13	13	
Methylene Chloride	3.1	1	8
Toluene	2	2	2
Cis-1,1-Dichloroethene	0.6	0.3	1
Trans-1,1-Dichloroethene	0.2	0.2	0.3

Well P115589 (µg/L)	mean	max	min
1,1,1-Trichloroethane	135	88	200
1,1,2-Trichloroethane	6.2	5.3	7
1,1-Dichloroethane	460.2	160	750
1,1-Dichloroethene	594	60	1000
1,2,3-Trichlorobenzene	1.5	0.98	2
1,2,4-Trichlorobenzene	2	2	2
1,2-Dichloroethane	46.8	39.1	54
1,2-Dichloropropane	2.6	2.2	3
Chloroethane	1.3	0.52	2
Chloroform	2.5	2	3
Diethyl Phthalate	2	2	2
Methylene Chloride	3.3	1.5	5
Trichlorofluoromethane	2.8	2.8	2.8
Vinyl Chloride	18	10	26
Cis-1,1-Dichloroethene	190.7	40	300
Trans-1,1-Dichloroethene	1.6	1.1	2
Tetrachloroethene	214	55	390
Trichloroethene	100.5	58	150
Carbon Tetrachloride	110	110	110

Well P114689 (µg/L)	mean	max	min
1,1,1-Trichloroethane	95.5	77	150
1,1,2-Trichloroethane	1.1	1	1.3
1,1-Dichloroethene	49.5	35	58
1,1,3-Trichlorobenzene	16.8	6	23
1,1,4-Trichlorobenzene	47.3	17	80
1,2-Dichlorobenzene	0.6	0.6	0.6
1,2-Dichloroethane	8.3	6	11
Chloroform	6.3	3.7	10
Ethylbenzene	0.7	0.7	0.7
Naphthalene	0.68	0.68	0.68
Trichlorofluoromethane	1.7	1.7	1.7
Vinyl Chloride	2.5	2	3
Cis-1,1-Dichloroethene	25.7	20	34
Tetrachloroethene	99.8	54	150
Trichloroethene	49.7	36	73
Carbon Tetrachloride	455	100	1000

Well P114789 (µg/L)	mean	max	min
1,1,1-Trichloroethane	2.8	1.1	4
1,1-Dichloroethane	1.6	0.9	3
1,1-Dichloroethene	4.1	2.1	7
1,2,3-Trichlorobenzene	0.6	0.6	0.6
1,2-Trichloropropane	0.5	0.5	0.5
Bis(2-Ethylhexyl)phthalate	130	130	130
Chloroform	0.7	0.5	1
Di-n-Octyl Phthalate	6	6	6
Diethyl Phthalate	3	3	3
Methylene Chloride	1.1	1.1	1.1
Vinyl Chloride	0.7	0.7	0.7
Cis-1,1-Dichloroethene	4.3	3	5.9
Tetrachloroethene	133	74	180
Trichloroethene	7.6	2.2	21
Carbon Tetrachloride	22	22	22

Well P115689 (µg/L)	mean	max	min
1,1,1-Trichloroethane	9.6	7	12
1,1,2-Trichloroethane	1	1	1
1,1-Dichloroethane	1	1	1
1,1-Dichloroethene	94	27	140
1,2-Dichloroethane	0.8	0.8	0.8
Bis(2-Ethylhexyl)phthalate	17	17	17
Vinyl Chloride	53.5	16	78
Cis-1,1-Dichloroethene	178.3	80	230
Trans-1,1-Dichloroethene	0.6	0.6	0.6
Tetrachloroethene	14	7	18
Trichloroethene	48.7	18	65

Well P215789 (µg/L)	mean	max	min
1,1,1-Trichloroethane	53.8	27.6	72
1,1,2-Trichloroethane	0.6	0.52	0.8
1,1-Dichloroethane	3.5	1.99	4.7
1,1-Dichloroethene	80.4	51.9	98
1,2,3-Trichlorobenzene	15	15	15
1,2-Dichloroethene	0.9	0.82	1.1
Bis(2-Ethylhexyl)phthalate	14.3	13	15
Di-n-Octyl phthalate	2	2	2
Cis-1,1-Dichloroethene	88.1	37.5	210
Tetrachloroethene	12	7	24
Trichloroethene	566.1	98.7	1100
Carbon Tetrachloride	0.51	0.51	0.51

Well P313489 (µg/L)	mean	max	min
Chloroform	0.2	0.1	0.3
Methylene Chloride	0.6	0.6	0.6
Tetrachloroethene	4	1	8
Trichloroethene	0.5	0.4	1.8
Carbon Tetrachloride	0.9	0.9	0.9

Well P209289 (µg/L)	mean	max	min
Chloroform	100	73	140
Methylene Chloride	6	6	6
Carbon Tetrachloride	155	55	230

Well 207389 (µg/L)	mean	max	min
Acetone	10.3	5	17
Benzene	4	4	4
Carbon Disulfide	0.2	0.2	0.2
Chloroform	2	2	2
Methylene Chloride	4.8	3	6
Toluene	15	15	15
Xylenes	8	8	8
Vinyl Acetate	2	2	2
Trichloroethene	5	5	5

Well P209489 (µg/L)	mean	max	min
Tetrachloroethene	2	1	1
Trichloroethene	0.3	0.2	0.4
Carbon Tetrachloride	28.9	7	75

Well P209389 (µg/L)	mean	max	min
1,1,1-Trichloroethane	2.8	1	5
1,1-Dichloroethane	2	1	3
1,1-Dichloroethene	57.9	27	92
1,2-Dichloroethane	0.62	0.62	0.62
1,2-Dichloroethene	2	2	2
Acetone	13	13	13
Chloroform	7.8	4.78	13
Methylene Chloride	2.8	0.3	5.8
Naphthalene	2	2	2
Cis-1,2-Dichloroethene	0.8	0.76	0.94
Tetrachloroethene	2	1	1
Trichloroethene	1.9	1	3
Carbon Tetrachloride	155	55	230

Well P21989 (µg/L)	mean	max	min
1,1,1-Trichloroethane	6.9	3.4	12
1,1,2-Trichloroethane	0.9	0.8	1
1,1-Dichloroethane	36.8	26	58
1,1-Dichloroethene	24.8	11.6	49
1,2-Dichloroethane	0.2	0.2	0.3
Chloroform	1.1	0.79	2
Methylene Chloride	0.02	0.1	0.3
Cis-1,1-Dichloroethene	0.9	0.9	0.9
Trichloroethene	0.3	0.2	0.4
Carbon tetrachloride	0.2	0.2	0.2

Well P210189 (µg/L)	mean	max	min
1,2-Dichloroethene		77	200
Bromodichloromethane			100
1,4-Dichlorobenzene			22
Acetone		70	970
Ethylbenzene			40
Chloroform		130	1000
Chlorobenzene			3300
Hexachlorobutadiene		1.9	2.01
Methylene Chloride		1.95	700
Dichlorodifluoromethane		2.7	2.91
Xylene		38	140
Cis-1,2-dichlorethene		44	120
Trans-1,2-Dichloroethene		0.788	0.79
Tetrachloroethene		7	13
Trichloroethene		88	8600
Carbon Tetrachloride		100	21000

Well 2586 (µg/L)	mean	max	min
1,1,2-Trichloroethane	0.3	0.3	0.3
2-Butanone	4	4	4
Acetone	6.7	2	11
Benzene	1	1	1
Carbon Disulfide	0.9	0.9	0.9
Methylene Chloride	4.6	1	9
Xylenes	2	2	2
Cis-1,3-Dichloropropene	1	1	1
Tetrachloroethene	0.3	0.3	0.3
Trichloroethene	0.4	0.4	0.4

Well 2686 (µg/L)	mean	max	min
Acetone	46	46	46
Methylene Chloride	4.3	3	6
Trichloroethene	3.8	2	7

Figure 4.2.4-1 Industrial Area Source Location and VOC Contamination Map